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Accident Investigation and Learning to Improve Safety Management in Complex System: Remaining Challenges Proceedings of the 55th ESReDA Seminar

Hosted by the Romanian Railway Investigation Agency AGIFER, 9-10 October, 2018, Bucarest, Romania

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European Safety, Reliability & Data Association

(ESReDA)

European Safety, Reliability & Data Association (ESReDA) is a European Association established in 1992 to promote research, application and training in Reliability, Availability, Maintainability and Safety (RAMS). The Association provides a forum for the exchange of information, data and current research in Safety and Reliability.

ESReDA membership is open to organisations, privates or governmental institutes, industry researchers and consultants, who are active in the field of Safety and Reliability. Membership fees are currently 1000 EURO for organisations and 500 EURO for universities and individual members. Special sponsoring or associate membership is also available.

For more information and available ESReDA proceedings please consult:
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Table of Contents

Preface

The 55th ESReDA seminar held in Bucharest the 9th and 10th of October 2018, was organized by the European Safety and Reliability Data Association and the Romanian Railway Investigating Agency – AGIFER, to invite participants to exchange ideas on "Accident Investigation and Learning to Improve Safety Management in Complex System: Remaining Challenges".

The seminar goal was to discuss results in specific areas, and to share and explore the experiences of using other paradigms, approaches, methods, databases, implementation of safety systems across various industries, through a forum for exploring these challenges and questions mentioned above.

More than 80 participants from 15 countries with some outside of Europe (Brazil, Israel, France, Germany, Lithuania, Norway, Portugal, Italy, The Netherlands, Finland, Czech Republic, Belgium, Sweden, United Kingdom, and Romania) contributed through their presentations, discussions and expertise in reviewing the state-of-the-art in the field, trying to answer which are the remaining challenges in accident investigation and learning. Useful information was given to the participants, to improve their scientific knowledge and expert activities with a possible conclusion that *"a greater consideration of the historical dimension and of the cultural aspects in complex sociotechnical systems seems to be one of the recurring challenges for accident investigation".*

Indeed, the process of globalization and the state of continuous movement in which we are, challenges our abilities to analyse, design and control complex sociotechnical systems. We need more and more information and more analysis to interpret them. The quest for continuous improvement in performance often implies that the "deadline" for our actions is always "yesterday". The current needs of people (workers, managers, regulators, customers, citizens), imposed by the faster (rapid) technological and economic development of the human society, can be sustained only in harmony with safety. But how safe is the transport which we use? How reliable is the information which we found? How sustainable is the source which produces the energy for us? Have the system's designers created enough barriers to prevent an accident? What are the practices and real performance of safety management?

Unfortunately, in most cases, we answer these questions only after an accident occurred, through a safety accident investigation. Safety accident investigation is a fundamental process in safety management, involving technical, human, but also organizational, cultural and societal dimensions. This activity is concerned by a number of challenges that limit its effectiveness and by a number of opportunities for improvement. In addition, many organizations and actors are proactive, through updates in risk analysis and learn from opportunities such as near-misses.

In order to address these issues, the technical programme committee invited three keynote lectures from:

- Raed Arafat, Internal Affairs Ministry, Bucharest, Romania
- Teodor Grădinariu, International Union of Railways, Paris, France
- Dan Șerbănescu, Academy of Science, Bucharest, Romania

In addition, participants had the opportunity to listen to 22 presentations (with their papers in these proceedings) within 7 sessions: "Past, present, future"; "Organizations and human aspects"; "Methodological aspects"; "Lessons learned and historical perspectives"; "Methods"; "Case studies" and "Going across sectors", made by stakeholders from research centres, universities, industry, government and safety authorities.

As regards the organization of accident investigation, the papers have highlighted issues related to the different functioning of the investigating bodies, the advantage and disadvantages to have a multimodal board but also the necessity for an effective exchange of information between investigating agencies from different countries, in the context of a globalising system. "*An incident with a freight train in the Port of Rotterdam that originated on the Black Sea could require the involvement of many parties all over Europe",* was one of the examples to support this statement.

How to manage communication after a civil aviation accident occurred on January 20, 2014 in Romania, by the investigating authority was a good example to explain why such an action has positive aspects even during the investigation. *"We should always keep in mind that the lack of communication could result in media speculation, with negative effects for the safety investigation activities"* was one of the conclusions.

Methodological aspects of accident investigation are trans-sectoral, they can be applied whatever the industrial sector. In this respect, the presentation of SAfety FRactal ANalysis (SAFRAN) investigation method, a "*method that is developed to guide investigators to identify where interventions might have the greatest impact for improving global system safety"* in a railway accident investigation, and *"how the ESReDA Cube model may be used to construct more reasonable and better targeted recommendations"* through investigations from three different sectors: a train derailment from Romania, an explosion at BP Texas in 2005 and an explosion at a company that makes aerosol products from Finland in 2018. How to use the method of the Accident Investigation Board of Norway was explained by a railway investigation after a train derailment occurred in Romania.

When competent investigators (in technical, human and organizational factors) are given enough resources (means to collect data, to conduct forensic analysis, to conduct interviews, time to analyse data with relevant methods), they are generally able to identify the direct causes, but also the contributing factors and root causes. Are we sure the accident investigation established the relevant "root causes"? Or did they miss some "deeper causes"? The answer of this question could be found in an analysis made through a method called "Organisational Analysis of Safety", *"which tackles three dimensions intending to cover the whole scope of the situation: "the historical dimension"; the "organisational network", and "work relationships channels"*. Another strategy relies on applying Analytical Hierarchy Process (AHP), which *"allows analyst to derive relative importance for the set of parameters through pairwise comparison",* explained by using the database of nuclear power plants related events.

Lesson learned from accidents and incidents as one of the fundamental processes in safety management is very important but at the same time, very challenging. These lessons should be identified by the accident investigations as a *"rational aim"*, but they should be understood by those involved. One of the issues concerning this understanding, is the non-reporting of some safety events, by field experts. An analysis of this aspect was made by using semi-structured interviews with Air Traffic Controllers and their managers, who were asked about safety, risks, lessons learned. A cause of some losses of opportunities to learn could be *"organisations don't look good (and deep) enough to find that there are also organisational causes for the accidents and incidents they are investigating".* The paper presents the necessity for the organisations to look *"for their own dysfunctions as possible precursors for accidents".*

"Are structural weaknesses limiting the capacity to learn from incidents?", started from the implication made in the *call for papers*, that developing, identifying and sharing "good practices" could happen to a greater extent than at present. By "*capacity to learn from incidents"*, the authors referred "*particularly to the practices of investigating and learning from incidents".*

"Do not repeat old mistakes in learning from accidents: It's better to prevent a runaway than be ready for it" is one of the titles, but also could be the conclusions from the papers which approached some case studies, to demonstrate the advantages of using these *"to promote an active way of learning from past incidents without repeating the costly mistakes"* or to describe *"in detail the processes, the interactions, the management tools to support the use of knowledge of accidents in practice",* in different industries.

The nuclear industry (sector) had a good representation by presenting a systemic method *"for assessing the systemic management of emergency management in case of nuclear accidents"* which started with a brief description of the Romanian National Emergency Situation Management System. The connection with railway industry was highlighted by analysing some aspects of the probabilistic versus risk evaluations of railways events, the result being an *"important new view on the interpretation and use of the existing railway event information in order to improve operation and decision-making process"* and also by analysing the impact of railway events that occurred in the proximity of Nuclear Power Plants and which should be included in their evaluation of the potential risks.

To increase the time available for expert debate, which is the essence of ESReDA community, the technical program committee organized within the framework of an ESReDA seminar, a workshop for one hour at the end of first day. The participants were divided (by the TPC) into 8 groups (4 in English language, 4 in Romanian language) and they were invited to identify problems and solutions regarding the four phases of accident investigation (organizational issues, fact-finding, analysis/recommendations, follow up). The results and ideas were presented within a reflection session to all participants the second day and are found also in this book.

The editorial work for this volume was supported by the Joint Research Centre of the European Commission in the frame of JRC support to ESReDA activities. A special thanks is due to A. Liessens (JRC) for the editorial work.

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Welcome speech

Vasile BELIBOU

General Manager

Romanian Railway Investigation Agency – AGIFER

No.393, Calea Griviței

Bucharest, ROMANIA

Dear guests,

First of all, we'd like to wish you welcome in Bucharest, in Romania, and thank you for trusting us with the organization of the 55th ESReDA, the 9th-10th October 2019.

AGIFER became ESReDA member, within the 50th ESReDA seminar, in the spring of 2016, when AGIFER delegation expressed his interest in the works presented and informed about our wish to find out many information about ESReDA activities. Taking into account that ESReDA organizes yearly two seminars and one of its working groups issued works specific to the investigations, AGIFER management decided to propose the organization of a seminar in Bucharest, this proposal being accepted by ESReDA BoD, in the autumn of 2017, within Ispra seminar.

AGIFER chose for the organization of the seminar the Convention Centre of the hotel Ramada Plaza Bucharest, that we hope to be good location for all the participants.

During the 8th October 2019, the day before the seminar, the members of the working group, in charge with the technical issues of the seminar, organized a training together with AGIFER investigators, when they shared many and varied information. We are sure that all this information, put together with the information got following the meetings of AGIFER with other European NIBs, will help Romanian investigators to perform investigations that contribute to the railway safety improvement.

Through the intended purpose and area, this seminar got the interest and participation of representatives from some important European and Romanian institutions. We mention here the colleagues from ESReDA, and representatives of other European institutions, that joined and helped us in the organization of this seminar, as follows: UIC, ERA, Romanian Academy, institutions from Romanian nuclear field, AGIFER homologous body from Romanian air field, that is Authority for Investigations and Analysis of the Civil Air Safety (AIAS), and so on.

The seminar will bring together 22 papers, some of the members of the working group Foresight in Safety, responsible for the Committee of Technical Program, but also of specialists from fields of interests for the investigators, that is the transport safety, both

railway and air ones, and human factor, from Europe and South America (Brazil). Among the presentations there will also be papers of our colleagues, investigators, drafted only by them or they collaborated at other papers, two papers of colleagues from air field and 4 from the nuclear field.
At the end of the first day, the Technical Committee of the Seminar prepared a workshop, firstly within an ESReDA seminar, where the participants will be invited to debate the problems met and the solutions corresponding to those 4 phases of an investigation.

The seminar will bring together 92 persons, from 15 countries, speakers and ESReDA members, AGIFER technical staff and technical staff from Romanian railway field, AGIFER wishing to let the cooperators know the most recent approaches and tendencies in the safety investigations and connected fields.

In order to have a good understanding of the papers presented and to have some constructive debates between participants, the simultaneous translation from and to English was assured.

At Worldwide and European level, the railway transports had in the last time a quick development, increasing the speed and comfort performances, but also through the decrease of the pollution. All of these could not have been possible without improving the traffic safety, finding some technical solutions as safety as possible, analyzing carefully all the possible risks, identifying some effective safety measures that prevent the occurrence of accidents. An investigation, performed with high responsibility, can explain why an accident happened, but in the same time, can contribute to the prevention of some accidents similar to the investigated one, issuing some safety recommendations.

We are sure that the seminar proceedings shall contribute to the improvement of the railway safety conditions, through a better understanding of the way to perform the investigation and through an understanding of the importance of its role. We also hope in a very effective cooperation between the actors involved in the safety of Romanian and European Union transports.

Romanian Railway Investigation Agency – AGIFER, past and future

Eugen ISPAS

Deputy General Manager

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Bucharest, ROMANIA

Abstract

Romanian Railway Investigation Agency - AGIFER, hereinafter referred to as AGIFER, that was set up on the 4th September 2015, resulting from the reorganization of Romanian Railway Authority - AFER and by the outsourcing of the investigation activity, being an independent body organized like legal public institution, completely financed from own funds.

AGIFER main tasks are:

a) *investigation of serious railway accidents;*
b) *investigation of the incidents happened in the train running, coordinated by an investigator in charge, appointed from AGIFER;*
c) *investigation of those accidents and incidents that in slightly different conditions could have led to serious accidents, including the technical failures of the structural subsystems or of the interoperability constituents of European railway high speed and conventional system;*
d) *other tasks specific to its field of activity, put under its authority through legal papers.*

AGIFER has no tasks in the investigation of tram accidents and cable car accidents.

The Government Decision 117 /2010 classifies the railway accidents and establishes the investigation procedure. Besides it, the decision stipulates the obligation for all railway actors in the market to report the accidents and incidents and establishes their tasks at the accident site.

Investigation of accidents and incidents is a process performed for their prevention, that includes gathering and analysis of information, settlement of conclusions, including the setting up of causes and, if case, issuing of some safety recommendations, for the improvement of railway and metro safety and for the prevention of accidents and incidents.

The main objective of AGIFER is the improvement of the railway safety and the prevention of the accidents, it being met through the issuing of safety recommendations in the reports for the investigations of the railway accidents and incidents and through a good relationship with the railway safety authority as well as with involved authorities.

AGIFER, in terms of organization, operation and decision making, is independent from Romanian Railway Safety Agency - ASFR, part of Romanian Railway Authority - AFER, of

any infrastructure managers, railway undertaking, charging body, allocation body, notified body, as well as of any entity whose interests could come in conflict with AGIFER tasks.
AGIFER has investigators responsible for the territorial structures, having offices and endowments, situated in Bucharest and in other 7 cities.

All the territorial offices have staff that assure the round-o'clock service. In 6 from those 7 territorial structures, the investigators have cars for the operative travel to the accident site
Both the Directive 2004/49/EC and Romanian legislation stipulates that the investigation is performed independently of any legal inquiry and does not aim to establish the guilty or the responsibility.

In order to be able to carry out its tasks at the accident site, AGIFER concluded cooperation protocols both with the police and with the prosecutors.

AGIFER is part of NIB network within European Union Agency for Railways, network that performs its activity with the support of the Safety Unit of the same European agency.
In cooperation with European Union Agency for Railways, AGIFER organized meetings for the investigator training.

AGIFER cooperates for the investigation of some accidents and incidents with other investigation bodies of the member states, in the conditions established by the Railway Safety Directive 2004/49/EC, as well as in the organization of meetings for sharing the good investigation practices.

Starting with 2016, AGIFER also cooperates with European Safety, Reliability & Data Association.

Operational analysis and projections in the prevention and management of emergencies

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Abstract

The presentation will begin with a summary presentation of the Emergency Interventions Department – DSU, part of the Ministry of Internal Affairs – MAI, and of its tasks, respectively the coordination, permanently, at national level, of the prevention and management of emergency interventions, assuring and coordinating the human, material, financial and other resources, necessary to restore the normality.

A part of Romanian critical infrastructure is the metro network in Bucharest – METROREX, consisting in 4 main lines with a total length of 69,25 km, double-track line and 51 stations. The emergency interventions within this network can be generated by earthquakes, floods, failures of different afferent equipment's, fires either in the train sets or in the tunnels, errors of the human factors and, not least, the terrorist attacks that are one of the world threats.

The presentation will illustrate the legal and organization measures taken for the improvement of the emergency interventions, through a good cooperation between the institutions involved, the achievements and the future plans.

The presentation will end with the operational analysis performed by DSU on the national situation of railway tunnels and bridges, in terms of the management of the emergency interventions and the need to draft some cooperation protocols.

SEMINAR PAPERS

SESSION 1:

Past, present, future

On a possible approach for the multi criteria event analysis in complex systems events

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Abstract

It is recognized that there are similitudes and the interconnections in the accidents investigation and learning processes, during various lifecycle phases and for various socio political environments for systems, which are using different and diverse technologies. However, the use of systematic approaches for such evaluations would be an example of very useful application of multi, trans and inter disciplinaraty methods for complex systems. A new approach is proposed for the evaluation of accidents by using multiple criteria. The approach is based on an analogy with some existing results and on the use of the topological description for systems and models.

Key words*: accident analysis, complex systems, topological modelling*

1. INTRODUCTION

The paper presents a systematic method and its results for the evaluation of the existing similitudes and the interconnections in the investigation and learning processes for major accidents in complex systems, for different technologies; the various lifecycle phases and socio-political environments during which such accidents take place are also considered. Figure 1 illustrates the aspects under evaluation for such analyses in complex systems.

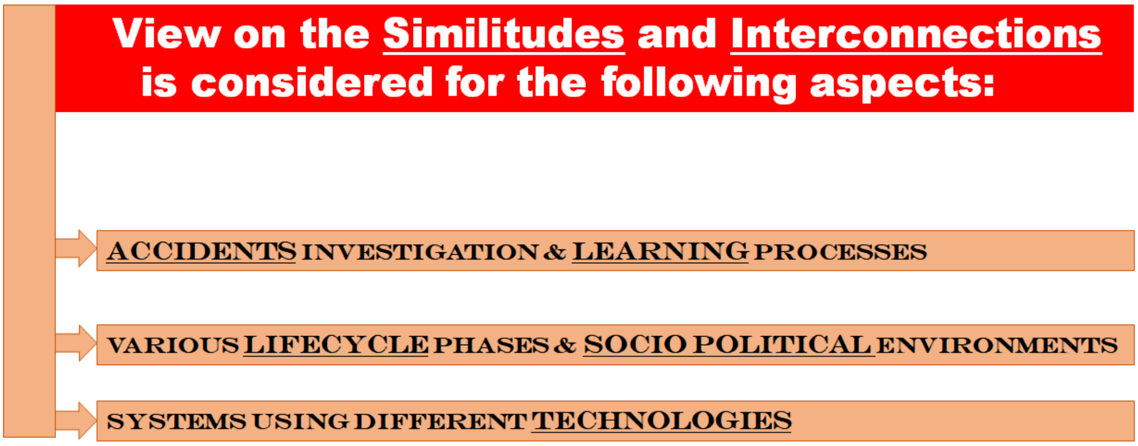


Figure 1. The goals of the review of various complex systems

The goal of the evaluation is to:

- Highlight the role of global approaches (crossing conventionally set limits in usual practices) on issues related to the evaluation of accidents and the learning process
- Consider impact of cross ties between various
  - lifecycle phases
  - socio political environments
  - diverse technologies
- Highlight the specifics of such cross dependencies for extensive implementation of results available in accident analysis of technical systems, as available in
  - *The series of activities and publications under ESREDA*
  - *Various technical areas at national and international level*
- Consider remarks as potential input for future activities of *the safety and reliability think tanks, on* topics like critical infrastructures and systems resilience

The ideas on the above topics are presented in the context and with direct reference to two specific technical domains (railways and nuclear) for a specific country (Romania). The proposed approach addresses some important practical questions, which are considered of interest in defining the accident analysis framework, methods for a given technical system by using also the experience from another system and / or environment (national or international) for any type of complex systems.

2. METHOD DESCRIPTION

The following four type of methods were identified as a quadrant of the general approach in the identification of the causes of accidents in any complex systems:

- Status of the organizational aspects potentially leading to a high contribution to occurrence and recurrence of accidents
- Detailed analyses using engineering methods on the causes of the accidents

- Existence of specially designed systems to derive conclusions on the accidents from the analyses
- Use of lessons learnt from own or similar installations

Details on each of the type of methods are in Figure 2.

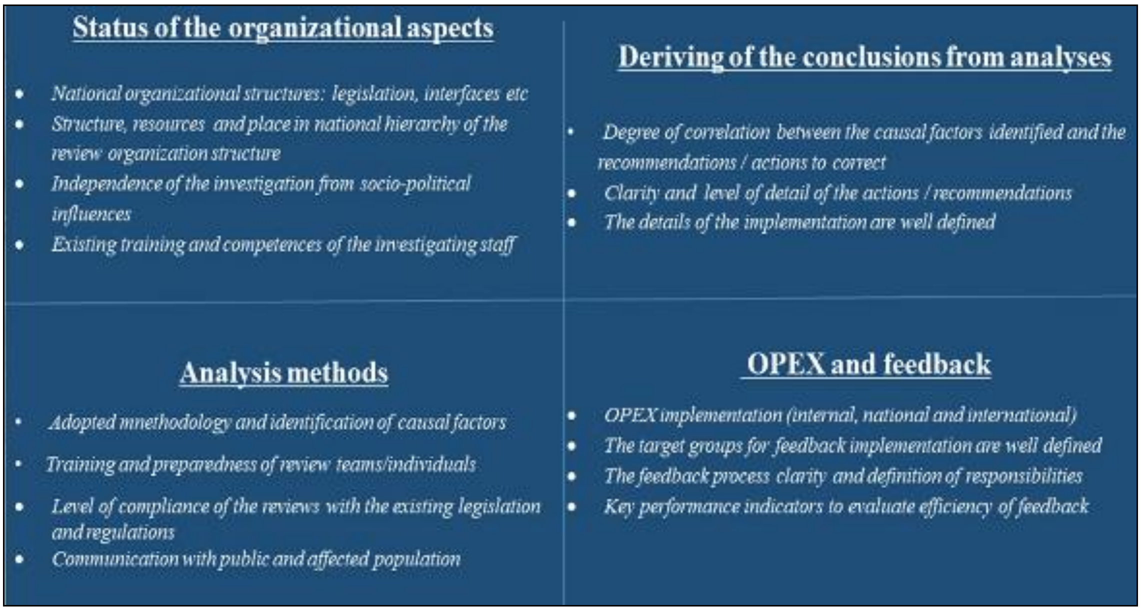


Figure 2. Quadrant of the types of methods for the accident evaluations – as considered in the paper

In order to reach the goal of evaluating similitudes and differences for various types of complex systems a scale was used to represent the compliance with the best / recommended practice of an accident evaluation system (Figure 3).

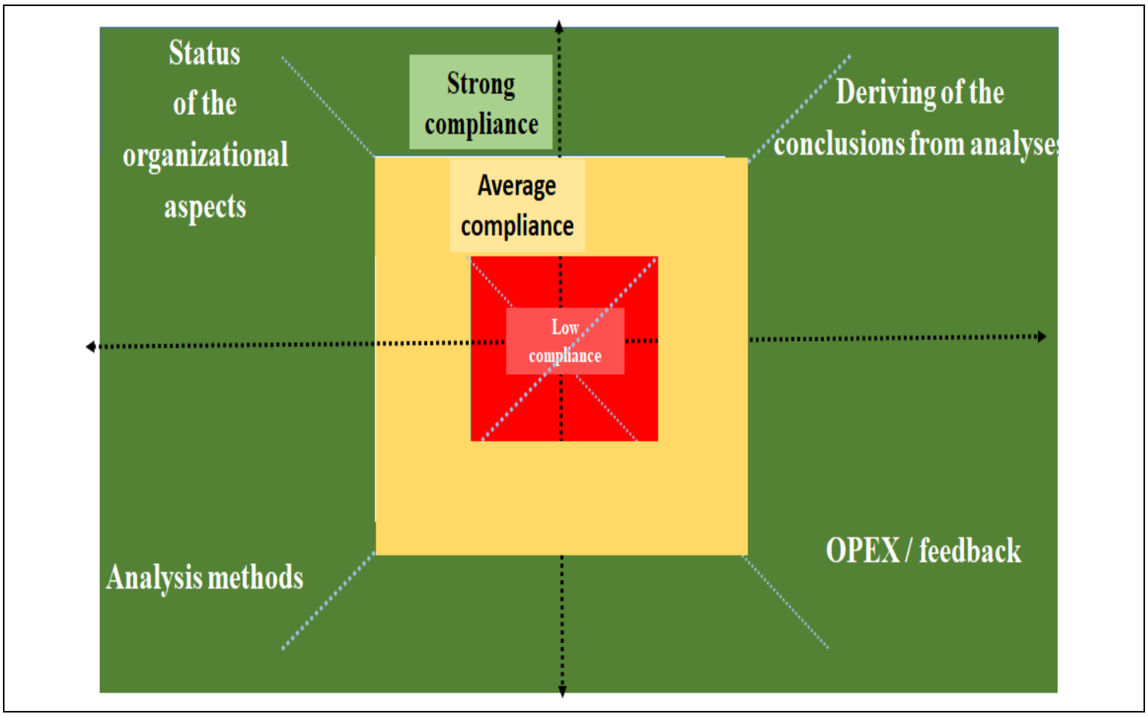


Figure 3. Compliance Scale with best / recommended practice of an accident evaluation system

The characteristics considered of interest in defining topics and strategies for accident analysis for a complex system are (Table 1) are as follows:

- Similitude (S)
- Accuracy in the evaluation of an accident (E)
- Usefulness of the implementation of the lessons learnt (L)
- Impact of the system lifecycle (C)
- Impact of socio political environment (P)
- Interference with other technologies (T)

Table 1. The characteristics considered of interest in defining topics and strategies for accident analysis for a complex system

Code	Short	Description of the characteristic: " The degree of:...
S	**Similitude**	Similitude
E	**Evaluation**	Accuracy in the evaluation of accidents
L	**Learning**	Usefulness and implementation of lessons learnt from accident evaluation
C	**Cycle**	Impact of the product / plant lifecycle phase
P	**Political**	Impact of socio - political environment
T	**Technologies**	Interference with other technologies

These characteristics define a matrix of evaluation of various options/situations, which might be encountered. The options in matrix format might be represented in geometrical format as nodes and facets of polyhedral, as shown in previous papers [3; 4]

In this paper the approach is used in order to identify specific features and compare two cases (two specific technical domains R=railways and N=nuclear), for a specific country (Romania) In Table 2 there is a more detailed representation of the common and different features, which have an impact (in the situation evaluated in the paper) on the comparison criteria from Table 1.

Table 1.Features that are common and features different for two industries

NO	COMMON FEATURES	NO	FEATURES THAT DIFFER
C1	Critical infrastructures for the country	D1	Independence of the review organization from political and social influences (R=Low; N=Medium)
C2	National structure defined, including event review organization.	D2	Obsolesce of infrastructure (R=High; N=Medium)
C3	Interface with international structures and organizations	D3	Different timings for the technology lifecycles (R=Short; N=Long)
C4	Socio political environment	D4	Resources of the review organization – material, training, organizational structure (R=Low, N=Medium)
C5	Learning and feedback systems implemented	D5	Cross industries connection (R=Medium, N=High)
C6	Connected to the emergency plans	D6	OPEX systems – feedback and databases (R=Low, N=High)
C7	Economical implications considered, but secondary in accident evaluation	D7	Feedback systems efficient Safety first (R=Low, N=High)

The sources of evaluations in table 2 are as follows:

- For **the Nuclear area –** the papers containing information to support the expert evaluations from and summarized in previous work ([1];[3];[4]):
  - *Evaluation of the impact of using risk driving evaluation criteria*
  - *Presentation of an example of event review and OPEX*
  - *Evaluation of a case study on cross industries impact (from R to N)*
  - *Presentation of emergency organizational structures at national and industry (N) level*
  - *Presentation of some specific safety evaluation techniques (N)*
- For the **Railway area** – the information available from [2].

In order to describe the interdependencies between various features / criteria specifics in cases N and R, used to develop the interdependence matrix the evaluation considered the existing results mentioned in papers listed before on the topic.
However, it was considered that the evaluation of interdependencies could be performed based on the same input by using three types of approaches (three approaches used in the literature in similar cases and one new proposed in this paper).

The main common idea of all types of approaches used will be however that the volume of admissible zones, as designated by specific tools of each approach, will indicate the set of optimal solutions.

- Type A - An approach as per the series of activities and publications under ESREDA , with a particular case, CUBE
- Type B - Analytical – parametric modelling – *function of a variable and one or two parameters*
- Type C - The *s- curve* accident analysis
- Type D Topological analysis based on Interdependence Matrix for defining criteria

<u>Type A of approach- Multicriterial analysis by using specialized tools as the ESREDA CUBE</u>

Type A is in accordance with the series of activities and publications under *ESREDA - Dynamic Learning from Accidents Bridging the gap between accident investigations and learning* [5;6].

Each node is defined by intersection of three facets, which are common areas of fulfilling any two out of three criteria.
The resultant geometrical form is of cube type, as presented in Figure 4. The nodes and the facets may be described in an Interdependence Matrix of the 3 criteria.
This principle is valid for any number of criteria. However, the resultant geometrical form is of more complex polyhedral type, as it will be shown under the type D of approaches.

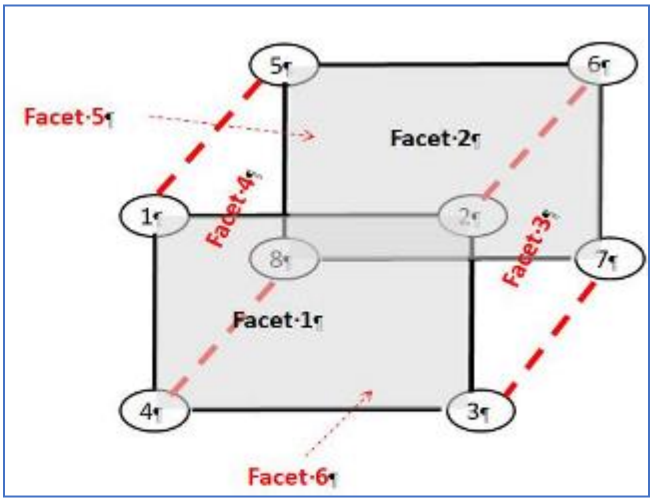


Figure 4. The facets of the multicriteria evaluations

The ESREDA CUBE is, from this perspective, a particular case of geometrical representation of the space of acceptable solutions for the optimization based on 3 criteria (Figure 5).
As mentioned in the introduction the evaluation needs to consider more than 3 criteria (in the R-N comparison case 6 criteria were considered).
For this case a new approach is needed and/or a generalization of the CUBE approach, based on mathematical modelling.

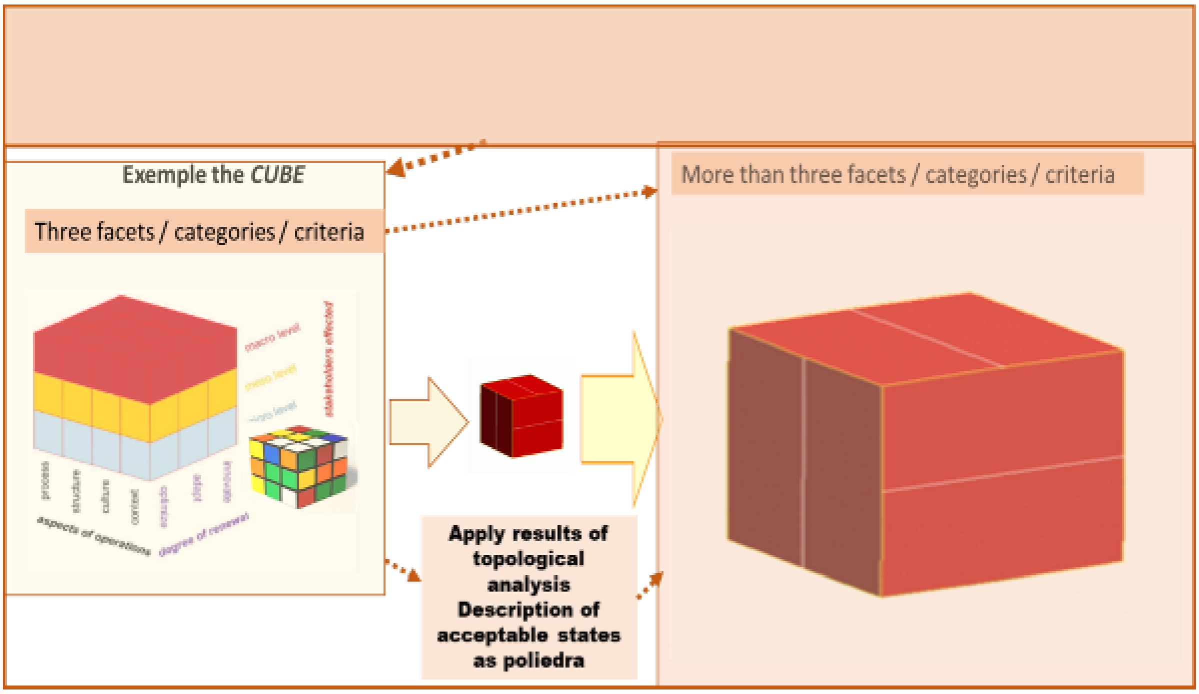


Figure 5. Use of ESREDA CUBE to evaluate optimal solutions in safety/reliability optimization based on 3 criteria

However, if there will be more than 3 criteria, then the acceptable space od optimal solutions will be described by a more complex type of poliedra, as the Type C of evaluation will illustrate (and which is symbolically illustrated in the right side of the Figure 5).

Type B of approaches – Analytical evaluations of the space (volumes of acceptable optimal solutions), i.e. a parametric modelling – *function of one variable and one parameter*

This type of approaches is based on the evaluation of the dependencies of the optimal space (in a two-dimensional representation) for each criteria defined in Table 1. This results in a set of acceptable spaces (as illustrated in Figure 6) for each criterion. The resultant acceptable space will be considered as an envelope of all spaces for a given situation (R or N for instance in this paper).

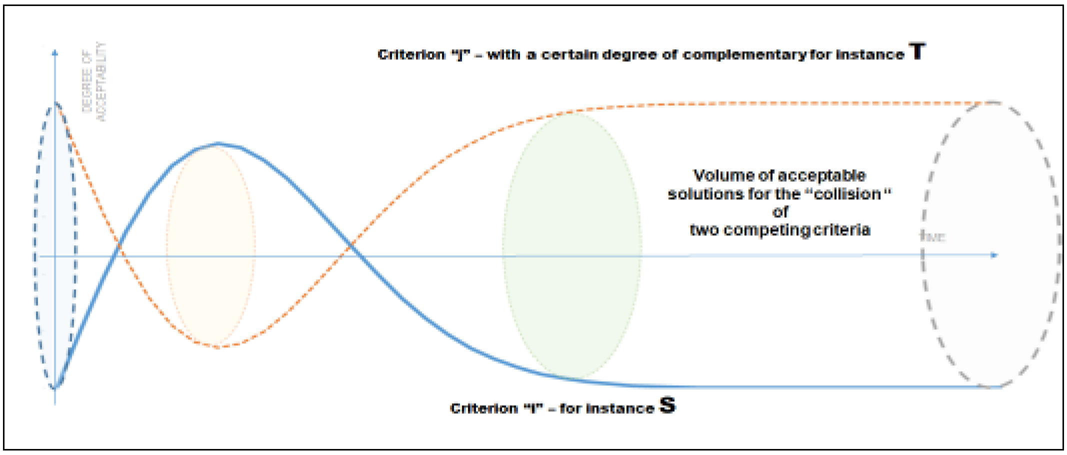


Figure 6. Evaluation of cross dependencies for extensive implementation in accident analysis of technical systems

Type C approaches – Use of the technological (s- curve)

In this type of approaches, the technological curve (the so-called s- ***curve***) is used in order to perform the evaluation of acceptable solutions. The curve is studied by comparing the ***"ideal s-curve***" with the **real one** (as resulted after as derived from the accident analysis (as illustrated in Figure 7 and it is presented in detail in [2]; [3]]). As shown in Figure 7, each major accident in N type of installations lead to a re-evaluation of the acceptable space of optimal solutions **(they became smaller and with more limitations and driven by various systematic biases called safety paradigms).**

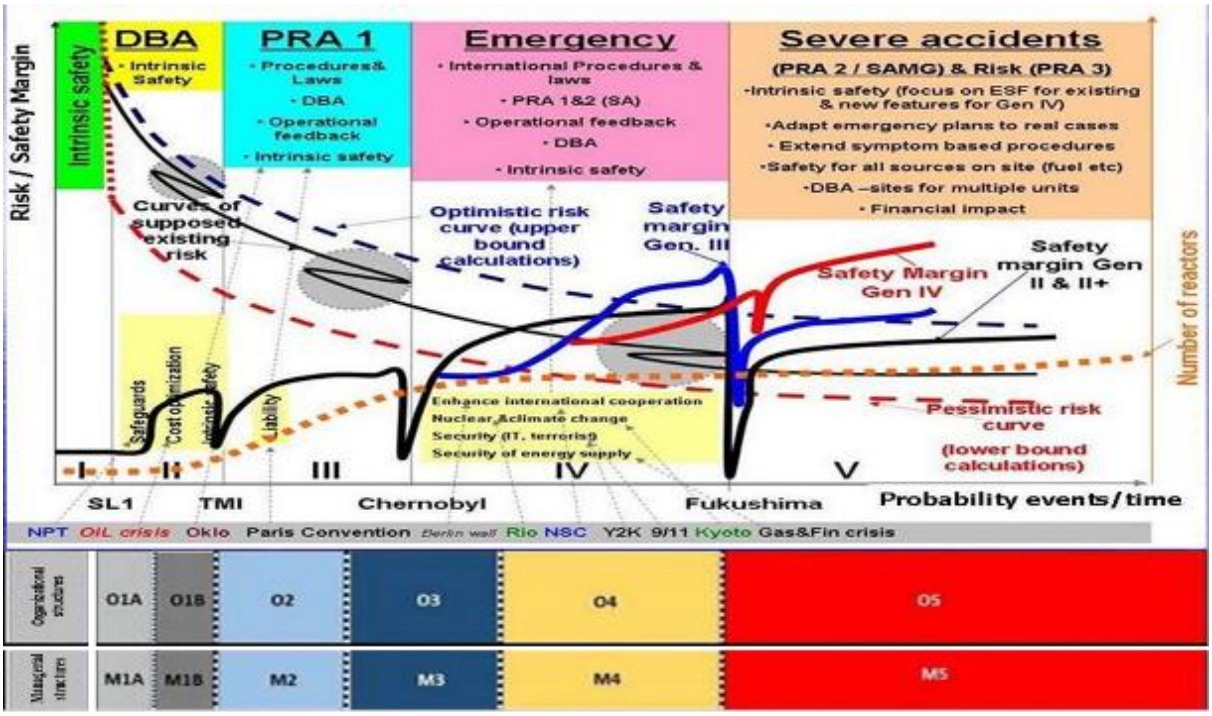


Figure 7. Type C approach event review for nuclear acse [3]

Evaluation of cross dependencies for extensive implementation in accident analysis of technical systems is similar for various technologies (In Figure 6 a nuclear NPP case is represented, while in Figures 8 and 9 a railway technology is shown) ([3]).

Figure 8. Type C approach event review for railway case [2] (1)

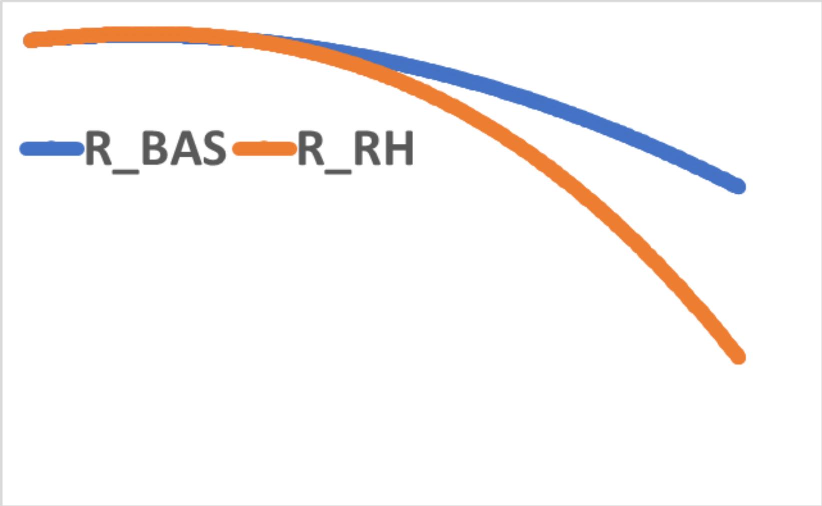


Figure 9. Type C approach event review for railway case [2] (2)

Type D Use of topological spaces for the evaluation cases with more than three criteria

A new approach is proposed for the case when there are more than three criteria for the evaluation of an optimal space of solutions for the risk management in a complex system. The method, called the **method of the topological spaces**, was used in previous tasks [3;4] and it is described in detail with examples of use in previous works [3;4].
The set of solutions of acceptable optimal choices in a complex system with multicriterial set of challenges is defined for various areas of the Interdependence matrix as per formulas (1) to (3). The acceptable space of solutions is defined as per formula (4)

$$M^{s} = M^{s1}(e \to l \to c \to p) \cup M^{s2}(e \to t \to p) \quad (1)$$

Where x→y = x is a function of y

$$M^{w} = [M^{w1}(e \to p) \cup M^{w2}(l \to p)] \cup [M^{w3}(e \to c \to p) \cup M^{w3}(e \to c \to p)] \quad (2)$$

$$M^{tot} = M^{s} \cup M^{w} \quad (3)$$

$$Acceptable\ space\ of\ solutions = M^{tot} = Volume\ Polyhedral \quad (4)$$

The solutions of the topological approach for the evaluation of the spaces of optimal results for a multi criteria decision in a complex system are represented by the matrix in Figure 10.

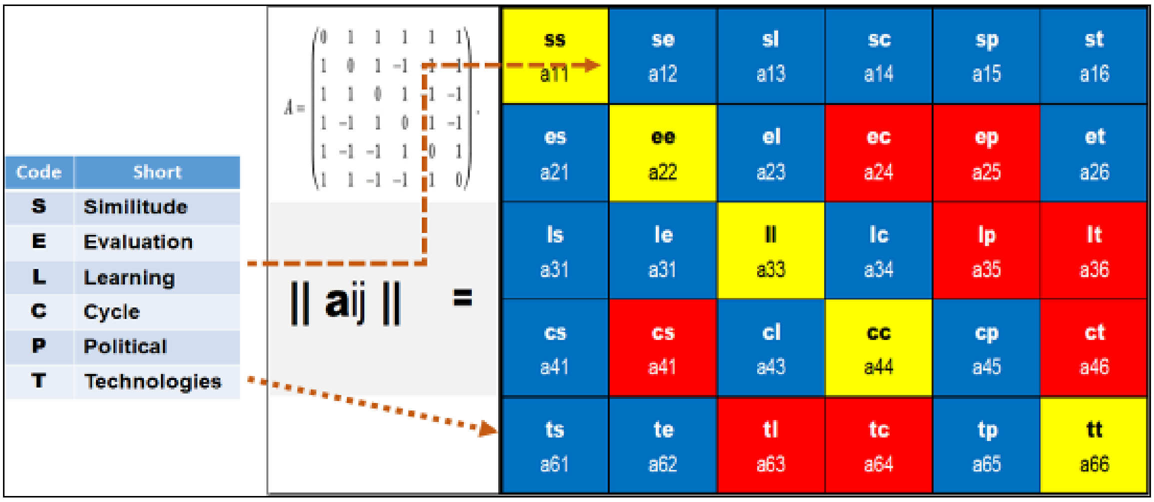


Figure 10. Interdependence matrix for evaluating criteria (in table 1) leading to acceptable spaces as defined by polyhedral type

In general, a multiple set of evaluations for an increased number of criteria leads to a set of solutions, which are in matrix format as per the Figure 10. However, there is a connection shown in [3] between the matrix format a geometrical representation, illustrated also in Figure 11.

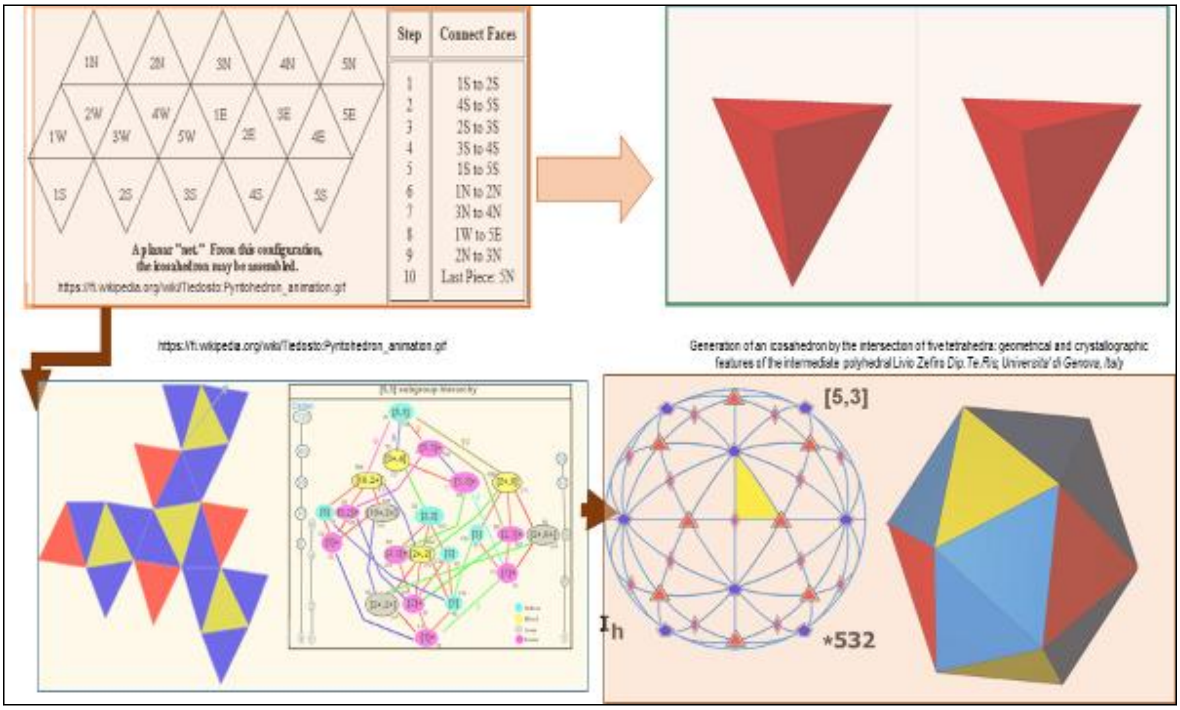


Figure 11. The polyhedral representation of the matrix of multi criteria decision for a complex system [3]

Practically for a set of criteria and the type of systems defined in tables 1 and 2 a set of results as represented in Tables 3-5 is obtained.

Table 2.Sample representation of the connections between various features for a randomly chosen case study (1)

Strong INDIRECT connections			
Evaluation	Learning	Cycle	Political Environment
Evaluation	Technologies	Political Environment	

Table 3.Sample representation of the connections between various features for a randomly chosen case study (2)

Very Strong DIRECT connections	
Similitude	Evaluation
	Learning
	Cycle
	Political Env
	Technologies

Table 5. Sample representation of the connections between various features for a randomly chosen case study (3)

Weak connections		
Evaluation	Cycle	Technologies
	Political Environment	
Learning	Political Environment	
	Cycle	Technologies

For the particular case of four criteria (of which the three criteria case of the CUBE is a particular situation) the results are in the polyhedral format of a tesseract (Figure 12).

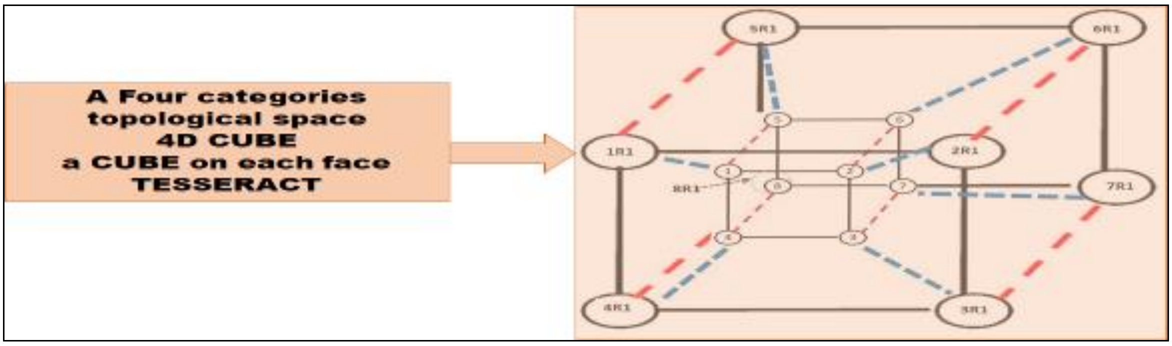
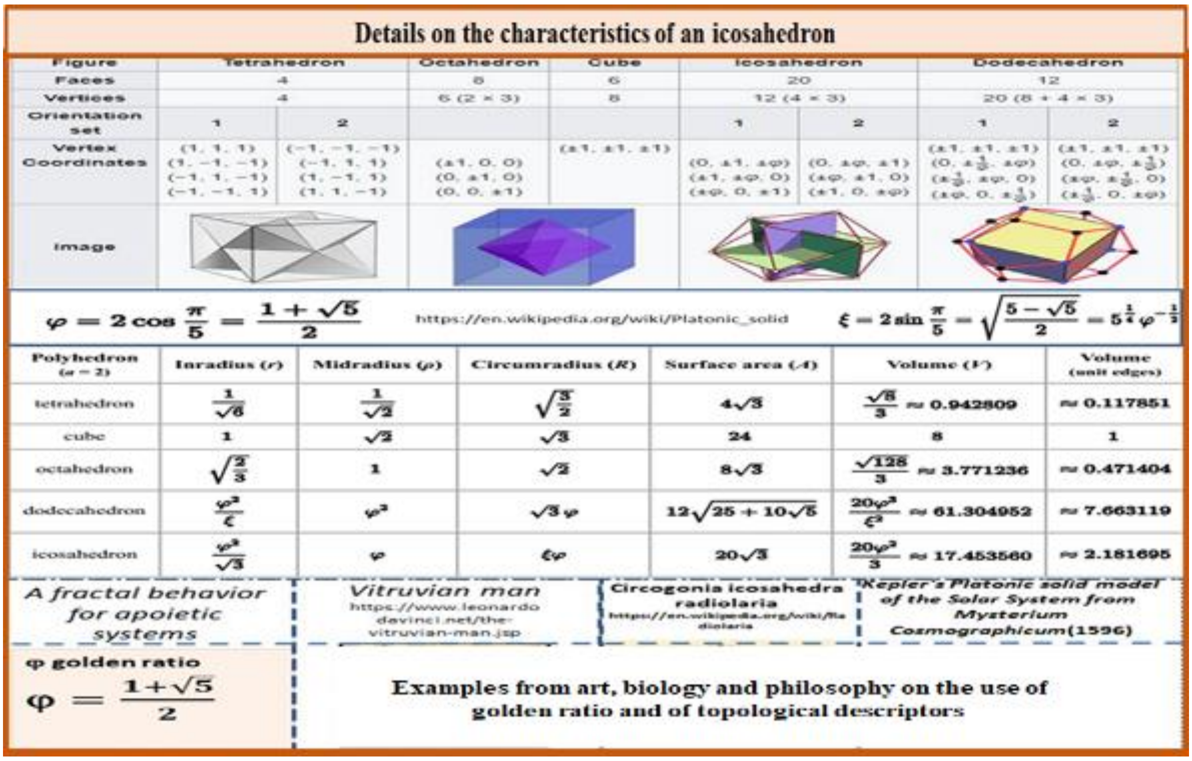


Figure 12. Set of results for a 4 criteria case (a first generalization of the three criteria CUBE case)

In general, for a complex system with more than 4 criteria the space of optimal results are represented as a series of polyhedral forms (Figures 13 and 14) [3;4].



Details on the characteristics of an icosahedron

Figure	Tetrahedron		Octahedron	Cube	Icosahedron		Dodecahedron	
Faces	4		8	6	20		12	
Vertices	4		6 (2 × 3)	8	12 (4 × 3)		20 (8 + 4 × 3)	
Orientation set	1	2			1	2	1	2
Vertex Coordinates	(1, 1, 1) (1, −1, −1) (−1, 1, −1) (−1, −1, 1)	(−1, −1, −1) (−1, 1, 1) (1, −1, 1) (1, 1, −1)	(±1, 0, 0) (0, ±1, 0) (0, 0, ±1)	(±1, ±1, ±1)	(0, ±1, ±φ) (±1, ±φ, 0) (±φ, 0, ±1)	(0, ±φ, ±1) (±φ, ±1, 0) (±1, 0, ±φ)	(±1, ±1, ±1) (0, ±1/φ, ±φ) (±1/φ, ±φ, 0) (±φ, 0, ±1/φ)	(±1, ±1, ±1) (0, ±φ, ±1/φ) (±φ, ±1/φ, 0) (±1/φ, 0, ±φ)
Image								

$$\varphi = 2\cos\frac{\pi}{5} = \frac{1+\sqrt{5}}{2}$$ https://en.wikipedia.org/wiki/Platonic_solid $$\xi = 2\sin\frac{\pi}{5} = \sqrt{\frac{5-\sqrt{5}}{2}} = 5^{\frac{1}{4}}\varphi^{-\frac{1}{2}}$$

Polyhedron ($a = 2$)	Inradius (r)	Midradius (ρ)	Circumradius (R)	Surface area (A)	Volume (V)	Volume (unit edges)
tetrahedron	$\frac{1}{\sqrt{6}}$	$\frac{1}{\sqrt{2}}$	$\sqrt{\frac{3}{2}}$	$4\sqrt{3}$	$\frac{\sqrt{8}}{3} \approx 0.942809$	≈ 0.117851
cube	1	$\sqrt{2}$	$\sqrt{3}$	24	8	1
octahedron	$\sqrt{\frac{2}{3}}$	1	$\sqrt{2}$	$8\sqrt{3}$	$\frac{\sqrt{128}}{3} \approx 3.771236$	≈ 0.471404
dodecahedron	$\frac{\varphi^2}{\xi}$	φ^2	$\sqrt{3}\varphi$	$12\sqrt{25+10\sqrt{5}}$	$\frac{20\varphi^3}{\xi^2} \approx 61.304952$	≈ 7.663119
icosahedron	$\frac{\varphi^2}{\sqrt{3}}$	φ	$\xi\varphi$	$20\sqrt{3}$	$\frac{20\varphi^2}{3} \approx 17.453560$	≈ 2.181695

Figure 13. Solutions of the acceptable spaces in the polyhedral form [3] (1)

The maximum possible space for a given complex system is a hypersphere [3] (Figure 14)

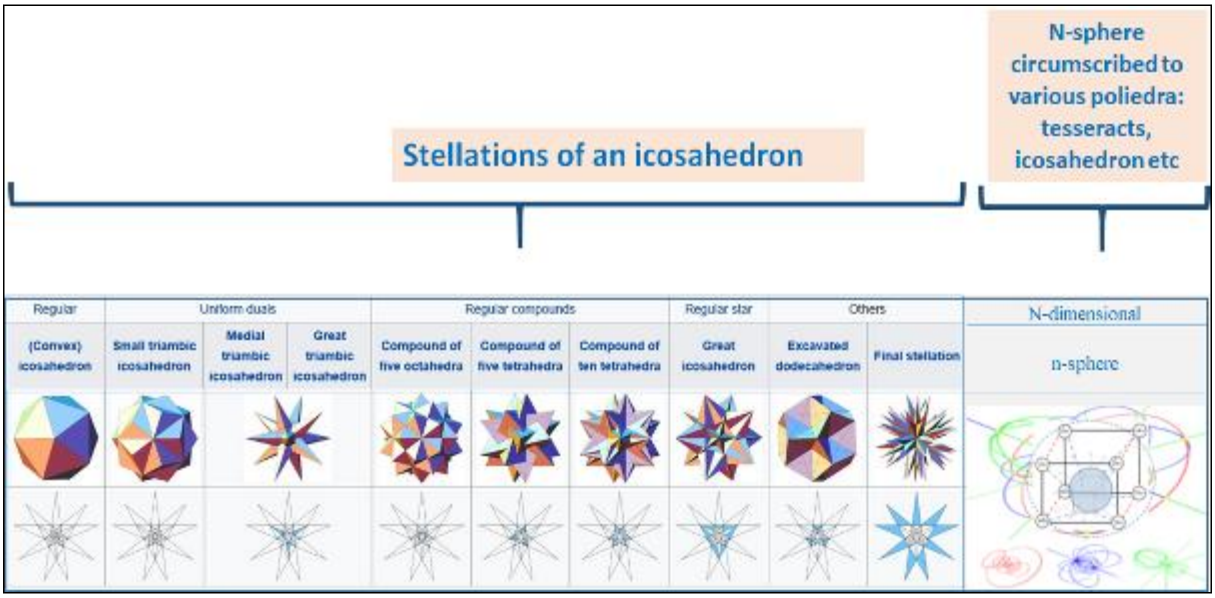


Figure 14. Solutions of the acceptable spaces in the polyhedral form [3] (2)

3. RESULTS

Based on the method described in the previous paragraph a set of cases were defined and evaluated for the optimization method as defined in the introduction and in Tables 1 and 2.

The following calculation cases were considered:

Case 1 *Weak interactions between all criteria*

Case 2 *Strong technical interaction between criteria and weak interaction with socio political ones*

Case 3 *Weak interaction between technical aspects and strong political dependencies*

Case 4 *Weak interaction between all criteria and low similitude with other technologies*

Case 5 *High similitude with other technologies/systems but no evidence of applicable common criteria*

The Interdependence matrices and the determinants are defined in the Figures (15) - (19).

-75

ss a_{11}	**se** a_{12}	**sl** a_{13}	**sc** a_{14}	**sp** a_{15}	**st** a_{16}
es a_{21}	**ee** a_{22}	**el** a_{23}	**ec** a_{24}	**ep** a_{25}	**et** a_{26}
ls a_{31}	**le** a_{22}	**ll** a_{33}	**lc** a_{34}	**lp** a_{35}	**lt** a_{36}
cs a_{41}	**ce** a_{42}	**cl** a_{43}	**cc** a_{44}	**cp** a_{45}	**ct** a_{46}
ps a_{51}	**pe** a_{52}	**pl** a_{53}	**pc** a_{54}	**pp** a_{55}	**pt** a_{56}
ts a_{61}	**te** a_{62}	**tl** a_{63}	**tc** a_{64}	**tp** a_{65}	**tt** a_{66}

0	1	1	1	1	1
1	0	1	-1	-1	1
1	1	0	1	1	-1
1	-1	1	0	1	-1
1	-1	-1	1	0	1
1	1	-1	-1	1	0

Figure 15. Case I weak interactions between all criteria

-237

ss a_{11}	**se** a_{12}	**sl** a_{13}	**sc** a_{14}	**sp** a_{15}	**st** a_{16}
es a_{21}	**ee** a_{22}	**el** a_{23}	**ec** a_{24}	**ep** a_{25}	**et** a_{26}
ls a_{31}	**le** a_{22}	**ll** a_{33}	**lc** a_{34}	**lp** a_{35}	**lt** a_{36}
cs a_{41}	**ce** a_{42}	**cl** a_{43}	**cc** a_{44}	**cp** a_{45}	**ct** a_{46}
ps a_{51}	**pe** a_{52}	**pl** a_{53}	**pc** a_{54}	**pp** a_{55}	**pt** a_{56}
ts a_{61}	**te** a_{62}	**tl** a_{63}	**tc** a_{64}	**tp** a_{65}	**tt** a_{66}

0	2	2	2	-1	1
2	0	-1	1	-1	1
2	-1	0	1	-1	-1
2	1	1	0	1	2
-1	-1	-1	1	0	1
1	1	-1	2	1	0

Figure 16. Case 2 Strong technical interaction between criteria and weak interaction with socio political ones

0

ss a_{11}	**se** a_{12}	**sl** a_{13}	**sc** a_{14}	**sp** a_{15}	**st** a_{16}
es a_{21}	**ee** a_{22}	**el** a_{23}	**ec** a_{24}	**ep** a_{25}	**et** a_{26}
ls a_{31}	**le** a_{22}	**ll** a_{33}	**lc** a_{34}	**lp** a_{35}	**lt** a_{36}
cs a_{41}	**ce** a_{42}	**cl** a_{43}	**cc** a_{44}	**cp** a_{45}	**ct** a_{46}
ps a_{51}	**pe** a_{52}	**pl** a_{53}	**pc** a_{54}	**pp** a_{55}	**pt** a_{56}
ts a_{61}	**te** a_{62}	**tl** a_{63}	**tc** a_{64}	**tp** a_{65}	**tt** a_{66}

0	0	-1	1	2	0
0	0	-1	-1	2	0
-1	-1	0	-1	2	-1
1	-1	-1	0	2	2
2	2	2	2	0	2
0	0	-1	2	2	0

Figure 17. Case 3 Weak interaction between technical aspects and strong political dependencies

11

ss a_{11}	**se** a_{12}	**sl** a_{13}	**sc** a_{14}	**sp** a_{15}	**st** a_{16}
es a_{21}	**ee** a_{22}	**el** a_{23}	**ec** a_{24}	**ep** a_{25}	**et** a_{26}
ls a_{31}	**le** a_{22}	**ll** a_{33}	**lc** a_{34}	**lp** a_{35}	**lt** a_{36}
cs a_{41}	**ce** a_{42}	**cl** a_{43}	**cc** a_{44}	**cp** a_{45}	**ct** a_{46}
ps a_{51}	**pe** a_{52}	**pl** a_{53}	**pc** a_{54}	**pp** a_{55}	**pt** a_{56}
ts a_{61}	**te** a_{62}	**tl** a_{63}	**tc** a_{64}	**tp** a_{65}	**tt** a_{66}

0	-1	-1	1	-1	-1
-1	0	-1	-1	-1	-1
-1	-1	0	-1	-1	-1
1	-1	-1	0	-1	-1
-1	-1	-1	-1	0	-1
-1	-1	-1	-1	-1	0

Figure 18. Case 4 Weak interaction between all criteria and low similitude with other technologies

-20

ss a_{11}	**se** a_{12}	**sl** a_{13}	**sc** a_{14}	**sp** a_{15}	**st** a_{16}
es a_{21}	**ee** a_{22}	**el** a_{23}	**ec** a_{24}	**ep** a_{25}	**et** a_{26}
ls a_{31}	**le** a_{22}	**ll** a_{33}	**lc** a_{34}	**lp** a_{35}	**lt** a_{36}
cs a_{41}	**ce** a_{42}	**cl** a_{43}	**cc** a_{44}	**cp** a_{45}	**ct** a_{46}
ps a_{51}	**pe** a_{52}	**pl** a_{53}	**pc** a_{54}	**pp** a_{55}	**pt** a_{56}
ts a_{61}	**te** a_{62}	**tl** a_{63}	**tc** a_{64}	**tp** a_{65}	**tt** a_{66}

0	2	2	2	2	2
2	0	-1	-1	-1	-1
2	-1	0	-1	-1	-1
2	-1	-1	0	-1	-1
2	-1	-1	-1	0	-1
2	-1	-1	-1	-1	0

Figure 19. Case 5 High similitude with other technologies/systems but no evidence of applicable common criteria

The results of the space of acceptable solutions (defined for those cases by the determinants) are represented in Figure 20. The Case 2 is the case with the best optimal space of acceptable solutions.

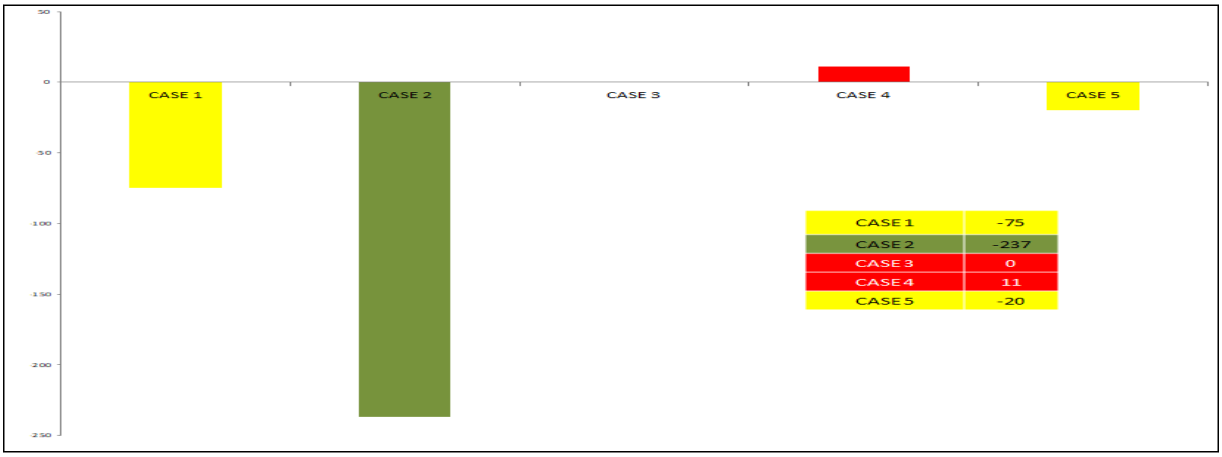


Figure 20. Comparison of the acceptable spaces of solutions for cases 1 to 5 (Green the best, yellow medium cases and red worst case)

For the comparison of R and N systems in the special case mentioned in the paper the results indicate that, for a R type of system the evaluation methods need improvement.

MAINLY

- From the perspective of being better connected with the learning process
    - **best team training,**
    - **use of databases and**
    - **detailed root cause procedures**
- Adapted to the degree of obsolesce of the infrastructure and
- By increasing the independence on political factors
    - **better structure at national level,**
    - **more resources and**
    - **administrative independence to the review organizations**

SECONDLY

- By eliminating any direct interference of the political factors in the evaluation process
- Improving feedback to operation and learning process by taking actions to force the operators of transportation means to implement the learned lessons

This result is represented in Figures 21 and 22.

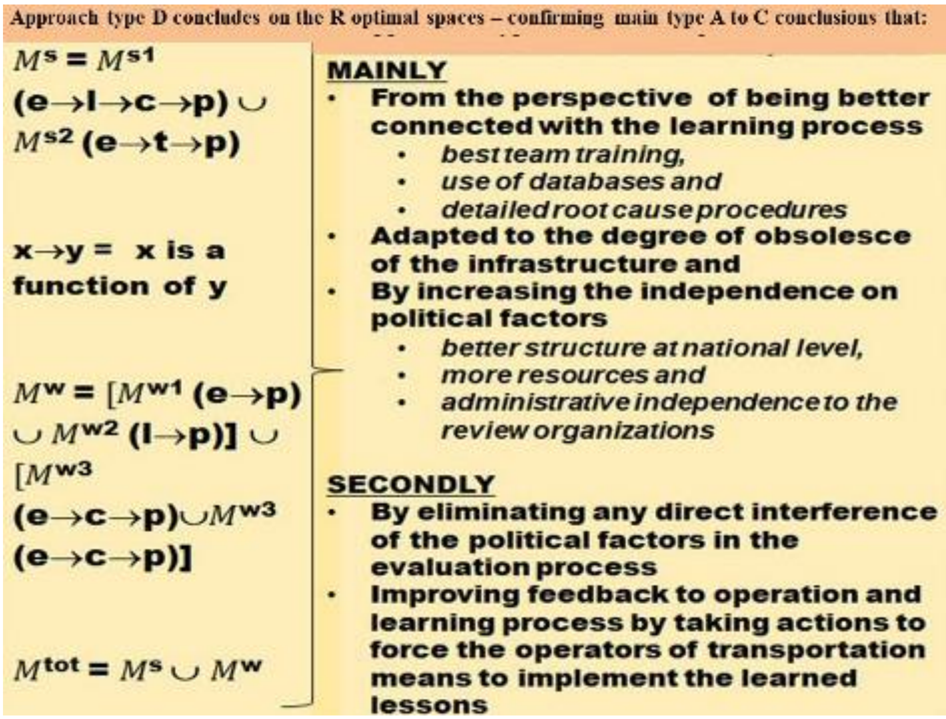


Figure 21. Results of acceptable spaces and actions to improve evaluations of R versus N (1)

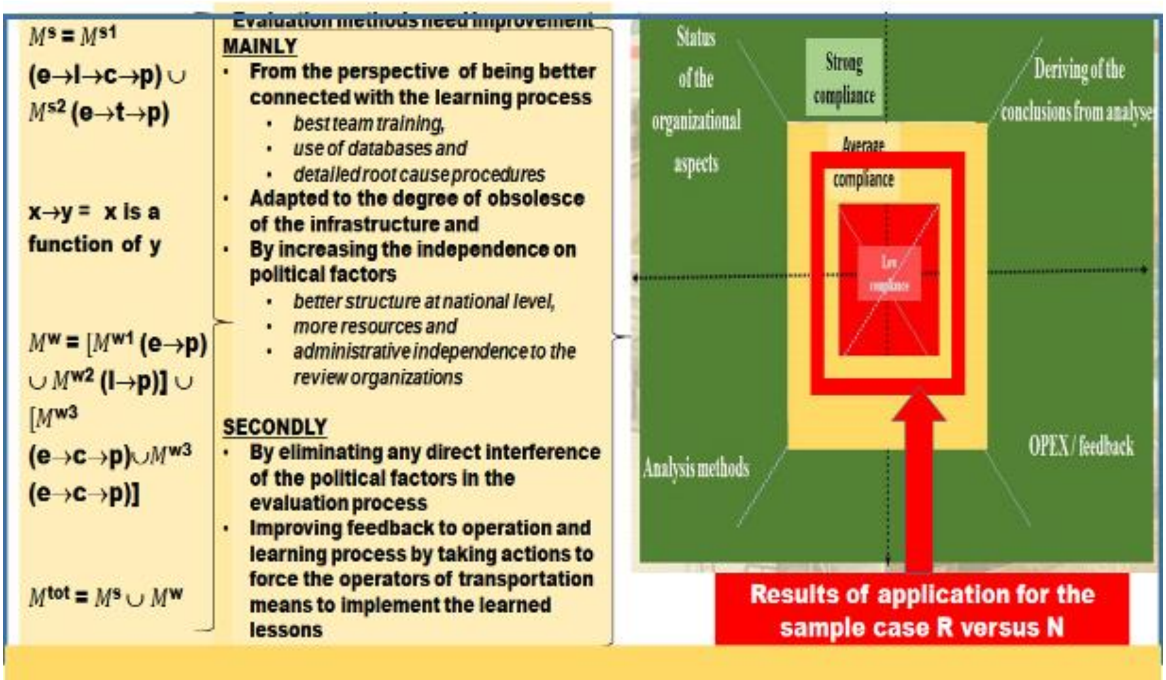


Figure 22. Results of acceptable spaces and actions to improve evaluations of R versus N (2)

4. CONCLUSIONS

The comparison of the methods considered for the inter technological comparison of systems optimized based on multiple criteria illustrate that, by defining in a systematic manner the strategy of the evaluation it is possible to:

- ➢ Identify better and in a systematic manner of the best fit of a recommended practice to a new domain and
- ➢ Improve the n – dimensional criteria evaluation of accidents for a given domain.
- ➢ Consider extending the evaluation strategies and methods to aspects like
    - critical infrastructures or
    - systems resilience

might be a possible approach for researches in safety and reliability, including a topic for the ***Safety and Reliability Think Tanks.***

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Railway accident investigation in a globalising system

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Abstract

For nearly two centuries railway accident investigation has been first and foremost a national affair. There were some standards of interoperability but safety and its supporting technology was local, national at best. All this is changing rapidly. The EU has formulated comprehensive interoperability standards touching every part of the railway system. Safety is going to become standardised in the EU with the expansion of ERTMS, the system of standards for management and interoperation of signalling for railways. Add to that the Chinese policy to develop the Silk Route and it is clear that rail safety is rapidly progressing from national to continental and soon intercontinental level.

The paper does not show existing research. What it aims to do instead is to identify deficiencies in the present system of railway accident investigation: safeguarding of knowledge and the exchange of experiences. An incident with a freight train in the Port of Rotterdam that originated on the Black Sea could require the involvement of many parties all over Europe. European high-speed trains are operating in Asia and America. Japanese technology is exported to the UK.

Responsibilities for investigation also differ from country to country. Some countries have independent safety boards, others see accident investigation as part of supervision by railway inspectorates or by the department of public prosecution. In some countries this responsibility is shared by railway inspectors and separate accident investigators all using different procedures, methodologies and approaches.

Is there a transcontinental or even intercontinental necessity for basic accident investigation standards, methodologies and the way reports are communicated?

Most findings are reported in the national language, making it very difficult for others to read them and learn from them unless they are written in one of the major languages.

Some countries are forerunners in the use of certain technologies and operational systems. Others are experiencing similar problems later on. How can we avoid a repetition of failures when we don't speak the same language, using a similar investigation approach and basic methodology?

That poses those in charge of railway systems for a major challenge, similar to the one that was observed in the airline industry post WWII. Accident investigation is not a goal in itself. It is a means to identify necessary fields of improvement, to learn from failure. Accident investigation in the airline industry has moved from national to global level but not without difficulties. It is inevitable that the railway sector most follow given the globalisation of railway technology.

1. Introduction

For nearly two centuries railway accident investigation has been first and foremost a national affair. There were some standards of interoperability but safety and its supporting technology was local, national at best. All this is changing rapidly. The EU has formulated comprehensive interoperability standards touching many parts of the railway system. Safety is going to become standardised in the EU with the expansion of ERTMS, the system of standards for management and interoperation of signalling for railways, and the transfer of a number of responsibilities from the National Safety Authorities to the European Railway Agency. Add to that the Asiatic markets which are increasingly expanding towards Europe, exemplified by Chinese policy to develop the Silk Route, and it is clear that rail safety is rapidly progressing from national to continental and soon intercontinental level.

2. Railways in the Netherlands increasingly international

For many years the Netherlands has been the North-western gateway to continental Europe. The Port of Rotterdam has developed into the largest port in Europe[1], generating a large volume of (international) freight transport by inland shipping, road and rail. Freight trains originating from Rotterdam extend to destinations all over Europe, including the Baltic, Mediterranean and Black sea. Rotterdam is one of the major docking ports for the very large Post Panamax container vessels.

Much of this cargo is transported by inland shipping or by road transport. However, rail transport plays a major part as well, with destinations in Germany, Italy and further away, such as the Black Sea and the Baltic region. Each 5 – 10 minutes a freight train arrives at or departs from the major Rotterdam marshalling yard at Kijfhoek. Many freight operators are international companies, the largest of them being DB Cargo, also the largest in Europe. There are workshops in Rotterdam which carry out maintenance, overhaul and repairs to locos and other rolling stock, often originating from countries far and away. The Dutch transport inspectorate has several inspectors permanently assigned to Rotterdam.

[1] In 2017 Rotterdam processed 467.3 mln tons and around 13.7 mln TEU. 29,646 sea-going vessels called at Rotterdam plus 105,000 inland vessels. It was larger than the next five European ports put together. Source: Port of Rotterdam Authority

Passenger transport shows a similar picture, although most of this is concentrated within the Netherlands itself. Nevertheless, the Dutch Government has proposed to make medium distance international rail transport more competitive with air traffic. This year a direct Eurostar connection has been opened between London and Amsterdam via Rotterdam. Other major international trains are the Thalys to Brussels and Paris, the ICE to Cologne and Frankfurt and the IC to Hannover and Berlin. Increasingly cross border services are being developed or enhanced, such as the Benelux between Amsterdam/The Hague, Antwerp and Brussels and the Aachen-Heerlen-Maastricht-Liege regional service. There is a strong wish to develop and intercity service between Eindhoven and Cologne.

All this is possible as a result of an increasingly standardised European railway system coupled with technological developments facilitating easier interoperability where systems differ such as the overhead power supply[2]. This is reflected in the increasingly important role of the European Railway Agency ERA. It is a matter of time before passenger rail transport follows developments in the freight market. National railway companies will be replaced by international firms, specialising in regional operations or intercity/long distance transport. Next to national intercity routes the Netherlands sees a number of international routes, a market that will be expanded over the coming years, see above. High speed railway operation is leading here, with German/Dutch ICE's operating to Frankfurt, French/Belgium Thalys to Paris and Eurostar to London.

The complexity of a modern railway system is illustrated by a recent incident, in which a NS/Dutch Railways intercity broke down on the Dutch high-speed railway. The train was a standard push/pull configuration. The coaches were Dutch Railways ICR type. The pulling loco was a Bombardier Traxx, leased as a freight loco from Belgium but adapted for passenger use by Dutch Railways. The pushing loco was also a Bombardier Traxx, again leased as a freight loco, this time from Germany and also adapted for passenger use by Dutch Railways. One train, three countries involved!

3. Railway accident investigation still national

Although railways are developing into an increasingly continental system, railway accident investigation is still looked at from a national point of view. There is no agreed European standard regarding format, process and methodology of such an investigation. There is no obligation to publish the results in a mutually agreed language, if only as a summary of the outcome and recommendations. There is no agreed central register of such investigations. It is all left to national initiatives. Only the NSA's have to report to the ERA.

Another challenge is that in some country's accident investigation is the sole responsibility of an independent transport safety board, such as in the UK. In other countries accident investigation is done by the national safety authority (NSA). This NSA is sometimes an independent government body, in other cases it still is part of the state-owned national rail operator. In the Netherlands we have a mixture of both. Major (fatal) accidents are usually investigated by the Dutch Safety Investigation Board (OvV), which is an independent body based on a separate Act. All the other investigations are the responsibility of the railway inspectorate section of the NSA (ILT), a government body.

[2] Standard power supply on the Dutch overhead is 1500/1800 V DC. The Betuweroute freight railway and the High-Speed railway have 25 kV AC. Germany uses 15 kV AC. Belgium has 3kV DC and 25 kV AC.

There is a fundamental difference between investigations executed by a safety board and those done by an NSA. The former looks at the accident from a systems point of view. The purpose of the investigation is first and foremost to learn from failure. The outcome is usually published followed by a set of recommendations. Investigations carried out by an NSA tend to focus on violations of the law: who is to blame? In some cases, NSA investigation reports are used as a basis for judicial prosecution. The outcome is published, followed by a set of offences that have been found, plus shortcomings and warnings/signals. The offences can result in a (temporary) loss of a licence to operate.

The danger of stopping the investigation once a 'culprit' has been found is, that the corporate role of the system in which the accident occurred is not fully understood. Every train driver knows he/she should stop at a signal at danger. Yet each year nearly 100 signals passed at danger (SPAD) occur in the Netherlands alone. Why? How? What were the circumstances? How was the sighting of the signals? Was there expectation of a positive aspect involved? Which preventive actions have been taken by the management? Was there pressure because of company penalties for running late? Was it because of concessions with impossible requirements from the safety point of view? All these questions need to be answered, instead of simply fining the train driver sometimes with hefty fines. And yes, if there is a case of gross negligence, of willingly taking risks, then there is every reason for severe action.

A weak point in railway accident investigations is the absence of agreed standards and methodology, even at a national level. In general, these reports describe sometimes in minute detail how an accident happened. In many cases they also explain why it happened, although the level of detail varies. Less obvious is what can be learned from what happened *after* the crash. Is it inevitable that given a frontal collision between two trains, passengers and staff get killed? How well did the rolling stock behave or did it show an unexpected failure mode? How effective were the emergency services? How well did the hospitals cope with the unexpected influx of casualties? How can we learn if we fail to investigate these aspects?

Dutch railway experts have an advantage that they are capable of reading foreign investigation reports written in German, English and French. That is, if they have become aware of the existence of such reports. However, equally important reports from Italy or former Eastern Europe are outside the reach of Dutch experts. In return there could be lessons to be learned by others from Dutch investigation reports which are now often ignored, simply because either the report as such is not known outside our country or the contents (in Dutch) is incomprehensible to foreigners.

Is there a transcontinental or even intercontinental necessity for basic accident investigation standards, methodologies and the way reports are communicated? Most findings are reported in the national language, making it very difficult for others to read them and learn from them unless they are written in one of the major languages. Some countries are forerunners in the use of certain technologies and operational systems. Others are experiencing similar problems later on. How can we avoid a repetition of failures when we don't speak the same language, using a similar investigation approach and basic methodology?

Still very fresh is the recent bridge disaster in Genua, Italy, August 13, 2018. Although this was a road bridge, the outcome of the investigation could affect the design and maintenance of railway bridges as well. Apart from that, the Genua bridge crossed a major railway line. It would be useful if the investigation reports were available to others outside Italy in a language they can understand.

4. Lessons learned

An interesting example of a national investigation with international implications is the investigation into the Amsterdam (2012) train collision. Although at first sight it looks like a Dutch problem, the recommendations show some interesting points that could also apply to other railway systems outside the Netherlands.

Saturday April 21, 2012 due to maintenance work on part of the local railway system, some tracks between Amsterdam Central and Amsterdam Sloterdijk west of Amsterdam were not available. This resulted in planned single line working over a 2 km long section in part of this important railway corridor. NS as operator and ProRail as infra manger did not deem it necessary to down-scale the normal (frequent) operation over this section. The corridor consists of three double track lines next to each other: from left to right to/from Haarlem, to/from Zaandam and to/from Schiphol, each seeing eight trains per hour in each direction, in total 16 trains per hour per line. The line in question was the centre line of the bundle, leading to and from Zaandam, see figure 1.

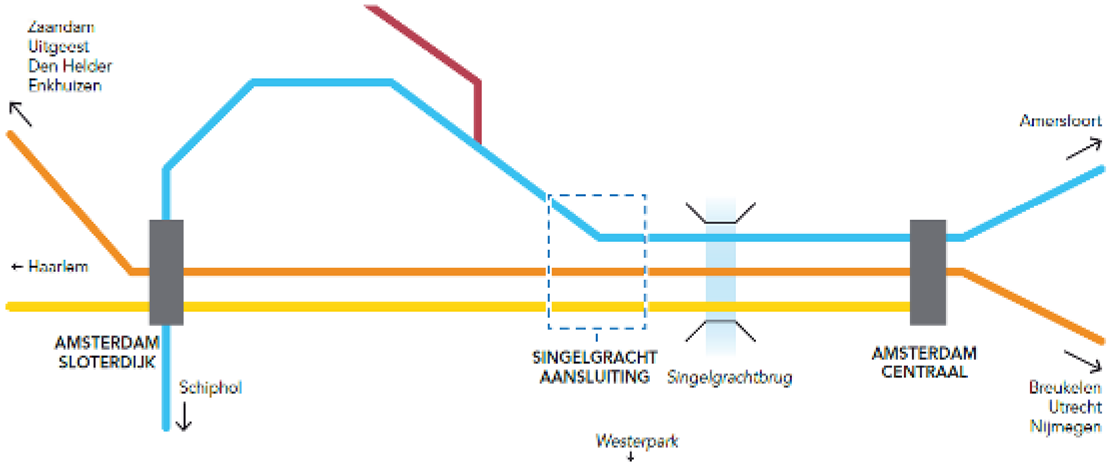

Fig. 1 Schematic diagram of the accident location. Source: OvV Report, 2013

Every signal in the Netherlands is equipped with automatic train protection (ATB-EG), which was originally developed in the USA. After WW II it was supplied to the Netherlands under the Marshall Aid and further developed by Dutch Railways. It is not used elsewhere in Europe. It works very well but it has one fundamental shortcoming: it does not stop a train after a signal passed at danger (SPAD) when it is travelling below 40 km/h. After a series of low speed collisions an improved version was developed beginning of this century called ATB-Vv, using extra beacons to safeguard an effective braking curve at lower speeds. Since then many signals at risk have been equipped with ATB-Vv. This effectively closes the 40 km/h gap in ATB-EG.

In the Amsterdam case no extra, preventive measures were taken to prevent signals passed at danger from happening[3], despite the fact that single line workings have been known to be amongst the most dangerous situations on railway systems, both in the Netherlands and

[3] Many signals have been equipped with additional ATB-Vv (ATP) beacons, which prevent SPAD's. The Singelgracht signals were not considered to be at high risk in normal operational conditions: double track operation with full separation of up and down trains.

abroad. After all it was only a temporary situation that occurred that weekend and would be over by next Monday.

Early in the evening of Saturday April 21, 2012 an NS/Dutch Railways Sprinter service consisting of a recently built SLT-type six car electric multiple unit (EMU) left Amsterdam Central for its destination Alkmaar. Due to the single line working it was forced to stop at the entrance to the single line section west of Singelgracht railway bridge West of Amsterdam Central.

An NS/Dutch Railways Intercity made up of VIRM-type electric double deck stock with six coaches on its way from Alkmaar to Amsterdam, was approaching from the opposite direction. A route had been set by the automatic route setting system for the intercity to pass from the left to the right track seen in the direction of Amsterdam Central. The driver of the Sprinter was distracted by a safety problem with another train on an adjacent track, which had failed tail lights. She didn't see signal 494 at danger ahead of here train. She travelled at 40 km/h, thus ATB did not act to stop her train when she passed signal 494 at danger at Singelgracht railway bridge, followed by a frontal collision with the approaching Intercity some 300 metres beyond, see figure 2.

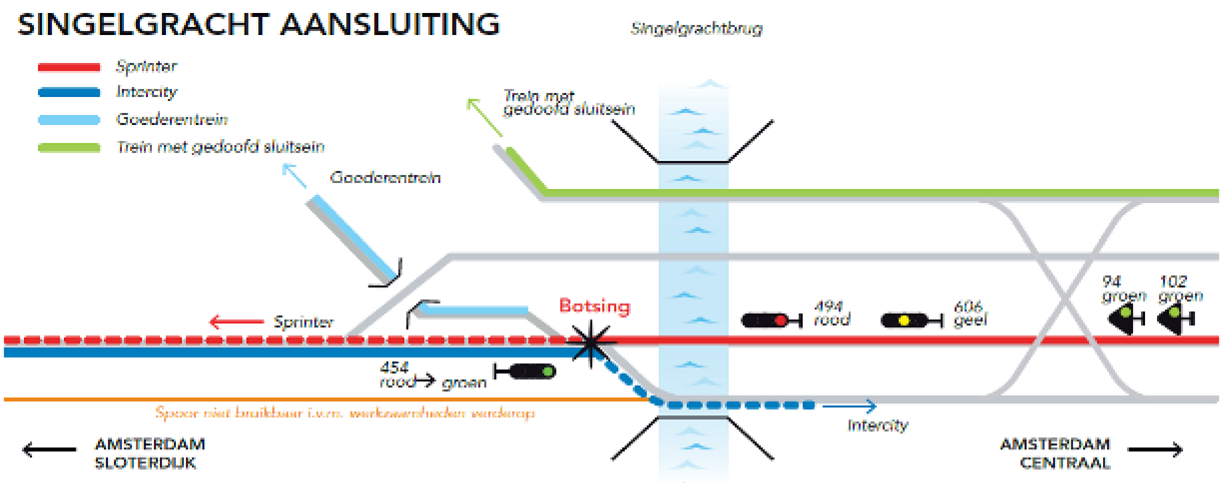

Fig. 2 Frontal collision between a Sprinter coming from Amsterdam Central and an Intercity coming from Zaandam. Source: OvV Report, 2013 The yellow line indicates the track that was out of operation because of maintenance works. Signal 494 at Singelgracht bridge was ignored by the Sprinter. Local line speed was 60 km/h.

The combined speed of the two trains was approximately 100 km/h. Just over 200 passengers and staff were injured, including both drivers and a trainee driver in the intercity who were lucky to escape alive. One of the passengers later died in hospital because of fatal internal injuries as a result of a collision with a sharp table in the Intercity. Material damage was substantial: the 6-car VIRM type double deck intercity was damaged beyond repair because of the buckling of all six cars in the train (which absorbed much of the collision energy as it was designed to do), see figure 3.

Fig. 3: The buckling action of the coaches of the VIRM-type intercity absorbed much kinetic energy. Picture by W.R. Beukenkamp

Fig. 4: The front of the SLT type Sprinter. The crash buffers have been pushed aside by the front of the VIRM type intercity. Picture by W.R. Beukenkamp

The almost new 6-car SLT-type sprinter needed partial rebuilding, although the cage in which the driver was sitting, survived the crash remarkably well. Also, remarkable: neither of the two trains had become derailed. Damage to the infrastructure was limited to some track movement and a damaged set of split points. There was no damage to the overhead. Disruption of train traffic west of Amsterdam Central lasted that whole weekend. By Monday normal traffic could be resumed.

Noticeable with the SLT EMU was that the collision fenders had failed to work (see figure 4), because they were not compatible to the central Scharfenberg coupler of the approaching intercity. Thus, what should have been an elastic collision on the part of the SLT Sprinter became an inelastic collision setting its passengers flying through the train and causing much bodily harm. The safety cage in which the driver of the Sprinter was sitting, functioned well as can be seen from figure 4.

The Dutch safety investigation board (OvV) recommended[4] amongst other things, that more attention should be payed to the interior design. The interior of trains should be made more crashworthy or crash friendly, such as thicker tables with soft edges, properly locked ceiling panels et cetera. Also, problems with the evacuation of casualties were identified, which were not covered by modern regulations such as the TSI's (technical specifications of interoperability). These recommendations are now standard requirements for Dutch train operators when ordering new or refurbished passenger rolling stock. As far as is known it is not a general requirement on a European scale. Thus, important lessons in railway safety learned at Amsterdam have been lost outside the Netherlands.

5. Globalisation of railway systems

The EU has formulated comprehensive interoperability standards touching every part of the railway system. Safety is going to become standardised in the EU with the expansion of the European Rail Traffic Management System (ERTMS), the system of standards for management and interoperation of signalling for railways. National railway networks are increasingly being operated by international train operating companies.

Rolling stock is no longer a market dominated by European suppliers such as Siemens and Alstom or the European division of Bombardier; Japanese suppliers are also active such as Hitachi. Others from Korea and China have expressed an interest in entering the European market as well. On the other hand, European manufacturers have supplied trains to Asia and America. The same can be said of signalling systems and components. Dutch railways use an automatic train protection system supplied by Alstom, which interacts with a train detection system supplied under the Marshall Aid by a subsidiary of General Electric. Add to that the Chinese policy to develop the Silk Route as an overland transport corridor in competition with sea trade and it is clear that rail safety is rapidly progressing from national to continental and soon intercontinental level.

It is quite possible that in the not too distant future an accident investigation involving trains in the Port of Rotterdam could extend to Shanghai or Seoul. The implications from this accident investigation (lessons learned) could be important for railways along the Silk Route. How do we safeguard some minimal standards of quality and comprehensiveness of the investigation plus accessibility to international interested partners?

[4] OVV Report 'Treinbotsing Amsterdam Westerpark' d.d. 26-3-2013

6. Follow the ICAO example?

The present situation poses those in charge of railway systems for a major challenge, similar to the one that was observed in the airline industry post WWII. Accident investigation is not a goal in itself. It is a means to identify necessary fields of improvement, to learn from failure. Accident investigation in the airline industry has moved from national to global level but not without difficulties. It is inevitable that the railway sector most follow given the globalisation of railway technology.

Perhaps the airline industry can show us the road ahead. Following the globalisation of air traffic after WW II the International Civil Aviation Organisation (ICAO), a United Nations specialised agency, was founded with international agreed rules. One of them regarding accident investigation is covered by Annex 13 *Aircraft Accident and Incident Investigation.* This annex covers:

- monitoring developments in accident investigation techniques and practices as well as accident prevention matters;
- monitoring developments in system safety concepts and practices, contributing to the ICAO Global Aviation Safety Plan and the ICAO Universal Safety Oversight Audit Programme (USOAP);
- managing safety recommendations addressed to ICAO;
- conducting and participating in seminars on aircraft accident investigation and prevention.

ICAO has a specialised Accident Investigation Section responsible for developing and updating Standards and Recommended Practices (SARPs) for inclusion in Annex 13. ICAO operates in close cooperation with national air accident investigation organisations.

7. Discussion

Following this paper, a number of subjects can be identified that need clarification:

- Need to establish an Annex similar to ICAO Annex 13 to the European railway interoperability directive relating to railway accidents and incident investigation, supported by a special section of the European Railway Agency responsible for developing and updating standards and recommended practices for inclusion in this Annex?
- Need to establish independent investigation boards relating to railway accidents?
- Need to report in a mutually agreed language?
- Need to upload investigation reports to a central public register, possibly supported by the ERA?

One thing is clear: although railways are now over 200 years old, we can still learn much from railway accidents, at home and abroad. It is the language and the methods that separates us, not the subject. It is important that this learning process is supported as much as possible and extends as far as possible.

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From Sectorial to Multimodal Accident Investigation Boards – Some Lessons from the Development in the Nordic Countries

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Abstract

During history, several large accidents have been followed by investigation or – often in modern times – by the setup of an ***ad-hoc*** *investigation commission, e.g. after the earth-quake in Lisbon in 1775, the Titanic shipwreck in 1912, and the explosion in the harbour of Halifax in 1917. These early kinds of investigations have some characteristics in common, such as: they were initiated ad-hoc, shortly after a specific accident, resulted in a report with recommendations, and were dissolved after the task had been fulfilled.*

Later – sometimes and somewhere – maybe in parallel, certain ***permanent*** *commissions were established within a specific sector, often within the air transport sector, to investigate all relevant and serious accidents or incidents as well.*

The third phase was characterized by the need to emphasise the ***independence*** *of such commissions as well as the necessity of splitting the police and the civil investigations.*

A fourth phase may be identified as the development of ***broader,*** *independent accident investigation commissions, such as the US National Transportation Safety Board, which was set up in 1967, and was responsible for investigating all transport accident in aviation, shipping, railways, road and pipelines. Partly based on the NTSB's experiences, Sweden and Finland came to include even broader sectors than transport in their mandate for a national accident investigation board. Denmark and Norway have had a similar development, but on a more narrow scale.*

In the paper, the developments in the Nordic countries will be described and discussed. The description will also include examples from The Netherlands (The Dutch Transport Safety Board), from the US (US National Transportation Safety Board) and from the EU approach. The role of international cooperation, such as The International Transportation Safety Association, will be evaluated. The discussion will include basic dimensions such as independence, non-blame, multimodal organisations, recommendations and follow-up.

Keywords: *Accident, investigation, commission, board, independence, multimodal.*

1. A global view – basic patterns, some developments and trends

After every major accident in human history, people have always asked the question: why? Both in earlies times and even today, some people answer the question with a religious interpretation: it is the will of God. Such accidents could be either natural catastrophes such as earthquakes, floods, hurricanes, wild fires, landslides, heat or cold waves, tsunamis, sand and dust storms or severe disasters damaging houses and even towns, shipwrecks, pest, hunger, pandemics etc. In order to influence the god(s) will and prevent disasters, many people turned to different kind of sacrifices, such as offerings, prayer or penances. Later, due to the technological development, new risks for other types of major accidents become more threatening, as accidents connected to aviation, rail and road, to nuclear power plants, to offshore installations, to industrial productions etc. Examples of new, emerging risks are climate change (global warming with droughts, storms, floods), biotechnology, nano-technology, artificial intelligence.

Gradually, a competing or parallel type of explanation developed, based on a secular and sometimes scientific attitude: accidents and incidents are mostly man-made, they can be investigated by systematic, rational methods, causes can be identified, and preventive measures be proposed.

In many sectors, investigation of accidents was for many decades done within the affected firm or institution or branch. Sometimes the company used an ad hoc-solution for each accident. Within a few sectors, typically the railways, the monopolistic situation included the responsibility to investigate all kind of accidents involving passenger transport on tracks. So, the international picture is rather complex and complicated.

In a historic perspective, the roots of modern accident investigations by a permanent, public commission can be traced to 1915, when a military aviation commission was established under “The Royal Flying Corps”, Accident Investigation Branch (AIB), in Great Britain, later (1922) expanded to include also civilian accidents. This invention was later followed by the establishment of similar commissions in other countries, first in the aviation sector, followed by the maritime and railway sectors, while the use of permanent commissions was not common in the road sector until recently.

It is obvious that an AIB cannot investigate all type of accidents and incidents. Several criteria may be used for deciding whether or not they should be used in a certain case. Common limitations are the nature of the event, e.g.:

- The seriousness of the accident or incident (e.g. only accidents with more than x fatalities and/or which include economic losses of a certain magnitude are investigated etc.),
- The probability that such event(s) will recur,
- The potential of the consequences of an event,
- The learning potential of an investigation,
- The societal interest or priority,
- The resources and competence of the actual AIB.

In addition, security events, clearly such as a criminal act and terrorism, and sometimes also natural disasters, will often be omitted. By tradition, some sectors in society are also omitted from AIB-investigations, usually the defence sector, working environment and the health sector. However, a few AIB include arenas as defence and health services, as the Dutch Safety Board (established 2005, when the board replaced the former Dutch Transport Safety Board). In fact, DSB has a very broad scope. Its mandate includes aviation, shipping, rail transport, road transport, pipelines, defence, industry and trade, crisis management and aid provision, healthcare, and nature and environment.[5] The Dutch Transport Safety Board has been an international role model in promoting the need for independent accident investigation[6].

In some sectors, international organisations have issued common procedures for investigations of accidents, such as:

– ICAO: Annex 13 (Aircraft Accident & Incident Investigation) to International Civil Aviation Convention

– IMO - International Maritime Organisation – has issued several resolutions to adopt code of international standards and recommended practices, guidelines to assist investigators and to harmonise reports.

EU has through the latest decades (since 1980) issued several regulations and directives to promote harmonised performances within the EU on a sectorial basis. Many commissions have been established, and the setup of European networks contribute to enhance safety.

ESReDA has also published (June 2009) a common, international guideline for safety investigation of accidents.[7] In addition, ESReDA has published a book “Shaping public safety investigations of accidents in Europe”, which has a broad description and discussion of many aspects of the historical and the recent development of AIB, including a chapter about challenges of investigation.[8]

[5] https://en.wikipedia.org/wiki/Aviation_accidents_and_incidents

[6] Van Vollenhoven, P. (2003) “Independent accident investigation: every citizen’s right, society’s duty”. *Elaborated Version of Third European Safety Transport Safety Lecture.* European Transport Safety Council, Brussels, 23 January 2001.

[7] https://esreda.org/wp-content/uploads/2016/07/ESReDA_GLSIA_Final_June_2009_For_Download.pdf

[8] Roed-Larsen, S., Stoop, J. and Funnemark, E. (2005) “Shaping public safety investigations of accidents in Europe”, *ESReDA Safety Series*, Oslo: DNV Publishers.

In addition to the sector-based cooperation within established organisations (ICAO, IMO), a new kind of cooperation between independent commissions in the transportation sector were founded 25 years ago:

ITSA – International Transportation Safety Association - is an international network of heads of independent safety investigation authorities (SIA). ITSA covers all modes of transportation, including aviation, marine, railways, road transport, pipelines and underground infrastructure.

In 1993, the independent safety investigation authorities (SIA) of 4 countries met and agreed to form the International Transportation Safety Association. ITSA was founded on the notion that independent non-judicial investigations of transportation accidents and serious incidents contribute significantly to the safety of the traveling public. Furthermore, that an international network, which brings together the safety investigation agencies from many nations, would be a mutually beneficial forum to share safety information.
Today, ITSA is composed of independent safety investigation authorities from 16 countries, including Finland, Norway and Sweden.
The mission of ITSA is to improve transport safety in each member country by learning from the experiences of others.[9]

2. The developments of AIB in Nordic countries (Denmark, Finland, Iceland, Norway, Sweden)

2.1 Denmark

The main accident investigation board (AIB) investigates accidents and incidents within the Danish aviation sector (Denmark, Greenland and the Faroe Islands) and within the Danish railway sector. In 1917, AIB published 43 reports. The former “Aircraft Accident Investigation Board for Civilian Aviation” was set up 1 January 1979, while railway accidents were investigated by a special commission from 1 December 1971 til 31 July 1996, organised as a part of the Danish State Railways.

Two other AIBs supplement in the investigation of accidents: The Danish Maritime Accident Investigation Board - DMAIB – (scope: merchant and fishing ships, ships in Danish and Greenlandic territorial waters, commercial diving operations), and the Danish Road Traffic Accident Investigation Board - DRTAIB. The DMAIB investigates about 140 accidents each year, and the DRTAIB publishes about 25 – 30 thematic accident reports each year.

Concerning main resources – the number of employees and the budget - the AIB has 9 employees and an annual budget of 14 million DKK. The DMAIB has 4 employees and investigates about 140 accidents annually. DRTAIB has a budget of 4,5 million DKK (about Euro 500 000).

2.2 Finland

The Safety Investigation Authority (SIA) conducts safety investigations through examining the course of events related to accidents or incidents, their causes and consequences, and the search and rescue actions as well as the actions taken by the authorities.[10]

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[9] https://itsasafety.com/about/
[10] http://www.turvallisuustutkinta.fi

The legal basis is the act on investigation of accidents (373/1985) and the regulation 1996/79. The Safety Investigation Act of 525/2011 defines the task and the mandate of the Safety Investigation Authority. The task is to investigate all major accidents and serious incidents regardless of type, as well as aviation, rail traffic, and maritime traffic accidents and events. The mandate includes organisation, training, preparedness, international cooperation, and issuing safety recommendations and monitoring their implementation.

2.3 Iceland

Iceland has organised a separate Icelandic Transportation Safety Board which cover maritime, air and road accidents. The Board was established in 2013. However, all information is written in Icelandic language.[11]

2.4 Norway

The Accident Investigation Board Norway (AIBN) covers all accidents and incidents that occur in the transport field (aviation, railway, road, marine), The AIBN started as a separate, permanent commission for major aviation events in 1989 and has expanded its scope and mandate through successive extensions: via including rail accidents (2002), later road accidents (2005) and lastly maritime accidents (2008). Today, the AIBN has an organisation with about 51 full-time employees (2017) and a budget in 2017 of 77 million NOK (about Euro 7,7 million). The organization chart shows that, in addition to the General Director, administration and advisory staff, there is a separate department for each transport sector: Aviation (7 inspectors), railway (5), Marine (12), and road (8). The AIBN published 39 reports in 2017 and had 49 current and 46 new investigations. The number of yearly safety recommendations is about 30 – 40.

Since the mandate of AIBN is limited to the transport field, other safety investigation commissions are supplementing the societal need: e.g. the Defence Accident Investigation Commission (FHK) was established in 2014[12], although accidents and events had been investigated according to regulations issued in 1995.

2.5 Sweden

In Sweden, the Swedish Accident Investigation Authority (SHK) was established as early as 1st July 1978. The area of investigation was from the start limited to civil and military aviation activities but extended in 1982 to include aviation accidents and incidents. The main change was done 1 July 1990. SHK was from that date responsible for investigating all type of accidents and incidents, based on the law 1990:712 about investigation of accidents. This was one of the first transformation of an AIB from focusing on a single sector to become a multimodal AIB.

3. Some important trends

A few trends[13] can be observed:

- The ad hoc-approach has in many countries gradually been replaced by permanent, public commissions, but public ad hoc-commissions can still in certain cases be established in connection with single major accidents, either by a Ministry or Parliament

[11] http://msa.is/

[12] Prop. 150 L (2015-2016) to the Parliament, page 9.

[13] See also: Roed-Larsen, S and Stoop, J (2006), "Major accidents – dealing with consequences", in *Int. J. Emergency Management*, vol. 3, nos. 2/3, 2006, pp. 168 – 177.

- The responsibility to invest major accidents/incidents has been expanded from the single firm/institution to a broader holistic, public AIB, maintaining the traditional responsibility for companies etc., but including every level of the socio-technical system
- A gradual shift from the single-approach tradition to a broader approach, covering major accidents in the same branch or sector (typically aviation or railway)
- A development where national and international guidelines (as ICAO and IMO) and regulations was partly harmonized
- A clear tendency in the mandate of AIBs to focus on certain values, such as independence, impartial and objectivity
- AIBs shall not allocate legal liability or apportion blame (no-punishment approach). The police have therefore now usually not its own representative in the commission.
- In connection with major accidents, the issues of victim care and family assistance have developed, particularly in the US and in Europe.

4. Multimodal AIBs – some problems

Several dilemmas are connected to the establishment and work of AIBs. Some of them can be summarized as:

- The mandate of the AIB (The Scope, sectorial, multimodal)
- The institutional connection (Ministry, Directorate)
- The leadership commitment
- The power to allocate resources and make priorities (man-power and budget)
- The composition of personnel (education, experience, competence, further education etc)
- The systematic use of scientific methods
- The vulnerability of core values, such as independence, integrity, competence, transparency, objectivity
- The ability to formulate and follow up recommendations
- The ability to gain necessary legitimacy from all parties involved in order to prevent a 2nd or even a 3rd investigation of the same accident
- The relations to important stakeholders and international organisations

These and other dilemmas connected to the investigation of accident are at present being debated both internally and externally, within AIBs as well as among politicians and researchers. There are no simple answers.[14]

5. Proposals for improvements

Some proposals for improvements could include[15]:

- More use of cross-sectorial or multi-modal commissions. Since accident mechanisms, investigation methodologies and preventive measures have so many conditions in common, many countries would benefit from the synergy effects of broader investigation commissions.

[14] Røed-Larsen, S (2004), «From ragnarok til Rocknes – storulykker og ulykkesgranskning», pages 183 – 199. (Major accidents and accident investigations), i Stian Lydersen: *«Fra flis i fingeren til ragnarok – tyve historier om sikkerhet»*, Trondheim: Tapir akademiske forlag

[15] Røed-Larsen, S., (2006) Public safety investigations of accidents – development, problems and dilemmas. Paper to the International Sociological Association's XVI World Conference. Durban.

- A new and enlarged scope. Partly as an extension from technological accidents to natural disasters, and at least to include all kinds of NATECH disasters. Such a wide scope of investigation seems to be especially relevant for small countries - for large countries, a close contact- and cooperation-model may be more appropriate.
- Implementation of proposed preventive measures. Today, each report from an accident investigation commission is concluded with a list of proposed measure which should prevent similar accidents to occur and improve safety management. The implementation of these proposals should be more persistent and systematic follow up in order to measure that the study has had a certain positive effect on the risk level.
- More safety studies. A classic accident investigation has the aim of preventing a similar accident to happen. In a very rapidly changing world with many technological innovations, the likelihood of such a similar event in the future is rather small. Therefore, systematic studies of a group of accidents with many homogeneous features may be a more efficient approach.
- More focus on accident prevention. Very often, a critical situation is handled in such a way that the potential accident is averted. Systematic studies of how such situations are managed by main, involved actors, may add valuable information to the preventive work done by public authorities and enterprises.
- Higher priority to competence building. The reputation and impact of accident investigation commissions, represented by reports and personnel, are depending on a high level of professional competence among investigators. Proposed preventive measures should reflect frontline knowledge, recent research results and modern methodology.
- More cross-national exchange of data and cooperation. In spite of the existence of valuable databases, as The Emergency Disasters Data Base in Belgium, and necessary contact systems, as the Natural and Environmental Disaster Exchange System in EU, much more resources should be allocated to sharing accident and near-misses' data and to exchange information on lessons learned. In the transport sector - organisations as The International Transport Safety Association (ITSA) and the European Transport Safety Council (ETSC) – play important roles but are too small regarding resources and power.

In more general terms[16]:
Major accidents have major consequences – whether it concerns a single event with large number of casualties and a major societal impact, or an accumulation of large numbers of small accidents, in which not only the victims themselves, but their social environment and life expectancy are seriously affected. Over the years, the focus has shifted from a direct and physical emphasis on prevention to also include the indirect and long-term effects with psychological and social components. The conduct of rescue and emergency has become a performance indicator of a system, open to scrutiny, criticism and investigation. In such an integral system perspective, accidents are not a by-product, but are being redefined as an issue of national healthcare or consumer protection. The need for independent investigation, advocated with strength by Van Vollenhoven, The Netherlands (Independent Investigation is a Citizen's Right and Society's Duty), and the necessity of including victims themselves as primary actors in the system, are recent and necessary acknowledgements.

[16] See end note 9

SESSION 2:

Organizations and human aspects

Learning from organisational dysfunctionalities, a Work in Progress

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Abstract

The investigations of many past major accidents still show that organisational factors have to be considered and not dismissed as an important part of the factors causing accidents. We see unfortunately that those organisational factors are in a lot of cases not treated seriously.

Especially when an organisation dysfunction (or becomes dysfunctional) the risk of having accidents increases. When an organisation dysfunction, some of the organisational factors with a potential negative impact become latent causes for accidents. These latent causes are dormant and lie hidden inside the organisation until a disturbance or deviation in the process "wakes up" the latent cause and the latent cause becomes a contributing cause, contributing in the causal sequence leading to an accident.

Unfortunately, the past has also proved that most organisations are very bad in detecting when and where their functioning becomes dysfunctional and, in this way, potentially very harmful. That is among other things because in investigations of accidents or incidents for several reasons' organisations don't look good (and deep) enough to find that there are also organisational causes for the accidents and incidents they are investigating. Which causes the loss of opportunities to learn.

So, all together it is no surprise that even now not much organisations are looking for their own dysfunctions as possible precursors for accidents. What is a serious deficiency. They miss a lot of early warning signs and learning opportunities.

So, in fact the purpose is improved learning from incidents, especially on management level learning and on organizational factors.

[17] Some of the insights here presented are founded on my experiences as Inspector, but the majority of the insights are based on study work and international meetings within the ESReDA – "Foresight in Safety" – project. As such the content does not reflect the opinion of my employer (Belgian COMAH Seveso Labour Inspection)

An organisation can dysfunction in many aspects and on several levels. To get a grip on this variety a generic functional analysis was made of an organisation with its structural and strategic factors as purposes, means, resources and their assignment, the policy deployment, roles and responsibilities regarding safety but also safety culture and learning culture.

This model leads to a list of symptoms. Together with their intra-relations a list of early warning signs can be deduced. These early warning signs should be used to detect if and where an organisation drifts away from a normal functioning to a dysfunctioning modus. Detecting this drift and acting upon it will prevent accidents and major accidents from happening, which is the initial step in Disaster Management.

Keywords: *organisational factors, EWS Early warning signs, latent causes for major accidents, dysfunctional organisations, investigations of accidents or incidents, learning culture, organisational governance*

1. Introduction: Learning from Organizational Dysfunctionalities a Work in Progress

This article is generated from the presentation given at the AGAFIR Conference, 55th ESReDA Seminar "Accident Investigation and Learning to Improve Safety Management in Complex System: Remaining Challenges "in Bucharest, Romania dd. 9 – 10 October 2018. The article and presentation describe the Work in Progress of a chapter inside the framework "Foresight in Safety", a working group of ESReDA (European Safety and Reliability and Data Association).

2. From Organizational constituents to Organizational Factors

To characterize an organization relevant organizational constituent were chosen. Every organization consists of the following components:

- The Governance Functions made up by the triad [Strategy – Structure – Policy]
- Management Systems
- Workforce inclusive Management
- Processes and Technology
- Culture

At the other hand in safety context, we can distinguish 3 types of Causal Factors influencing Safety in an Organisation: Technical Causal Factors, Human Causal Factors and Organisational Causal Factors.

First, Technical Causal Factors are Causal Factors related to Technical elements: Processes used in the industrial organisation and the technology: Technical components (equipment, apparatus and installations) used in these processes.

Secondly, Human Causal Factors are Causal Factors related to all humans involved in the organisation. And there should be no difference in which function or level." All the humans involved in the organisation" means: operational people (operators, planners), people of all supporting services (maintenance, designers, research, logistics, procurement). Moreover, in every of these functional categories the decision makers on all levels are involved from frontline operators and front-line technicians, the supervisors, the managers, every senior manager up to the CEO and the Board of Directors.

The last (third) category of Causal Factors are the Organisational Causal Factors.
In this category of organizational causal factors, we distinguish management system failures from organizational dysfunctionalities. In the frame of this article we limit us to internal Organisational Causal Factors. (External Organisational Causal Factors could be regulation dysfunctionalities)
The focus of the safety efforts companies deploy should be well balanced between these three factors. Nevertheless, we observe that the focus of some industrial operators it is still mostly or even uniquely directed to the technical factors in strong disadvantage of the two others and especially neglecting organizational factors.
These three categories of Causal Factors can be linked to the former listed organizational components with following results:

The Technical Factors can be linked to Processes and Technologies
The Human Factors can be linked to Workforce inclusive Management
The Organizational Factors can be linked to two organizational components:

- The Governance Functions made up by the triad [Strategy – Structure – Policy]
- Management Systems

Culture is somewhat more difficult, some authors or safety experts consider it belonging to the organizational factors. Other choose rather to categorize it under Human Factors.

3. Hidden latent causes and organizational Factors

If we divide organizational Factors in two subsets being Management Systems and Governance, we consider under Organizational Causal Factors two subsets:

- Failures of Management Systems
- Failure of Governance leading to a dysfunctional organization

The relationship between organizational causal factors and latent causes is depicted in figure 1 below

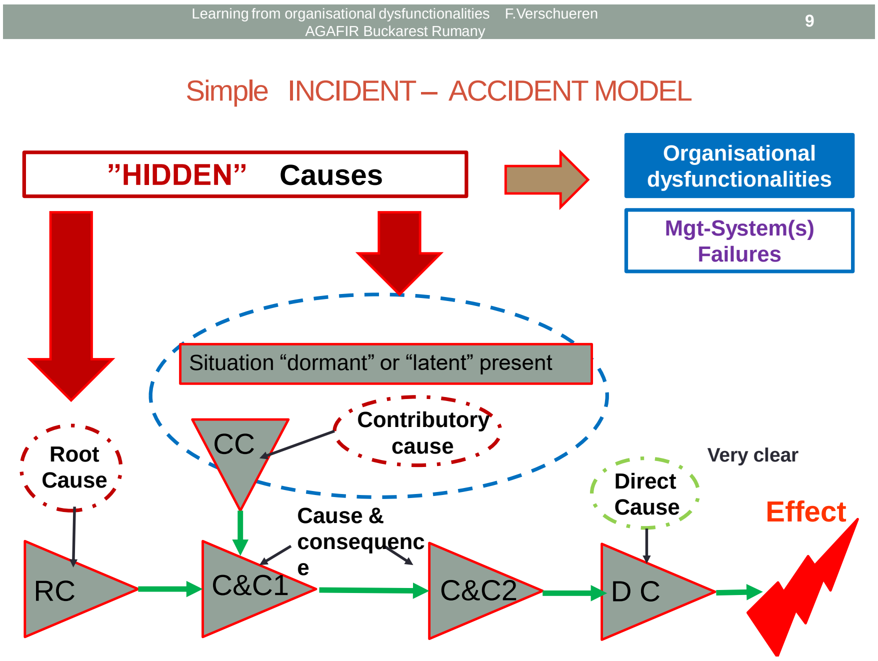


Figure 1: relationships in a simple accident model situating latent causes

Investigation of Incidents and accidents learn that Organizational Causal Factors, being Failure of Governance leading to Organizational Dysfunctionalities or being Failures of Management Systems when they are not the root cause they are very often contributory causes. ("Bovendien") (What is more) They are hidden causal factors as they are dormant or latent present in the organization.

Another difference between the Organizational Dysfunctionalities (failures of Governance) and Failure of Management Systems and the Human or Technical Factors is how deep one has to dig (e.g. in an investigation of an Accident) to detect the Causal factor linked with an event of fact.

If we consider the following findings in an investigation:
(sequence of findings is produced by consequently continuing asking "why?"):

First was found that (1) the operator made a mistake

- ⇨ Why? (2) The procedure he used turned out to be faulty
- ⇨ Why? (3) The person (function) who used to check the procedures was not there anymore
- ⇨ Why? (4) There had been a reduction in staff because of cost cutting
- ⇨ Why? (5) This had been a corporate strategically decision/policy

That means that one can easily get stuck in the "Human Factor" by limiting one-self to "scratching the surface": and finding ONLY a very direct and easily found cause "off course the operator is to blame as he made a mistake."

If one looks a little bit deeper ("just below the surface") one gets to the failures of the management system: a faulty procedure and a non-existing independent (from the procedure producer/writer) check: being the "shallow" organizational factors as they are still near to the surface

It is only if one digs even deeper that one gets to the "deeper hidden" organizational factors: the organizational dysfunctionalities, staff reduction as induced by a strategy/policy of cost cutting.

The same sequence [operator mistake - … - policy of cost cutting] can show us how that sequence escalates in a as shown in figure 2 below

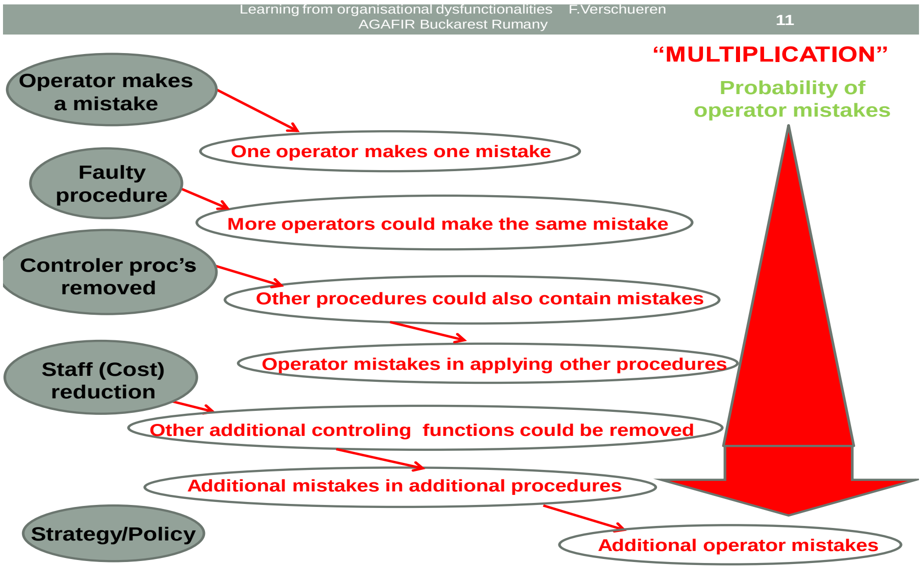


Figure 2

The great added value of digging deeper and finding organizational dysfunctionalities is that not only the probability of operator error gets larger when getting deeper but also the coverage.

This coverage is the positive impact if we reverse the situation once we take a measure on the appropriate level. When one stops with staff reduction with negative impact, a larger reduction in error probability is achieved then when one would only correct the procedure.

A first set of conclusions is:

Organisational disfunctionalities

can be **be latent present for a long period** and **still remain hidden**
So

there is need for a good and thorough investigation ("DEEP DIGGING")
by

knowingthe link
between **organizational dysfunctionalities** and incidents/accidents
so

Foresight is created
by

recognizing sooner (BEFORE accidents) Organizational dysfunctionalities

This recognition is increasingly supported by gradually observing signs, signals or early warning signals.

First observations are deviations, change of characteristics, abnormalities, unexpected or less expected events. These are observed signs.

When those observed signs can be related to a certain danger or risk they become signals. This is realized after adequate interpretation in their context of safety: e.g. they are present in a scenario which (can) lead to an incident or an accident.

If the risk potential of this scenario (severity and probability) is realistically estimated, it can be judged if this signal can act as an early warning signal. Those are the signals which should be detected and treated early enough to prevent the incident or worse accident from happening.

4. Failing Governance or Organizations becoming dysfunctional

To have a good functioning organization each of the three elements [strategy – structure – policy] in the triangle of Governance by the top of the Organization has to function adequately. If one of the three elements are failing, the Organization doesn't function any more as it should and is "dysfunctioning".

As illustrative example the failing of the structure is chosen:

> To meet the objectives of an organization, an effective and efficient execution of all tasks and activities is needed. This creates a need for **coordination** which is realized by building a STRUCTURE inside the organization.

This structure fulfills several primary purposes:

- the structure defines all needed **roles or functions** in the organization
- the structure defines all **internal relationships** (e.g. the hierarchical structure)

And by creating the structure with its **roles, functions** and **internal relationships,** the organization

- will assign authority to each **role/function**
- will assign responsibility to each **role/function**
- should provide **checks and balances** between the roles and functions

5. Signs of failing Organizational Structure as illustration of the WiP

Related to a failing structure a first set of phenomena (1 to 3) can be observed:
these first three phenomena all lead to [decisions being deficient or taken too slowly] causing risks, incidents and accidents.

- Phenomenon 1:
  When an incomplete or insufficient structure leaves
  no room for delegating
  Which can lead to
  - Decision makers having overload

- Phenomenon 2
  When the structure is overcomplicated to complex because of
  too many levels in the structure
  Which can lead to
  - Obscurity
  - Conflicts
  - Bureaucracy and related rigidity

- Phenomenon 3
  When the structure poses a too large spread
  between decision makers
  Which can lead to
  - Insufficient coordination

Essential information reaches too late the decision

Decisions
Deficient
Or
Too slow

↓

Risks, incidents and accidents

A second set of phenomena (4 to 7) observed with a failing structure lead to [a diminished responsibility] also causing risks, incidents and accidents.

- Phenomenon 4:

  When the roles and or functions are unclear, incomplete, vague or ambiguous

  Which can lead to
  - "micro-management" where managers perform tasks of their subordinates (on a lower level)
  - Too few or Nobody takes responsibility
    - Confusion and stress

- Phenomenon 5

  When the distribution of roles/functions is inadequate or imbalanced

  Which can lead to
  - Gap: where the responsibility is not assigned to a role
    - Nobody "is" responsible
  - Overlap: where the same responsibility is assigned to two or more roles
    - Confusion
    - "Nobody takes" responsibility

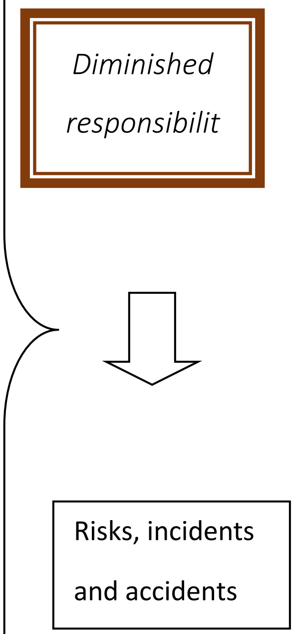
- Phenomenon 6

  When roles assigned to one person are conflicting

  Which can lead to
    - Work overload
    - One responsibility goes at the expense of the other

- Phenomenon 7

  When a role is incompatible to the person (values, expectations)



Each of the items described under the 7 phenomena can act as a sign. Depending on the safety context and on further information this sign can evolve to an early warning signal as described in the definitions of signal and early warning signal.

6. Texas City Refinery case as illustration of a failed structure

If we take the well know Texas City Refinery case (see CSB (Chemical Safety Board) report 341pages).
(*www.csb.gov/assets/1/19/CSBFinalReportBP.pdf* we find one of the most investigated and commented recent industrial calamities with many examples of organizational causal factors both

- system failures

and

- organisational dysfunctionalities

If one looks at the investigation and focuses on the results related to the former section 5. Failing Organizational Structure one can see the Texas City case as a clear example of Failing Organizational Structure,
because of the presence of

- the Complexity of the organization
- Frequent re-organizations
  with **continually changing roles and responsibilities**

This caused **confusion about roles and responsibilities** with as most sever consequence that

No one felt responsible for essential decisions concerning process safety

7. Conclusion

When GOVERNANCE (STRATEGY, POLICY or STRUCTURE)
of an Organization fails,
the Organization will DYSFUNCTION

These ORGANISATIONAL DYSFUNCTIONALITIES have already caused many MAJOR ACCIDENTS

BUT (on the positive side!)

ORGANISATIONAL DYSFUNCTIONALITIES
Can be detected because they show SIGNS
which when interpreted correctly can act
as EARLY WARNING SIGNALS

Effective Communication During and After an Aviation Accident

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Abstract

Accidents are unforeseen and unintentional occurrences that result in material or human losses, deterioration of transport infrastructure, bottlenecks in transport routes, reduction of transport capacities, all of which lead to an increase in the operating costs, less efficiency, and other long-term negative effects. Accidents also have a considerable impact in the media, and may affect the public image of state authorities, and at international level may even affect the State's image. We should always keep in mind that the lack of communication could result in media speculation, with negative effects for the safety investigation activities.

Therefore, as soon as possible after an aviation accident, a representative of the safety investigation authority should give a press statement, communicating the preliminary data that can be made public (e.g. date and hour of the accident, location, aircraft type, dead/wounded, etc.) and the timing of the next updates on the information provided, so as not to leave room for speculation in the media that may affect investigation activities and which may increase the pressure on the public institutions involved in the investigation.

Keywords: communication, aviation, accident, safety investigation

1. What to expect in the days immediately following an aviation accident and how can the communication team be better prepared for coping with the public pressure and media requests?

Let’s take a practical example. How we managed the communication during and after the civil aviation accident occurred on January 20, 2014, near Horea village, Alba county in Romania, crushing in the mountains during winter, with 7 people on board (a medical team a pilot and a co-pilot), considering that, as a consequence of this accident, the aircraft was destroyed, and two persons on board died (the pilot – a public person in Romania – and a young student girl of the medical team)?

During the first hours after this occurrence, the exact location of the accident was unknown. Meanwhile, news agencies broadcasted live information about this accident. On TVs, this was a breaking news and media interest was extremely high.

2. Massive pressure from both internal and external factors

The number of unvalidated and incomplete information was very large, internal pressure was very intense, and there were many personal and divergent views from the authorities with attributions in the field.

In this context, the Romanian Ministry of Transport requested to not disclose any information without prior approval. But survivors and family victims desperately wanted to quickly find answers to their questions and concerns. Also, the media interest was growing, resulting in a large number of requests for information and a lot of speculation, in the absence of coherent information.

The wreckage of the aircraft was located after almost 5 hours from receiving the notification about the accident. But for the pilot and for the young student girl it was too late...

3. What we did immediately and after the accident?

First of all, the General Director of the Romanian civil aviation safety investigation authority informed the minister of transport about this civil aviation occurrence. Also, he made, at internal level, all necessary due diligence to inform the persons directly involved, as completely as possible, on aspects of the accident that occurred and arisen from the questions asked by journalists, in order to be able to give an official response within the limits of competence.

Immediately after being notified about this accident, the investigation team went toward the accident site, even if they did not know exactly where to go. On the road, the go-team was permanently in touch with the representatives of the local Emergency Situations Inspectorate. And, the most important, the investigator-in-charge made a press statement directly from the accident site, communicating factual information about the accident and the next steps of the safety investigation. He followed the rule of thumb that anything that could have been said the day before the accident can be said the day of the accident and afterwards. The outcome was positive, as the press was satisfied and the crisis was eased.

In the meantime, the spokesperson assured the journalists that further information and an official point of view about this accident will be presented as soon as possible, disseminated press releases and responded to media enquiries.

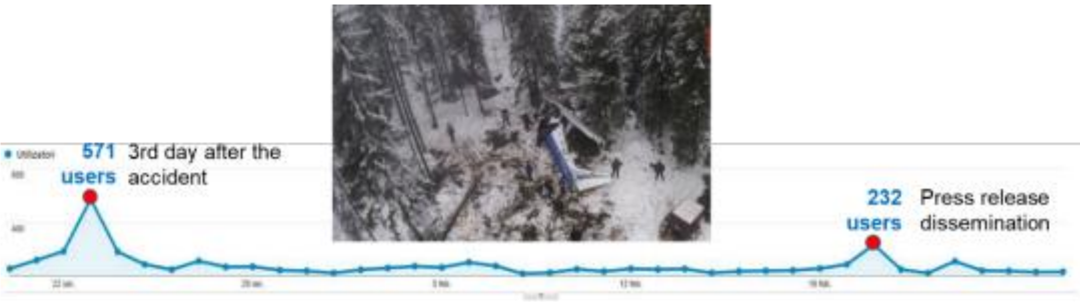
4. How high was the public interest?

As you can see from Figure 1, on the third day after the accident (January 23, 2014), the website of the Romanian Civil Aviation Safety Investigation and Analysis Authority[18] (www.cias.gov.ro) was visited by 571 users, which represented a top of the audience for January 2014, in which a total of 1,561 users were registered. Basically, the number of visitors on the third day after the accident accounted for about 36.5% of the total number of visitors in January 2014. Also, on February 21, 2014 (one month after the accident

[18] Former Civil Aviation Safety Investigation and Analysis Center, renamed as the Civil Aviation Safety Investigation and Analysis Authority, according to Romanian Government Ordinance no. 17/2018

occurrence), following the press release dissemination, there were registered 232 users on the website, representing 20,5% of the total number of users in February 2014. The most visited website pages were the homepage (in Romanian and English) and those related to the investigation reports, list of civil aviation occurrences and press releases, accounting for about 50% of the total visited web pages during January 1, 2014 – February 28, 2014.

Public interest was therefore a huge one, materialized in numerous requests for information on the causes of the accident or the safety investigation activities carried out for this aviation accident. These requests came from the victims' families, from the Ministry of Transport, other state authorities and the media, putting a lot of pressure on the communication team and also on the investigation commission.



	Pagină		Afișări de pagină	% Afișări de pagină
1.	/index.php/ro/	1. Homepage RO	2.119	19,60 %
2.	/index.php/en/	2. Homepage EN	1.320	12,21 %
3.	/index.php/ro/publicatii/rapoarte	3. Investigation reports	820	7,58 %
4.	/index.php/ro/informatii-de-interes-public/lista-evenimentelor-de-aviatie-civila	4. List of civil aviation occurrences	687	6,35 %
5.	/index.php/ro/publicatii/comunicate-de-presa	5. Press releases	489	4,52 %

Figure 2. www.cias.gov.ro website traffic data between January 1, 2014 and February 28, 2014 (Source: Google Analytics)

One year after the accident, when the Romanian Civil Aviation Safety Investigation and Analysis Authority issued the preliminary report, the public interest was also high. As you can see from Figure 2, on January 19, 2015, there were registered 327 users on the website, representing 33,7% of the total number of website users in January 2015.

Figure 3. www.cias.gov.ro website traffic data between January 1, 2015 and January 31, 2015 (Source: Google Analytics)

However, public interest culminated with the dissemination of the final investigation report on October 19, 2015[19]. On that day, a press conference was also held, in which the Romanian Civil Aviation Safety Investigation and Analysis Authority presented the findings of the investigation commission, the causes of the accident and the safety recommendations issued following the aviation accident occurred on January 20, 2014. As it can be seen in the Figure 3, 661 users visited the website on October 19, 2015, representing 44,6% of the total number of users registered in October 2015.

Figure 4. www.cias.gov.ro website traffic data between October 1, 2015 and October 31, 2015 (Source: Google Analytics)

After four years from the occurrence of this aviation accident, the public interest is still high, as it can be seen from Figure 4, showing some interesting insights following the publication of an anniversary article on the Facebook page of the Romanian Civil Aviation Safety Investigation and Analysis Authority. The article was reached by 6,305 people and received also 154 reactions, comments and shares.

Figure 5. Facebook insights for the 4th anniversary article published on January 20, 2018 (Source: Google Analytics)

5. Lessons learned. The most important lesson learned, from the communication point of view

The very first lesson learned was that expectations of different audiences (Ministry of Transport and other authorities, media, accident victims and their relatives etc.) are also different and we have to ensure coherence and consistency in communication.

[19] The safety investigation final report is published on the Romanian Civil Aviation Safety Investigation and Analysis Authority's website: http://www.cias.gov.ro/images/rapoarte/2015.10.16%20Final%20Report%20-eng.pdf

We have also understood that breaking news of an aviation accident will usually appear first in social media, even before being officially notified, so we have to be prepared to respond within minutes!

And – very important – crisis situations require crisis management plans, as crisis can also be caused or amplified by the poor communication with the media or victims/relatives. As we can't control the release of information but we can control the release of our information, we should always remember that refusal or failure to communicate information to the press can affect the image of the safety investigation authority, management reputation, can boost media speculation and even put at risk the investigation activities. And spokesperson's statements, especially in public environment, are the official point of view of the institution.

But the most important lesson learned, from the communication point of view, was that as soon as possible after an aviation accident, a representative of the safety investigation authority should give a press statement, communicating the preliminary data that can be made public (e.g. date and hour of the accident, location, aircraft type, dead/wounded, etc.) and the timing of the next updates on the information provided, so as not to leave room for speculation in the media that may affect investigation activities and which may increase the pressure on the public institutions involved in the investigation.

Issues with lessons learned, as seen by field experts and managers, and synergy between experience reporting and experience sharing

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Abstract

Lessons learned present some issues, especially the non-reporting of some safety events by field experts. Are the reasons given for that absence of reporting the same when managers or field experts are asked? This paper will show the similarities and differences between these two populations in Air Traffic Control.

This double perspective on non-reporting may help us to understand the different roots of this issue, and to determine relevant solutions that could be implemented to improve the safety of the system. For instance, this analysis will show the synergy between experience reporting and experience sharing, as well as Human Factors training for analysts and organisations.

Keywords: Lessons learned, non-report, field experts, managers, experience sharing

1. Study

1.1 Introduction

The reporting system has flaws: while some are known, others are not. The events that are non-reported may put the system at risk, because their risks are not revealed. These flaws can come from some discrepancy in the ways field experts and managers approach lessons learned.

Experience as an air traffic controller, and as a Human Factor facilitator training Air Traffic Controllers, as well as experience in attending meetings with ATC managers, especially safety report meetings, led me to perceive discrepancies between these two populations, especially on reporting. The non-report of these safety events can sometimes be measured: in some areas, there is some automatic report by the computer system, which gives an exhaustive view of the safety events. Some other means, such as maintenance reporting, Air Safety Reports (ASR) by pilots, or on-board automatic systems, may also reveal possible lack of reporting from the field experts.

The fact that some safety events are not reported is a real issue, because this reporting, however mandatory, cannot be forced. If it were forced, safety events would be hidden, concealed to avoid blame or sanction, and the safety of the whole system would decrease.

So during my Degree in Cognitive Engineering and Human Factors, I conducted a study to confirm or infirm the discrepancy felt between managers and field experts on the reporting and the causes of non-reporting seen by these populations, as well as other safety topics. Would they give the same reasons for non-reporting? How might reporting be improved? Could experience sharing and experience reporting complement one another?

Of course, the aim of this study is not at all to stack these groups against each other. On the contrary, it is rather to deeply understand how their representations complement each other, to enrich the perceptions, the knowledge of the constraints and resources of these groups, in order to achieve the ultimate goal of a more complete and more systemic vision of the organisation. This could lead, in the long term, to decreasing misunderstandings and tensions, and to developing curiosity and therefore knowledge and safety.

1.2 Methodology

This study involved semi-structured interviews with twelve air traffic controllers and managers, who were asked what they thought about safety, risks, rules, communication and lessons learned. The interviews were recorded and transcribed and the transcripts were analysed regarding different topics, which were counted by two people. The main limit of this study is that its sample is not scientifically representative. Therefore, the aim of this presentation is not to claim any absolute truth, but rather to give food for thought: how are safety and risks addressed in one's own organisation? Do the perceptions from managers differ from those of the field experts? What can be improved?

1.3 Results

The results are given in percentage of all verbatim on the topic of lessons learned.

Some reasons for non-reporting are given exclusively by field experts:

- 10%: the event is not deemed a safety event
- 6%: they prefer experience sharing
- 10%: the previous replies to reports were judgmental

Some reasons are given exclusively by managers:

- 4%: the local culture
- 10%: the feeling of responsibility of the field expert involved in the event.

Some reasons are given by both field experts and managers:

- The duplication with another means of reporting: 10% in total: 4% for field experts and 6% for managers.
- The non-availability of field experts and the workload: 18% in total: 10% for field experts and 8% for managers.
- The uselessness of reporting and the fact that reporting does not help the system to improve safety: total 32%: 16% for field experts, 16% for managers.

1.4 Verbatim

1.4.1 Field experts only

For field experts, sometimes, the safety event is not labelled as "risky": "it started to flash, but it was managed, you see", or "it was just, you know, during take-off, if he crosses and there's no traffic", "there was no risk somehow, it was just a deer crossing the runway without any plane in the control area". In these examples, field experts estimate that as soon as the event is detected, managed, and there's no consequences for safety, there is no reason to report it.

Sometimes they prefer to share their experience rather than to report it. "It is merely to share our experience, on the corner of the table, or behind the position". "What is reassuring is that we often have the same analysis", or "a second opinion is better than one, it was good too, to talk about that with the handover colleagues: 'what would you have done?' ". The need to receive feedback from their peers is more important than from the hierarchy, and is more reassuring to them.

Basically, the feedback given by their hierarchy is regularly not the one expected: the answer given is a judgement about their work. And these judgements are not positive: "we got hit back", "in reality, there's judgement anyway", "we won't hand them the sticks with which to beat us". As a result, they limit reporting for fear of that stick.

1.4.2 Managers only

Managers are concerned with the local culture of the field experts: "clearly, the reporting culture is not the same on every field!", as they see different fields and can compare them.

They think about the feeling of responsibility of the field expert involved in the event: "I don't know if it is conscious or unconscious, 'I am implicated, I think it's gonna come back to hit me, so I prefer keeping quiet' ". " 'Oh, sh… I am involved. Sh… I didn't put enough distance between aircrafts, so, do I file a report??' so is this conscious, unconscious, there we go, that's what it's like to be human".

1.4.3 Managers and field experts

Both managers and field experts know that there can be redundancy with another means of reporting, or with other actors: maintenance, pilots. "Here, we're analysing a radar event, which was not directly reported by the controllers, but which was reported to maintenance. So, we found it in the maintenance minutes".

Both know that controllers are not always available to write the report: "you also got a traffic peak on approach, you got a huge workload, you are sick to the back teeth, you don't feel like filing paperwork on top of that". "it's because of the lack of time, the workload, you're having a hectic day, you can't stop in the middle to report, so you wait a bit, you get the change of shift, you're worn out, you don't feel like filing the report right away, then it's the end of the shift". Reporting then becomes secondary to workload and rest.

The most important reason for both managers and field experts is the uselessness of some reporting. Reporting does not always help: "see here, I did it twice, there's no answer, I get the reply that it's closed", "archived", "archived for statistical purposes". "No answer after 4 months: closed. It didn't answer our questions, so you just stop reporting when that's the case", "answers are sometimes off track". The answers are sometimes turned down flat and do not lead to improvements: "at the beginning we started reporting, then we were told 'anyway, it's not gonna change anything', so we don't report any more". "When there's no result, at the end, they stop reporting, because it's useless!" For managers, another point is the time it takes to solve problems: "we feel that they are weary to report (…), because they see, they have the feeling that it's not gonna change anything. But the problem is difficult to solve". Field experts, who are used to quick responses to their actions, are sometimes fed up with this delay that gives them the feeling that their reporting is useless and does not have any impact.

2. Discussion

In the previous section we touched on points that call for more in-depth analysis: preference for sharing experience, deeming events not risky, or safe, judgmental feedback, differences between the reasons given by managers and field experts, and the perceived uselessness of reporting.

In this next part, we offer hypotheses related to the verbatim of both field experts and managers, to understand the issue in depth, then we analyse its root causes, and finally, we suggest ways to improve reporting and safety.

2.1 Competition between experience reporting and experience sharing or synergy?

Despite regulatory requirements, some field experts tend to oppose experience reporting and experience sharing, and prefer experience sharing. There are different reasons for that: reporting requires time in addition to controlling traffic, time that may encroach on what some consider break time. It also takes additional time later, because field experts sometimes need to meet with analysts, and answer their questions. Then it takes time to wait for answers "we expect it to be processed quite quickly, reporting, it's true that it can take time…"

In experience sharing, on the contrary, peers give their feedback immediately, which contributes to reassuring the controller who asks himself a question or who is confronted with some specific event. Often, experience sharing is done with a peer who witnessed the event and does not need to be told the whole story again. No need to make an appointment or bother anybody in the office, who's already working on something else.

Therefore, field experts often prefer experience sharing, which holds more advantages for them: non-judgmental fast feedback from peers. They tend to disregard experience reporting which is more inconvenient: mid- to long-term feedback, often useless, by managers sometimes judgmental and not deemed legitimate. It could thus be interesting to develop methods to answer their reports in ways that could be more appealing to them. Nonetheless, some rare field experts spend a year in the safety analysis department, to assist with events analysis, and nearly all analysts used to work as field experts.

To improve experience reporting in this context, several steps/measures could be taken. One of them involves redefining experience sharing. First of all, experience sharing is not only about talking informally at the coffee machine, or behind a working position. It is every experience shared but not recorded or traced with formal minutes. It can therefore take the shape of debriefings, meetings without minutes, and be institutionalised in CRM or HF training (Company Resource Management, Human Factors). Actually, these trainings include many debates linked with operational issues, Human Factors, safety and efficiency. They allow field experts to gain some hindsight to analyse their daily work, its limits and strengths. They develop metacognition and reflexive activity, both of which are important cognitive activities to improve adaptation to unforeseen events, and hindsight on difficult and stressful situations. Experience sharing can then support safety by developing safety culture (communication, debating and debriefing are important elements of safety culture), but also efficiency by multiplying views on a situation and analysis, and also quality of working life by sharing values among peers, having contradictory debates, breaking taboos, collectively finding solutions, and getting out of the isolated feeling encountered when facing issues. Instead of being opposed to experience reporting, experience sharing can then feed it, and give field experts the willingness to report issues to their hierarchy, for them to find solutions on recurrent problems. Experience reporting can also feed experience sharing through debriefings on specific safety events, case analysis, or positive safety. This synergy and complementarity between these two systems can only improve safety, efficiency and quality of working life for these field experts.

There are several ways to defuse the inconvenients of experience reporting. It can be interesting to increase one's knowledge of the other group: just as some field experts spend time in the safety analysis department, analysts too may accompany experts on the field, in order to gain a better understanding of all aspects of their work. Knowledge of cognitive processes could also be developed: the fact that safety analysts in Air Traffic Control have no real training in Human Factors, in cognitive decision-making processes for instance, has a deleterious effect not only on their understanding of field experts' decision-making, but also on their own decision-making in analysis. Reporting could also be centred on experience, operational needs and constraints in field experts' messy real life, instead of only focusing on regulatory requirements. Cross-checking work-as-done, work-as-prescribed and work-as-imagined could greatly improve the safety of the whole organisation. Safety events debriefings based on these multiple points-of-view may then help to ensure safety on a high level, in a complex system with dynamic and messy situations.

The legitimacy of the analysts comes from their operational background, but it is not sufficient, according to field experts. It is often called into question, as soon as they leave the field and appear to have forgotten everything about operational constraints. The field expert saying is quite revealing: when they leave the field, they "join the obscure side of the force". This legitimacy could be increased by implementing "activity sharing spaces" (Thellier & Falzon, 2016). Working groups focus exclusively on technical goals, and these activity sharing spaces between field experts and managers could help understand and redefine the other group's priorities, as well as address non-technical subjects, such as issues with regulation, risk perception by different jobs and different hierarchy levels.

2.2 Risk estimation of safety events

Some safety events are not deemed risky by field experts. Are they risky? Or are they deemed risky by analysts, with cognitive biases linked to post facto analysis?

Here are some of these cognitive biases:

- Hindsight bias (or retrospective bias): it implies after the fact reconstruction. "We are tempted to assign the operator a rational mindset, with attention to everything, and to judge him on the basis of what has been discovered in the analysis, including a past of foreshadowing incidents that should have alerted him. But in most cases, the operator was following a routine, was not aware of the past warning signs, and did not imagine he could find himself in dramatic conditions because of his decisions. All deviation from an ideal standard following of regulation is seen, a posteriori, as an error or a violation, although these deviations are justified in the reality of the context of the instant (workload management, anticipation, external interruption…)" (Amalberti, 2013)

- The "excessive attribution of the accident cause to the first line operator" bias: The analysts tend to attribute the cause of the accident excessively to the field experts: "the issue is, on the contrary, to consider the model of the dynamic coupling of all parts of the system" (Amalberti, 2013) and therefore, to consider the system globally instead of just what is visible and accessible.
- The "lack of imagination" bias: analysts often limit their considerations to a universe of known and identified causes, which makes them "unable to see the non-standard as soon as a known cause is catchable" (Amalberti, 2013)
- The confusion between error and accident: "too often we forget that making errors (routine errors especially) is a price to pay to work quickly, that is, to reach a certain social and economic efficacy. Wanting to control everything and avoid every error generally ends up slowing down execution so much that the most important risk is transferred on to 'not doing any work at all' ". (Amalberti, 2013).

Like other people, field experts have many cognitive biases, in decision-making, judgment, risk estimation; for instance:

- The error immunity bias: tendency to not see one's own errors,
- Selective perception bias: selective interpretation of information, depending on one's own experience,
- Hypothesis confirmation bias: tendency to prefer elements that confirm the hypothesis rather than elements that infirm it.

So, do analysts' biases prevail over field experts' biases? These two groups are experts, and are therefore subject to expert bias (Lannoy & Procaccia, 2001), in addition to all the other biases.

Are the specific events truly risky or not? Only the final outcome can tell. Sometimes. Because, in addition to Organisational and Human Factors, sometimes there is a chance factor, which can be the timing, or other contextual factors, which are often disregarded. Moreover, the specific topic of risk perception has not been taught to any of these groups.

Knowing how much this area is rich and complex, lack of training in this crucial subject can harm realistic risk estimations at different levels and different times of the organisation.

Analysts, managers, field experts can have cognitive biases that can distort their vision of reality, and of causes of safety events. This is intrinsic in human cognitive operating, but it can also be favoured by silo operating, where representations about others representations are not shared, where confrontations between work-as-imagined, work-as-prescribed and work-as-done are rare, and where the hierarchy vision is mostly normative, based on a safety vision nearly only regulated, omitting the adaptive safety, as the global results of the study show (Jégoux, 2017).

Risk perception is an area that is not often studied, although it is at the basis of our understanding, our representations, and our decision-making process. Our understanding of risks depends on our perception, on its estimation, that we tend to think of it as real, as a rational evaluation, although every cognitive or group bias, every personal experience and emotion may distort it (Jégoux, 2017). We take our perceptions, our impressions too much for granted, although they are biased.

Though these numerous cognitive biases need to be known, knowing them is not enough to suppress them. Despite that, training on cognitive bias linked to safety events analysis (Hindsight bias, error-accident confusion, excessive attribution of the accident cause to the first line operator bias) could help analysts and managers to analyse these events in greater depth and identify more decisive root causes in safety events genesis. That could help to improve both the relationship with field experts, and the solutions that are implemented after these analyses.

Silo operating may also be improved by transversal analysis and actions, and a better knowledge and recognition of these actions. Projects can be implemented with some constraints of transversal participation, to improve meta-cognition and meta-competencies. Safety day's events can help to break down the barriers between silos, and improve conviviality, togetherness (Morel, 2018), which definitely improves safety. Activities sharing spaces may help to confront work-as-imagine with work-as-prescribed and work-as-done, as well as exchanges in operational conditions. These two options can make it possible to take one's distance with a normative and frozen view of safety in order to better grasp adaptive safety. Training on risk perception could improve the quality of evaluations, and extract them from a rigid frame of certainty that can hinder safety.

2.3 Judgmental feedback

Judgmental feedback from managers to field experts is one of the topics that penalise reporting the most: they do not want to hand them the stick to beat them with. This expression comes up often when talking about reporting. Field experts have the feeling that they are judged like children who are given approval or disapproval by external people who do not know their work. Nonetheless, it all depends on how analysts approach feedback: "before, it was like we were put on trial, so reporting stopped, then, when X arrived, it started to increase again". Analyst selection and training on benevolent listening and constructive criticism therefore shows much room for improvement.

Anonymity is somehow relative, whether the feedback comes from peers, or from management, whether it is implicit or explicit. In this organisation, anonymity is a feature of the system, but analysts need to contact the field experts affected to analyse safety events better. If needed, after they are studied by managers, events are analysed during a local safety committee, with managers from different services, the controllers affected, and their representatives. And, if necessary, the event is analysed on a national level, with a representative of the local analysts. Along this process, anonymity is relatively respected, but, locally, peers witness the event, and rumours are the same wherever you work.

Judgmental feedback can have different causes, for instance culture. Analysts are nearly always former controllers who passed very selective and competitive exams, and are used their performance's being judged harshly, sometimes very harshly. Initial training can leave marks on them: unreasonable performance demands, or a belief that perfect performance is possible. The tendency is then to judge others in the same way they have been judged by authority (family authority, school teachers, instructors, and then managers). The cultural differences between organisations or countries are then particularly relevant: hierarchy distance has been thoroughly studied (Hofstede, 2010).

The analyst position is indeed highly sensitive. It requires some delicate diplomacy, in listening, debriefing, pulling back into line when needed, at risk of counter-productive actions that trigger defence mechanisms from the field experts. It is indeed essential to both supports, understand and provide constructive criticism, set limits, in order to foster a genuine just culture within the safety culture. This delicate position, as many jobs based on human relationships, requires debriefings between peers affected by similar issues. Actually, when professionals from other sectors encounter interpersonal risks that can affect their work, they receive practise analysis, debriefings, supervision, to get hindsight and insight into their work, to analyse it better and in greater depth, and to adjust the way they work to people, situations and issues. In some sectors, this kind of specific training is even mandatory.

Additionally, in this organisation, analyst training focuses exclusively on technical skills, and not at all on non-technical skills or knowledge. The safety events analysis therefore lacks this knowledge. Understanding elements of the operational constraints like cognitive trade-offs that happen in real life are rarely taken into account in the analysis. As they are not known by analysts, they are hardly conceptualised, and mostly put aside, to the benefit of the technical elements of the analysis and of an old conception of the individual "human error". Analysis misses' elements about work organisation and systemic vision, which would permit a shift away from an antiquated vision of safety centred on the "human error" of the first line operator.

Another point about this incomplete analysis is the level analysed. It is only the first line level, the field expert level, not the intermediary or high levels of the organisation that are analysed on their decision-making process. This is resented as unfair by the field experts: because they have to find solutions to all problems that have not been anticipated and managed by the hierarchy, this system shows some disequilibrium between decision-making process on the field and on the high spheres, that they have to endure and compensate for. It also ends up with putting all the weight of safety on their shoulders: if they are the only ones who provoke safety events, are they the only ones responsible for safety? In this case, going a little further in the reasoning: what is management worth? And still a little bit further, what are the rules, norms, and regulations enacted by management worth?

So, to limit the judgments felt by the field experts, different steps may be taken:

- Training aimed at analysts and focusing on Organisational and Human Factors, such as cognitive operating in the real world, cognitive trade-offs, better understanding and managing of violations,

- training about non-judgment, active listening, and benevolent listening, non-violent communication, would improve analysis, as well as constructive criticism and assertive communication, taking into account the person, his-her operating modes, and reactions. They have to "connect before correct". Analysts would benefit from a better understanding of resistance and protection mechanisms when they question field experts, mechanisms that play a role during analysis and interviews: denial, passive aggressiveness, sidesteps, evasion, banalisation, aggressive projecting, lies…

- Debriefings or practise analysis may help analysts to analyse their own practise, and to lighten the burden of evaluating the work of their colleagues, to give recommendations, without assuming an omnipotent position over the others, which can sometimes be counter-productive in reporting. Helping field experts to reflect on their practise instead of judging it can bring more individual and collective intelligence.

- Analyst recruiting could be improved by taking into account these soft skills.

- In-depth training on safety culture and on Organisational and Human Factors could also improve analysis by taking into account systemic and contextual factors. Field experts would then understand that the safety committee is not there to judge them, but to judge safety events. In addition, safety actions would therefore be more relevant.

To help field experts who are nonetheless the second victims of safety events, as stated in health systems, it would be interested to know what they would prefer when bad events happen. When there is an unwanted event, peers and managers do not know how to behave with the field experts affected. Should they talk about it, should they talk about other common subjects, should they say nothing? Or just ask them how they feel? Or what do they prefer? In these very sensitive times for all those affected, it is important to favor collective intelligence.

Of course, offering specific support to them when bad things happen is essential, for the safety as well as the efficiency of the system. The Critical Incident Stress Management is an important tool to implement in units, to enable field experts to recover with no after-effect for them and for their work.

2.4 Self-centred vision

Some reasons given by managers and controllers are similar, others differ. Let us see what lies behind the divergence.

Field experts' answers are the non-risky situation in safety events, the preference for experience sharing instead of experience reporting and the feeling of being judged by hierarchy. So, they mostly imply an issue with the managers. On the other hand, managers' answers are about field experts: the culture of the field or the feeling of responsibility of the controller.

This double transfer on the other group may reveal some bias, especially the self-serving bias: the tendency to see others' flaws without seeing one's own. It can also be linked to the feeling of belonging in one's group, which limits the ability to call it into question and develop group protection mechanisms. May it be the former or the latter, leaving our own perceptions and thoughts behind to be able to considerate the situation with the point of view of someone else is difficult. In most of our cultures, it is a reflex to think and act according to one's interests. No training time is devoted to developing empathy or broadening our points of view. Working groups on different technical topics exist, but nothing is done to limit or decrease the ego game, or to develop high reliability decision-making process (Morel, 2018) and collective intelligence. Regularly, some people do not feel heard and stick to their ground, defending their positions and views. The organisational waste and mess are colossal.

The fact that managers promptly attribute non-reporting to field experts and field experts attribute it to managers could be improved by introducing empathy training, and other techniques like constructive or Non-Violent Communication, which help to get used to having a representation of another's point-of-view, his-her constraints, habits, priorities. The activity sharing spaces could then play their role in full, combined with scientific methods to develop collective intelligence and high reliability decision-making process.

2.5 The perceived uselessness of experience report

The most important point of this study is this feeling of uselessness, noted by field experts as well as managers. It is the most important cause of non-reporting, and it is perceived as the most important one by both populations. It calls into question the very principle of reporting. If reporting is of no use, if it does not bring about any progress, or even dissuades field experts from reporting, what is the point? What is the use of this system which is heavy, complex, costs a lot, regarding this perceived uselessness?

What are the real aims of reporting system? Statement, analysis, to put a figure on problems, to find solutions and improvement actions? It is evident that if solutions are targeted, the result is not there: "we decide on beautiful actions, but often, they are not implemented in the long term".

Managers are often unable to provide practical answers to field experts on the questions they ask, be they technical or regulatory. It is then tempting to rely on easy answers that do not go deep, that do not truly consider the messy reality and complexity of the field. "Easy-to-find answers", easy to implement, easy to put a figure on, by "easy-to-find" indicators, but the results of our study are that these easy-to-find solutions are not enough. Is the "lack of imagination" bias also hitting the search for solutions? Or are relevant solutions difficult to implement and to put a figure on?

The actual structure of the reporting system, centred only on field experts' activity, shows its very limits. To systemic complex, deep, ancient and often non predictable problems, we look for, and find, simple, rapid, easy-to-find, easy to evaluate, local (or even sometimes centred on the first line activity). This simply doesn't add up. The verbatim and results prove it. This doesn't add up or lead to good results, at least not to enough consistently good results, both groups agree on that.

Solutions should match the types of problems encountered; they too should therefore be complex, impact the system and its interactions, take time to be implemented, be difficult to put a figure on, and difficult to evaluate. They should also look for the light side of the force, and not only the dark side: if reporting is so denigrated by field experts, it is because of its limits and its limited view. Reporting only looks for “safety events”, but these are not real “safety events”, but incidents and accidents, that is to say: what goes wrong. This view has been called Safety 1 by Erick Hollnagel and it is deeply rooted in ‘safety’ events analysis. The way “not-safe” events are called ‘safety’ events is a positivist distortion that denies reality and limits the possibility of envisioning another kind of safety, truly positive this time. Field experts have integrated this distortion and are puzzled when we ask them about real safety events: events that reveal the strengths of the system, of the team, of the individual. For them, those events are just their everyday job, there is nothing special to say about them. Yet, better understanding of daily operations could help to improve the system and increase its strength instead of always concentrating on flaws.

Reporting system is centred exclusively on safety, completely missing efficiency. Airlines companies have started another kind of reporting system a few years ago: “Service quality Air safety Report”. Then they ask Air Traffic Control Organisation explanations about service quality, unexplained delays, elements that can hinder their efficiency. Efficiency reports could therefore enable organisations to analyse daily problems, where field experts do their best to find solutions, with their constraints and the resources they have on hand. This kind of reporting would help to understand the detrimental aspects of the system and the high cognitive costs aspects. This kind of reporting would help to identify the priorities on which management should act and find solutions or adjustments.

In addition, the reporting system has some very inherent limits: it has been conceived only for bottom-up information reporting. For a few years, field experts who filed reports have received feedback, and usually did not appreciated it: the feedback comes late, and does not often provide any valuable information. Conceiving a reporting system that would be used both in bottom up and in top down ways could now become a priority.

Another part of the uselessness of the reporting system is linked to the normative constraints and their inflation, which is not always justified (Morel, 2018, Jégoux, 2017). Some non-practicable rules cannot be changed by managers, who often tell as much to field experts while also telling them to comply for conformity’s sake. There should be a reporting system for regulation makers as well, and some obligation for them to provide interpretation of the rules, and their non-practicability when relevant.

So, these causes of the perceived uselessness of reporting will be linked to solutions that have to take into account complexity. They will have to bring the organisation to a systemic and cindynic (science of the dangers) approach, to set aside the illusion that situations can be controlled by simple and quantifiable indicators. This culture of quantifiable indicators does not lead to good concrete results for field experts, and getting out of this culture may be an important step towards improving safety and reporting, and not only managers’ feeling of safety. The reporting should be enough to contribute to changing non-practicable rules, regulations, administrative communications, procedures, orders and instructions. By taking into account the issues reported by those who apply any kind of rules, and by “law of rules” (Morel, 2018), the system would limit its normative issues.

Redefining reporting on Safety 2 principles (Hollnagel, 2014) can also improve safety, by analysing and developing real safety events, not only flaws, to help improve the strength of the organisations, of the teams, of the individuals, to improve safety in a more creative way.

A kind of reporting system based on efficiency and not exclusively on safety could help to understand better the trade-offs that are made between safety and performance, and the importance of the means of enforcing safety in action. In this comprehensive view of reporting, what could be improved as well is some reporting for support services. In many organisations, administrative services, IT department, logistics, do not have any formal reporting system, although their work may also have an impact on safety, or on health and safety issues, and security.

A global reporting system taking into account these aspects may improve both the safety and efficiency of the organisation. With bottom up information and top down information, all actors of the organisations could contribute and see what happens with their contribution to safety. This can be done on a vertical axis, to enforce an Organisational Resource Management (ORM) (Jégoux, 2018): both on bottom up and top down directions. This could improve field experts' opinion of their reports' usefulness.

3. Conclusion

The reporting system could benefit from various tools routinely used to understand individuals, teams, and organisations, from formal training on human and organisational factors, with specific attention drawn to general cognitive bias and analysts' bias, on such topics as violations management, and work-as-done. Synergy between reporting experience and sharing experience is yet to be implemented for a cross-fertilisation to improve safety.

Nonetheless, if we wish field experts to report as well as share their experience, it is important to ensure that reporting ends up providing solutions to the issues they bring forward. Reporting systems still need to be improved, especially in the efficiency of safety events analysis, as both groups noticed. Safety as a whole would therefore be enhanced.

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SESSION 3:

Methodological aspects

Method and Mindset: Two Basic Elements for Accident Investigation

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Abstract

The role of accident investigations and, more generally, of event investigations, is to identify causes that have led to their occurrence in order to eliminate them by implementing corrective measures and thus improve the system. Unfortunately, according to the Columbia Accident Investigation Board, "[M]any accident investigations do not go far enough". The CAIB statement shows, among other things, that event analysis methods must be improved in order to address the real issues that led to the failure. In the paper we will present a method called "Organisational Analysis of Safety" which tackles three dimensions intending to cover the whole scope of the situation: "the historical dimension"; the "organisational network", and "work relationships channels" (interactions between the different strata of the organisation). Furthermore, we will also argue that, for a method to be effective, as relevant as it is, analysts as well as decision-makers must demonstrate a certain mindset, a certain open-mindedness.

Keywords: *Event Analysis Methods, Deep Causes, Organisation, Mindset.*

1. Introduction

Industrial safety is mainly based on two principal pillars. The first is **risk analysis,** the role of which is to foresee negative outcomes, and the scenarios leading to them, in order to design and implement preventive safety measures (such as safety equipment, backup systems, and procedures, etc.). Unfortunately, real life thwarts designers' expectations by "proposing" unplanned or ill-defined situations which lead to unwanted results such as failures, incidents, or even accidents. Each (negative) event is analysed in order to figure out its causes. This kind of analysis, that is mandatory in some at-risk industries, is the **lessons to be learned process**[20], which is the second pillar of safety. It aims to eliminate causes of occurrence by implementing corrective measures and so improve the safety (and reliability) of the system.

[20] Concept of lessons **to be** learned process is developed by Dr John Kingston (personal communication).

Surprisingly, despite substantial efforts and resources put in the lessons to be learned process, "*the same human errors, or series of similar technical breakdowns, seem to reoccur*" (Dien & Llory, 2004, p. 36). Have the lessons of previous events been learned poorly? According to the Columbia Accident Investigation Board (CAIB), "*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"* […]. *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*" (CAIB, 2003, p. 97). This statement marks an epistemological breakthrough for accident investigations which remain strongly influenced by the "human error" paradigm.

This means that issue of the analysis / investigation method is not yet totally settled.

On the other hand, if the analysis is weak, then the corrective measures put in place will be inappropriate for solving the problems. In view of this situation, the CAIB added that "***putting these corrections in place leads to another mistake – the belief that the problem is solved***[21]" (CAIB, 2003, p. 97).

Furthermore, event investigation is a whole process, from event occurrence to improvement actions implementation, without forgetting analysis itself and definition of correctives measures. Some researchers [e.g. Llory (1996)] and some accident investigations [e.g. CAIB (2003)] have stressed the importance of decision-making processes in the genesis of accidents. These decisions are usually made (or not made) by managers responsible for the strategy and / or operations of the company. Are managers "self-reflexive" enough to accept that the results of the investigation question their (previous) actions / decisions? Are decision makers ready to take account of recommendations which could be at odds to their own current "ideology" regarding safety? This implies that those who define and implement corrective measures will be open to analysis of events that is suitably broad and incisive.

In the next section we will explain the "**Organisational Analysis of Safety**" method (Dien, 2006; Llory & Montmayeul, 2010) using an example from a real investigation[22]. Then we will show how stakeholders in the event investigation process must be prepared to consider weaknesses in operational feedback; weaknesses that are symptomatic of organisation's failure either to question themselves or to put in place the needed corrective measures.

2. Organisational Analysis of Safety

The factual data in this section are drawn from the reports released by the enquiry commission chaired by Lord Cullen (2000) and from Martin et al. (2007).

Synopsis of the Accident

On 5 October 1999, at Ladbroke Grove Junction, about 2 miles west of Paddington station in London, a Turbo train, operated by Thames Trains, passed a signal at red (signal SN 109 on gantry #8) at 08:08:25. The train which was travelling at 41 mph increased its speed. It was directed towards a line on which a High-Speed Train (HST), operated by First Great Western, was travelling in the opposite direction at about 80 mph.

[21] Emphasis added.
[22] Trains crash at Ladbroke Grove (England).

Signallers at the Integrated Electronic Control Centre (IECC) at Slough, who were in charge of monitoring trains traffic, did not react properly, and when they took action in putting a signal back to red right before HST approached the gantry, it was too late. Train drivers braked, but it had no significant effect. Furthermore, it is not certain that signallers contacted the Turbo train driver to warn him that he had passed the signal at red (see § 0).

Thirty-three seconds after the Turbo had passed SN109 at red, the two trains collided head-on.

The accident killed 31 people (including both train drivers) and injured a further four hundred. We should note that it could have been worse but for the efficiency of the rescue teams.

Neither train was equipped with an Automatic Train Protection System (ATP) which ensures compliance with signals and speed limits. ATP monitors the status of signals and applies the brakes in the event of an unsafe situation[23]. The two trains were equipped with an Automatic Warning System which "only" alerts the driver when approaching a signal (and when approaching some speed restrictions).

Understanding / Analysing the Event

Direct Cause(s)

The case seems simple. We face a double human error: an error made by the Turbo driver who passed a signal at danger, and an error made by signallers who did not react as planned/expected in the situation.

Turbo Train Driver "Error"

First of all, it is certain that the SPAD[24] was not due to the driver of the Turbo train being rendered incapable by an acute medical problem, such as fainting, or a heart attack. Indeed, the driver accelerated after passing signal SN109 and (attempted) to brake just before the crash.

Secondly, we can discount that driver acted in a malicious manner ["*There is no suggestion that the driver, Hodder, deliberately ignored what was shown by that signal*" (Cullen, 2000, p. 77)] or that he committed suicide: according to his colleagues, he was always in a good mood, always smiling "*and that morning was no different*"[25]. Furthermore, when he would have returned home, he would have celebrated the seventh birthday of his son[26].

The reasons why Turbo train driver passed SN 109 at red could be linked to the track infrastructure in the Ladbroke Grove area. In order to increase service frequencies, it was decided in 1989 to upgrade infrastructure between Paddington Station and Ladbroke Grove. This modernisation led to the construction of six parallel bi-directional running lines, with connections between them, which were intended to be used at high speeds and in both directions. As consequence, the signalling layout on gantry #8 was one of the most complicated in the United Kingdom, and due to the unusual layout of signals[27], their legibility was very poor. It was even worse because drivers' view of the signals was obstructed by the

[23] A cost / benefit analysis concluded that equipping trains with ATP was not justified as the costs outweighed the benefits!!!
[24] SPAD: Signal Passed at Danger, i.e. train does not stop despite the traffic light at red.
[25] http://news.bbc.co.uk/2/hi/uk_news/1397112.stm, retrieved on May, 16, 2018.
[26] https://www.theguardian.com/uk/1999/oct/09/ladbrokegrove.transport2, retrieved on May, 16, 2018.
[27] Thus, the positions of the lights on the signals on gantry # 8 were reversed comparing to the usual signals.

underside of a road bridge (above the rail tracks). Indeed, signals on the gantry could be seen for only 8 seconds while approaching, during which the train driver must be wholly focussed checking the "appropriate" signal and not distracted by any other duties.

Furthermore, as the sun was bright and at a low angle at the time in question, the driver may have perceived the signal to be at a proceed aspect[28].

Signaller "Error"

The role of a control centre is to monitor the operation of the system, i.e. to monitor progress of the trains and to intervene when necessary. The only efficient and safe action for avoiding crash was to call the Turbo train driver and tell him to stop the train[29].

Depending on the dynamics of the situation, the signaller had only few seconds in which to react: to realise that a SPAD had occurred; to detect where and which train; to check how to contact the train driver, and finally; to contact him.

The type of communication systems between IECC at Slough and train drivers depended on the operating companies[30]. For some companies, such as First Great Western and Virgin trains, the communication system did not provide a direct means of communication between the IECC and the train driver. For those services, messages had to be passed to, and relayed by, an Integrated Control Centre located at Swindon (the Centre in charge, among other activities, of management of the infrastructure across the Western route of Network Rail). For others, as Heathrow Express and Thames Trains, the system enabled direct communication between the IECC and the train driver.

Within 10 seconds after the SPAD an audible alarm sounded three times in the IECC[31]. The only action we can be sure of (see § 0) is that the signaller put signal SN120 back to red in face of the HST while it approached the signal. This took effect at 08:08:50, i.e. 25 seconds after SN 109 was passed at danger and 8 seconds before the impact.

It may be noted that the day of the crash was the seventh successive day on which the signaller in charge had worked a 12-hour shift. Indeed, in accordance with one of the recommendations made ten years earlier after the Clapham Rail Crash (Dept of Transport, 1989), a railway Group Standard specifies that a signaller should not work for more than 72 hours in a week.

Lessons to Be Learned from An Analysis oriented to "Direct Causes"

This type of analysis, focusing on direct and immediate causes, is the more common analysis in industry: it can be labelled "conventional" analysis and belongs to the "human error" paradigm.

Many lessons can be learned, and improvements can be made and implemented in the system. For example:

- Improvement of signals ergonomics;

[28] Illumination conditions led, *"that the effect of direct sunlight on SN109 was to cause its image to be less easy for a driver to read"* (Cullen, 1999, p. 70). [Aspect = the visual indication displayed by a signal.]

[29] The diversion of the train to another track led to a risk of derailment.

30 The same for every control centre and every operating company.

31 "*It may be noted that this audible alarm also served to give warning of a number of types of malfunction* [...]. *The signaller had to consult the alarm screen to see the reason for it, and the position to which it referred.*" (Cullen, 2000, p. 85)

- Other/New directives or injunctions to train drivers such as to remind that a train must be stopped when the signal is at red (!!);
- Improvement of communication tools between signallers and train drivers;
- Improvement of signallers' control room, especially the alarm systems;
- Complementary training to signallers;
- Improvement of fatigue prevention policy;
- …

Nevertheless, it is open to question whether these kinds of analysis cover the whole scope of an event. Do not they forget some of its features? To put another way, could we go beyond the "human error" paradigm to gain a more global vision of the situation and a wider explanation of the event? More specifically, should not the organisation be part of the analysis?

Deep Causes

Deep or Root Causes

We prefer to use the concept of "deep causes" instead of the widely used concept of "root causes". Too often, root cause analyses stop at those organisational layers that fall within the "human error" paradigm, such as competence or team relationships. However, the study of numerous industrial events (accidents, incidents, and crises) has shown that "*any event is generated by direct or immediate causes (technical failure and/or 'human error')* ***nevertheless*** *its occurrence and/or its development is considered to be induced, facilitated or accelerated by underlying organisational conditions (complex factors)*" (Dien, 2006 p.148).

According to James Reason's model (1997) an event analysis starts with the analysis of direct causes and goes all the way down to figure out the organisational factors. That is why an event analysis has to take account of the thickness and depth of the organisation: it is what we intend to do with the next sections.

Recruitment and Training of the Turbo Train Driver

In 1994, British Rail, the state-owned, sole British operating company was privatised and split into a hundred different companies.

New private companies, established after the privatisation, hired former British Rail drivers for their trains. After a while this recruitment pool dried up. Companies "came back" to a more conventional recruitment process: they hired persons who had no previous experience as train drivers[32].

The Turbo train driver obtained his licence on 22 September 1999. The day of the accident was his 9th day of work. During his work period he made twenty trips outside the Ladbroke Grove area, i.e. he had no previous encounter with gantry #8.

Furthermore, the Cullen inquiry found that the Turbo train driver was poorly trained (from both the theoretical and practical points of view). Among the shortcomings, were:

- Training had departed from the standards provided by British Rail at the time of the privatization of the British railway system. This "new" training was neither assessed nor validated;

[32] As was true of the Turbo train driver involved in the accident who was recruited in February 1999.

- Trainees' characteristics – that is, their experience or inexperience – were not taken into account. They received the usual training designed for "internal" recruitment;
- Training sessions were not upgraded (e.g. some maps and signal plans used for training were not up-to-date with track modifications[33]);
- "*There was concern about the length of the course, its content and its disjointed nature* (Cullen, 2000, p. 59);
- No specific training about "risky signals" and SPADs

"*It must be concluded therefore that* [the Turbo train driver's] *training was not adequate for the task for which he was being prepared*" (Cullen, 2000, p. 60): "*there were significant shortcomings in* [Turbo train driver's] *training*" (Cullen, 2000, p. 2). It has to be noted that these training weaknesses concerned all train operating companies. It led to the conclusion that "*the safety culture in regard to training was slack and less than adequate.*" (Cullen, 2000, p. 4)

Operating Companies Safety Management

There were significant failures in communication between organisations and within each organisation. For instance, train drivers made many complaints to their (company) management about signal sighting, but these companies did not forward them to Railtrack, the company in charge of rail infrastructure.

Several working groups were set up in order to deal with the SPAD issue. They worked in parallel and none succeeded. The "proliferation" of working groups added to the confusion. There was never a comprehensive approach to this problem. The few solutions provided were always specific, individual, reactive and non-proactive, that is, in response to specific events, and with poor follow-up of any decisions made. This behaviour "*betrays a culture of apathy and lack of will to follow up promised actions*" (Cullen, 2000, p. 113).

Furthermore, during the years preceding the accident, a number of proposals and recommendations were made for carrying out a risk assessment of the signalling in the Paddington area. "*However, none of them was carried into effect*" (Cullen, 2000, p. 113). "*There was also a persistent failure to carry out risk assessment by whatever method was available*" (Cullen, 2000, p. 3). *There was a reluctance to carry out risk assessments, and a deep-seated laissez faire culture within the Zone* (Cullen, 2000, p. 137). This is all the more striking given the emphasis placed on risk assessment by the Health and Safety Executive since 1993. For example, the 1994 Railways Regulations required notification of any risk assessment which has been carried out.

The "*shortage, and* […] *high turnover, of driver* […] *of managers*" (Cullen, 2000, p. 158) may be behind this shortcoming and lack of commitment[34].

In conclusion, there seemed to be no learning from previous SPADs.

Operational Feedback Related to SN 109

From 2 August 1993 to 22 August 1998, signal SN 109 was 'passed at danger' eight times[35]. Based on these actual data, a statistical study showed that there was a likelihood of 0.86 (an

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[33] "*Signalling maps and plans are available for some routes but these have not been updated with essential information such as high risk (eg multi-SPADed) signals etc*" (Cullen, 2000, p. 58).

34 We have to note that this situation is similar for Railtrack.

35 First SPAD occurred 7 months after the new tracks and signal system were put into service.

86% chance) to witness at least one SPAD at SN 109 in a given year. A SPAD does "automatically" lead to a train collision. Regarding collision, there was a 7.2% chance of a collision in any given year, which means one collision every 14 years.

"*One could say SN109 was a black spot. At the time of the crash, SN109 was one of the 22 signals on the Railtrack network at which the greatest number of SPADs had occurred*" (Cullen, 2000, p. 56).

In spite of this situation, no significant action was taken to correct this defect before the disaster.

The Signallers

As it was previously said (see § 0), the only safe action was to contact the Turbo train driver. It is quite difficult to know whether it was done or not. Indeed, signallers made inconsistent and contradictory testimonies about it. Furthermore, the recorded data were not recovered even though, as recalled by Lord Cullen, this was specified some years earlier by recommendation 13 of the formal inquiry into the accident at Royal Oak on 10 November 1995. In any case, "*it is unsafe to determine whether* [a stop message] *was received before the collision, let alone how long before it*" (Cullen, 2000, p. 92).

Signallers have also to cope with numerous and complex instructions and regulations for managing and mitigating the effects of a signal passed at danger (e.g. "Regulation 47 of the Signalling General Instructions", "Regulation 4.1.1 of the Track Circuit Block Regulations", "Regulation 4.3 of the Track Circuit Block Regulations", "Regulation 6 of the Track Circuit Block Regulations", "Sections 1 & 2 of the "The Instructions to Signallers at Slough New").

Nevertheless, "*despite all the written instructions, SPADs were regarded by signallers as a matter of driver error. That showed not only a dangerous complacency but a lack of collaboration in the management of safety*" (Cullen, 2000, p. 98). Silo-thinking and a lack of a co-operative spirit between train drivers and signallers is illustrated by an excerpt from an interview. This shows that the general feeling amongst signallers is that "*the driver is supposed to stop at a red signal*":

"*Q*[36]*: Was that the overall feeling? If a SPAD happens, that is essentially a driver problem?*
A: Well how can it not be? If a person at a traffic light goes through a red light, is it not his fault?
Q: What about the problems that there had been in the Paddington area of drivers going through, not just SN109 but other signals, on a number of occasions when they were red against them?
A: Yes.
Q: Was it still felt that the problem was exclusively the driver's?
A: Well, if a driver fails to stop at a red signal, he is at fault". (Cullen, 2000, pp. 94-95)

It seems that regarding SPADs management, signallers were in "a wait and see situation". They did not see themselves as a line of defence against SPADs.

Railtrack Safety Management

The culture of safety and responsibility were damaged at Railtrack. Taking account of risks, through their evaluation and operational feedback, was very deficient with respect to the design of signalling and the circulation of the tracks (i.e. choice of bi-directional lines). Furthermore, this malaise extended to the provision of training and information to both train drivers and signallers.

[36] Q = Question by Cullen Commission; A = Answer by Signaller.

Forty-six "SPADs" occurred in the Slough IECC zone from 1993 to 1999. Some managers were members of the working groups dealing with SPADs, but there was no structured operational feedback regarding SPADs: neither mandatory analysis nor debriefing. Moreover, real improvement of the infrastructure was impossible because "*there was a reluctance to consider solution which might impact on capacity and performance, and there were a number of management deficiencies*" (Cullen, 2000, p. 137). "*Cost, delay and interference with the performance objectives underlay that resistance*" (Cullen, 2000, p. 107).

A Whistle-Blower

A train by operated by the company, First Great Western, passed SN 109 at red on 4 February 1998. Six months later, on 6 August 1998, a train by operated by the company, Thames Trains, also passed SN 109 at red.

These galvanised the Operations and Safety Director of First Great Western to write a letter to the Chairman of a recently set up Working Group dealing with SPADs. The Chairman, incidentally, was employed by Railtrack. In her letter of 26 August 1998, the director asked the chairman about the actions envisaged "*to mitigate against this high risk signal*" (Cullen, 2000, p. 117). She was told that a study will be launched and that the output (report) "*will ensure that effective solutions are identified for early implementation*" (Cullen, 2000, p. 117). The report was never released, and the Chairman left the "Paddington Zone".

On 22 December 1998, the same director wrote another letter to the Railtrack Operations Manager, informing him of her concerns about the timescales of the future Working Group he was setting up. She was afraid that they would not be "*sufficient to mitigate against the very obvious risks*" (Cullen, 2000, p. 117). Two months later, she received a letter telling her that a consulting company had been commissioned to review the signalling system in the "Paddington Zone". No review was ever commissioned, and the Operations Manager left the "Paddington Zone"!!

On 9 June 1999 she wrote a third letter, this time to another Railtrack Operations Manager who was the new Chairman of the Working Group. She wrote: "*It is almost 12 months since FGW*[37] *had a SPAD of an ECS train leaving Paddington following which Railtrack Zone promised a major review of the signalling in the 0-4 mile post area. I remain seriously concerned that after all this time (a number of meetings to discuss SPAD mitigation methods) that I am being asked to consider a solution to a problem in isolation and as a result of an event(s). If we carry on in this way we will continue to solve one problem but its solution will create another hazard. This is clearly not the manner in which to manage risk and an approach to which I am strongly opposed. Therefore, I suggest that an holistic approach is taken to SPAD management in the Paddington area and all changes to infrastructure or methods of working are properly risk assessed*" (Cullen, 2000, p. 118). She did not receive any reply.

In spite of her efforts to sound the alarm, no serious action was taken or decisions made. The accident occurred four months after her last mail. We should also note that employees of her company were not relaying her concerns/requests within the different working groups they were members of.

[37] First Great Western.

Some Conclusions about Investigation Method

Analysis of the deep causes underlying the event reveals that the "management" of the Paddington Zone was "*adrift over many years*" (Cullen p. 4) and was drifting to failure.

The approach used for determining deep causes, which can be called an *organisational approach*, allows on the one hand to "question" the commonly accepted (direct and immediate) causes of the event and, on the other hand, to propose improvement measures that go beyond conventional enhancement measures taken after an event, such as training, improvement of the human-machine interface. The intention of the organisational approach is to go beyond a logic that proposes necessary improvements, to reach one that proposes a raft of change sufficient to prevent future accidents[38].

The *Organisational Analysis of Safety* method is designed to go as far upstream as possible in the history of the event in order to shed light on the circumstances that may have led to the occurrence of the immediate cause (s) of the event. It is designed to highlight the decisions (or lack of decision) that more-or-less directly influenced the event. Finally, it focuses on relationships between the different entities involved in the event. Organisational Analysis of Safety is a means to describe the dynamics of the event.

The organisational approach, by widening the field of research of the causes of occurrence of an event, allows other types of corrective measures. In this sense, Organisational Analysis of Safety is complementary to the usual causal analyses.

The organisational approach is based on three dimensions which define an "analysis space" (Dien, 2005; Dien et al., 2004; Llory & Montmayeul, 2010):

- **The historical dimension**: An event does not start with the beginning of the event sequence. It is the outcome of a process in which the safety level degrades over time. To go upstream in the history of the organisation helps to figure out the significant dysfunctions, that are symptoms of a regression of the safety level. The analysis of the historical dimension is done while examining, in parallel, contextual variables so as to better understand the effects on the evolution of safety. This dimension allows the analysts to "dive" into the "*incubation period*" (Turner & Pidgeon, 1997) of the event. In this way, the analysis can correct for investigative hindsight bias. Hindsight makes the accident look inevitable, and the decision-makers vividly culpable. Correction recognises that those people assessed the medium and long-term consequences of their decisions and actions without knowing the "end of the story" (the accident) or the "scenario course" that led to it. Correction can be achieved by historically re-contextualising the decisions and actions of the people involved.
- **The organisational network**: Before the event, organisational entities[39] communicated with each other, exchanged data, collaborated to ensure the required safety levels, and so forth. It is important to establish the organisational network of the entities concerned (i.e. actual "living" operational relations between entities). This network does not strictly correspond to a formal, prescribed, rigid structure (as organisation charts or contractual relations between entities). The network should be seen as a convenient way to visualize the complex and numerous interactions that have occurred.

[38] CAIB statements, § 1.
[39] Entities could be part of the same company or of different companies.

- **The work relationships channels or the hierarchical relations (and reporting) in the organisation**. We must keep in mind something which is often forgotten: organisations are hierarchical systems with relations of dependence between people. This dimension pays attention to:
  - the modes of relationship (mode and type of cooperation);
  - communication (e.g. freedom of speech, and he capacity to listen)
  - decision making processes;
  - information flow (top-down and bottom-up) between the different categories of staff.

  Analyses of accidents usually reveal degradation of these modes between managers and/or experts and/or field staff (which could include front line manager). Taking this dimension into account makes it possible to focus not only on the field staff, but also to include the 'off-stage' decision-makers when searching for cause(s) of the event occurrence.

Carrying out an Organisational Analysis is to go as far as possible along each dimension taking account of relevant contextual data and identifying Pathogenic Organisational Factors. POFs are factors or phenomena that have a negative influence on the safety of the system (Dien, 2005). For example, if production culture has displaced safety culture, the analysis would construe *production pressures* as a POF. For example, Railtrack was reluctant to undertake any infrastructure improvement work that could interfere with performance. A POF could also be *weaknesses of operational feedback* that might alert management to failing processes. The treatment of SPADs by operating companies and by Railtrack is an example of this.

The organisational analysis, also tries to detect and to highlight phenomena which are often seen as marginal or incidental, such as "whistleblowing". Whistle-blowers are persons who commit themselves to warning of poorly managed threats to safety; for example, the Operations and Safety Director of FWG.

Mainstream investigations do at least try to identify direct and immediate causes, but usually end there. These are the gateway for accessing deep organisational causes [see Reason's Model (1997)].

3. Mindset

It is clear that in numerous companies, event analyses "*do not go far enough*". They are limited to finding out immediate and direct causes, such as technical failures and "human errors". Restricting the causal frame of event occurrence leads to a limitation of the scope of corrective measures, as CAIB (2003) states.

We will see from a few examples that this state of mind remains present in some, not to say, many companies.

Accident at Texas City BP Refinery

On March 23, 2005, an explosion at the Texas City BP Refinery followed by several fires resulted in 15 fatalities and 180 casualties, including 60 who were seriously injured. The accident occurred during the start-up of an isomerisation unit, after a scheduled shut-down for maintenance. The immediate cause of the event was an overfilling of a raffinate splitter tower (height, 50m) leading to release in the atmosphere of flammable volatile products, which met an ignition source. The start-up procedure requested that the level of products in the splitter remains around 2m. The automatic control of valves was designed to maintain the fluid at the required level. Yet, the operators had intentionally put the valves under manual control in order to keep the level at around 2.75m. As the valves were kept closed, the splitter tower was fed with flammable fluid for over three hours without any liquid being removed. It must be noted that "*critical alarms and control instrumentation provided false indications that failed to alert the operators of the high level in the tower*" (CSB[40], 2007, p. 21). In the press and media, "*operator error*" was immediately cited as explanation for the disaster (Cordeiro & Resnick-Ault, 2005). It is also (perhaps unsurprisingly) retained by BP as one of the four critical factors in the occurrence of the accident, who named it "*Raffinate splitter start-up procedures and application of knowledge and skills*" (Mogford, 2005b, p. 23). As a result, BP fired some staff and blamed / disciplined others involved in the occurrence of the event (Belli, 2005; Macalister, 2005).

According to the CSB there was in the refinery, a "*work environment that encouraged operations personnel to deviate from procedure*" (CSB, 2007, p. 69). Furthermore, "*these deviations were not unique actions committed by an incompetent crew, but were actions [that] operators, as a result of established work practices, frequently took to protect unit equipment and complete the start-up in a timely and efficient manner*" (CSB, 2007, p 70). So, is this "error" a surprise? For 18 of the previous 19 start-ups of the unit, the level had been maintained beyond the limit recommended by the procedure. This operational practice was known and so acknowledged by the first line management. We can therefore think of being faced with a "*normalization of deviance*" (Vaughan, 1996). Some procedures were not adequate, and not updated to take account of the evolution of process and equipment[41].

Furthermore, after its in-depth investigation of the accident, the CSB (2007) found out, amongst other things:

- Drastic production pressures leading, for instance, in cost-cutting in maintenance expenses, training reduction and staffing downsizing;
- A lack of focus for controlling major hazard risks;
- A flawed learning from experience process with, in particular, a confusion between occupational safety and process safety, and an approach mainly based on indicators rather than incidents analysis;
- A weakness of the Safety Administrative Authorities that had little presence on the field and had failed to impose appropriate equipment to secure release of flammable products in the atmosphere.

BP's willingness to tightly focus on human errors is not surprising, since looking at deeper causes could have brought into question its policies (with regard to safety, financial management, and concerning management involvement and commitment…). It seems that instead of handling process risks, BP preferred managing its image issues. Indeed, right after the accident, the public relations chief of BP America e-mailed other executives: "*Looks like injuries and loss of life are heavy. Expect a lot of follow up coverage tomorrow. Then I*

[40] U.S. **C**hemical **S**afety and Hazard Investigation **B**oard.

[41] For instance: "*SOP 201.0 was last updated on October 1, 2003, and the Superintendent confirmed in the last annual certification (early March 2005) that all ISOM unit operating procedures were current and accurate. However, on January 31, 2003 the Overhead RVs (RV-1001A/B/C) were de-rated from 70 psig to 40/41/42 psig respectively and this* ***change was not reflected*** *in SOP 201.0,* ***although most of the operators were aware of the change***"!!! A (Mogford, 2005a, p. 17) [emphasis added].

believe it will essentially go away -- due to the holiday weekend". She cynically added: "*This is a very big story in the U.S. right now -- but the Terry Schiavo story*[42] *is huge as well*" (Boudreau & Yager, 2010).

Amagasaki Train Station Accident

On April 25, 2005, in Amagasaki, western Japan, a train from the West Japan Railway Company (JR) "derailed in a curve due to speeding and hit the front of a residential building". This accident killed 107 people and injured more than 500 others. According to the investigation commission ARAIC[43], the direct cause of the accident was entering in the curved track with an excessive speed of 116 kph, much higher than the specified speed of 70kph. Delay in braking could have been due to driver inattention because he was conversing with the train dispatcher (ARAIC, 2007). So, "human error" is not in doubt.

Nevertheless, we learn that "*drivers who caused an incident or a mistake are put on an "off-the-train" re-training course that can be considered as a penalty or are subjected to a disciplinary action*" (ARAIC, 2007, p. 58). The question is whether— harsh, unjust or not— these measures had a history of sustaining or improving levels of safety.

We can assume that the train driver tried to recover the 90 seconds lost after overrunning the previous stop by 40 metres (which is a mistake according to the JR standards[44]). He had already been reprimanded three times during his career, including 13 days of "re-training" (McCurry, 2005).

The re-training sessions could be seen more as degrading and humiliating retribution than as tools for improving skill and expertise (Japan Time, 2007). The sessions could (McCurry, 2005; Pons, 2005; Japan Today, 2011) take the form of:

- Writing 6 to 8 reports a day, detailing the reasons for the driver error and the inconvenience it had caused;
- Wearing his drivers' uniform and standing on the platform to greet incoming trains and wish the driver a safe journey, so that the other drivers could realise he was being punished;
- Put into a tiny office and continuously yelled at by managers;
- Toilet duty;
- Cutting weeds.

JR conducted more than 500 re-training sessions per year, usually lasting four to six days, but sometimes as long as 51 days[45] (Japan Times, 2005).

Furthermore, JR was the only Japanese railway company that linked pay rises to employees' performance (McCurry, 2005).

Due to these psychological pressures, some employees committed suicide (McCurry, 2005).

[42] The Terri Schiavo case was a right-to-die legal case in the United States from 1990 to 2005.
[43] Aircraft and Railway Accidents Investigation Commission.
[44] Schedules were timed to the second because of the high frequency of trains.
[45] Once, JR ordered an employee to attend re-training for over five months. The cause was that he had running three minutes late at work!!! (Japan Today, 2011).

Taking account of all these facts, can we disagree with a trade unionist from the company who said: "*The accident is the consequence of management choices that prioritize efficiency and profit over safety*" (Pons, 2005)?

Investigation and Mindset

The examples above, even if seen as extremes, are symptomatic of the normal situation in industries. Safety is not forgotten: units dealing with safety are set up and staffed; workshops, seminars, "Safety Days" are organised; posters with safety mottos or principles are pinned up on walls. Yet, despite all of that, safety often seems to be missing from decisions, especially when it is weighed against production.

Safety is matter of acts, not only speeches. Unfortunately, when it comes to accidents and incidents, the whole burden is often, if not always, put on shoulders of the first line or middle management employees. This is mainly because the event analysis methods are limited to finding direct and immediate causes. As such, some issues are rarely questioned in analysis conclusions. Notable by their absence are issues such as:

- Decisions made by top management about cost cutting. These invariably have direct impacts on matters such as maintenance, equipment upgrading, employee training, but have indirect impacts on safety;
- Role and acts of Safety Authorities based on logic that is insensitive to the safety deficiencies of a plant or company, leading to insufficient safety inspections or a lack of follow-up to recommendations made after safety audits;
- Weaknesses of lessons to be learned, visible as reoccurrence of similar events, insensitivity to precursors, and poor trend analyses, amongst other things.

The ability of decision-makers, who define and enforce safety policies and rules, to reflect on (some of) their past decisions, is one important issue for development of a "new" paradigm regarding event analyses. In other words, their capability to acknowledge that they could have been wrong would help to improve event analyses by allowing a wider scope of analysis: moving from a technical failure and human error paradigm (direct and immediate causes) to an "organisational analysis" paradigm (deep causes).

Nevertheless, analysts have also to be convinced that another vision of event occurrence is needed. Often, they have implicit stop rules which prevent consideration of deep causes. The "culture of efficiency" is a widely shared paradigm in the industrial world. It can lead to focus on more manageable causes, that is, causes for which corrective measures have a quick, positive (but limited) effect and that can be easily implemented. It could also be difficult for them to see beyond their zone of accountability: for instance, would it be easy for them to question the company's policies regarding production towards safety (Dien et al., 2012). It means that, often, analysts implicitly halt searching for causes beyond those that they can handle (Hopkins, 2003).

4. Conclusion

The aim of event analysis is not only to figure out causes of an event's occurrence, it is also to define and to implement relevant corrective measures (related to causes), so that the same or similar events do not occur again. To reach this result, the event analysis method must have the capacity to embrace the whole situation.

First of all, persons in charge of analyses must "break some epistemological barriers". People with an engineering background are predominant in industry. In the main they are influenced by a technical epistemology which is more "causally deterministic": it means that an event is treated as directly and completely determined by the previous states of the system. It follows that analyses are carried out by "experts" who have an external vision of the event. Organisational analysis is more in line with a social epistemology which calls for a comprehensive approach; one which listens attentively to every actor involved in the event, whether directly or indirectly. A comprehensive approach assumes that those who work in the system, from the top manager to the field operator, have a vision of past and present situations. It is through the clash and contrast of these different visions that a global picture can be elaborated.

Furthermore, analysts have to avoid:

- Overly strict stop rules (analysis is a iterative process);
- Self-censorship due to fear of the investigation getting off the tracks (mission creep);
- Having "taboo issues";
- Compromising their independence of mind;
- Thinking too early about corrective measures.

Improvements are not just in the hands of the analysts because they are not the only ones to be in the loop of the "lessons to be learned process". They are also connected to behaviour of recipients of the analyses and of decisions makers who need to:

- Think and act beyond the operator(s) error;
- Avoid defensive attitude and be able to take distance with past decisions and acknowledge potential mistakes;
- Remain with listening capabilities (i.e. to be able get an empathetic hearing);
- Learning ability according to "pressures";
- Be able to learn lessons from events while ignoring the pressures.

But, as the popular saying goes, "*there are none so deaf as those who will not hear*". Let us hope this proverb proves false with respect to event analysis.

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Events groups' importance ranking with consistent preferences consideration

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Abstract

Deriving insights and selecting issues for more detailed investigation from events analysis is a challenge. There are many methods and ways developed to derive insights and lessons learned from the events assessment. In general, this is done either by investigating individually the most significant events or by analyzed all available events with various groups and rankings. This paper is focused on the analysis of groups of events.

Conventional analysis of events from database is based on the events characterization, rankings and related evaluation. The evaluation is based on trends for selected categories (e.g. causes and consequences) or relative importance rankings. Most important groups of events are then conventionally selected based on the agreed preferences and further analysed in details. The usual existence of multiple categories raises the question of their relative importance. This is typically solved by established weighting and with limited possibilities to consider different preferences. It is important to assure that applied preferences are verified for consistency. One way to make consistent variations of analyst's preference with multiple parameters is to apply analytical hierarchy process (AHP).

The AHP allows analyst to derive relative importance for the set of parameters through pairwise comparison. Resulting weighting is accompanied with quantified level of consistency so that analyst could re-evaluate pairwise comparison before further assessment.

The paper presents application of the AHP to the database of nuclear power plants related events. Events characterization scheme is presented first. Then the AHP application is described. Finally, selected results for the five years of events (about 1500 in total) are presented. Described application also includes simple quantification of uncertainty.

Results obtained from the practical application prove that AHP could improve consistency of the events database evaluation for ranking purposes. Future work might investigate how to select important events present in more than one group and how to look for important event groups insensitive to parameters weightings.

Keywords: *event importance, characterization, consistency, analytical hierarchy process (AHP).*

1. Introduction

European Clearinghouse on Operating Experience Feedback for Nuclear Power Plants has the objective to enhance NPP nuclear safety through the dissemination of lessons learned from past operating experience. Learning from event analysis is a challenge for multiple reasons (0). Event analysis could be performed at different levels considering selected examples or looking at all events together. Lessons learned are raised by a first-level analysis, i.e. investigation of individual events but operating experience feedback can also be gained by a second-level analysis consisting of screening a large group of events. This second-level analysis allows identifying possible trends (in terms of time, components affected, causes of events…) which are not visible through the investigation of individual events and also to highlight types of events which should be further investigated because most important in terms of recurrence, consequence, common cause failure, and other events characteristics. Very often practical approach is mixture of event analysis at both levels by focusing on the selected events related to special topic, e.g. 0.

This paper is addressing potential to analyse all events in order to provide new insights and point to groups of events which might be candidates for more detailed analysis. New method and tool, named OPERATE, has been developed as second-level analysis tool of events at Nuclear Power Plants which allows identification of possible important trends which are not clearly visible through individual event investigations and also identifying important types of events which should be further investigate based on events characteristics and experts relative preferences. The most important findings from pilot characterisation and assessment are presented here. More detailed description of the method and results is described in 0, 0, and 0.

2. Method

After events of a database are characterised according to a predefined taxonomy (in the present case the IRS taxonomy but in principle other taxonomies of national databases are also possible), they are grouped according to five parameters: *Activity* (maintenance, inspection…), *Direct cause* (mechanical deficiency, electrical deficiency…), *System*, *Component*, and *Root cause & Causal factor* (personal work practice, training/ qualification. etc…).

In a second step, these groups of events are ranked according to seven parameters: *Frequency*, *Trend* over time, induced *outage Extension*, *Multiple failure*, *Safety consequences*, *Category* (plant transients, release…) and *Consequences*.

The user can allocate different weights to each of these ranking parameters thanks to the Analytical Hierarchy Process where one is able to generate weights through pairwise comparison of parameters. The level of confidence in the results obtained is then evaluated with uncertainty and sensitivity analysis.

Special attention was given to the accounting for uncertainty and verifying that results are not too sensitive to some selected comparison values and resulting weights.

2.1 Implementation - OPERATE Tool

The tool is implemented as a stand-alone application based on the database. The program is named Operational events ranking tool (OPERATE).

OPERATE is designed with intuitive user interface for on-screen, text, graphical and file reporting options. The program consists of four different parts: ***Statistics***, ***AHP***, ***Ranking*** and ***Confidence***.

The ***Statistics*** part presents reports for all parameters which are used for grouping and ranking plus the following parameters: ***Vendor, Reactor type, Status, Group of staff*** and ***Time of event*** (yearly, monthly, daily and hourly).

In the ***AHP*** part of the application, the user can perform pairwise ranking comparison to allocate ranking indexes weights. Program provides also consistency ratio (CR) for resulted weighting (pairwise comparison is considered inconsistent if CR value is >0.01). Ranking is then performed based on the AHP results. Figure 1, left part, presents AHP module with example of indexes comparison and related consistency result.

The ***Ranking*** part determines total and groups ranking based on the AHP and ranking weights values. Figure 1, right side, presents ranking module and results for *Direct cause* group.

Finally, the ***Confidence*** part calculates the uncertainty and sensitivity for the selected groups ranking. This is done by ranking additional cases recalculation for changed RI weighting. For each RI two cases were calculated with increased and decreased weighing by selected factor. Based on confidence results user can go back on the AHP module and change RI relative importance comparison in order to better reflect their importance and impact on final ranking order.

All results can be printed and exported to the file or clipboard. This allows results to be incorporated into reports or used as a basis for some additional assessment.

Results from real demonstration set of five years of US NRC LERs show that method is working and providing interesting and valuable results. For example, two the most important component groups are clearly Mechanical and Electrical; four top ranked important systems are Reactor auxiliary and primary, Electrical and Secondary (i.e., FW, CS and PCS); four most important direct causes are Electrical, Mechanical and Hydraulic and pneumatic deficiencies and Human factor.

As it can be seen ranking results for different groups should be viewed together. Quantitative ranking estimate allows additional insight besides rank.

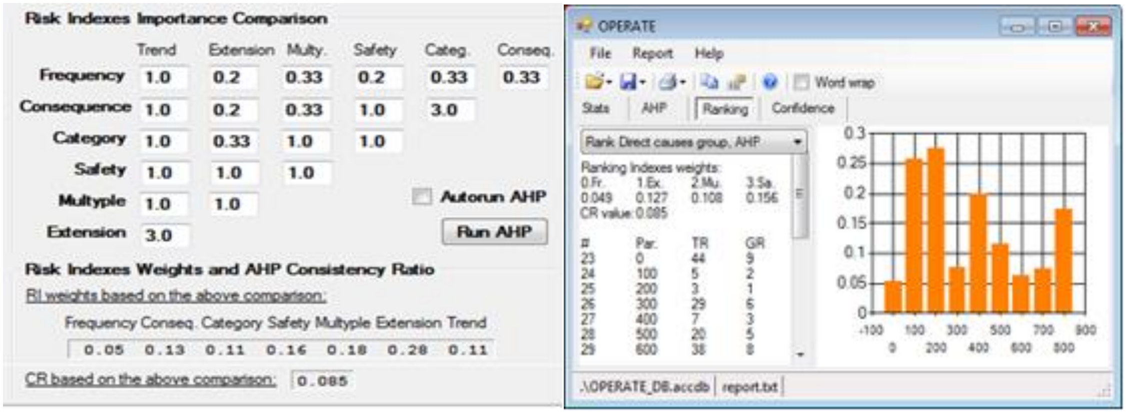

Figure 1. OPERATE: AHP and Ranking modules.

3. Results

Method was pilot tested with characterisation and assessment of almost 1500 events taken from five years of the U.S. Nuclear Regulatory Commission (NRC) Licensee Events Reports (LERs) database. Results are presented for all five groupings separately. For each group, the graph is also presented and the ranking score is noted in brackets (scale 0 to 1).

In the ***Activity*** group, events occurred during the *Normal operation* (.95) and *Routine testing* (.49) are distinctively the most important, after that six more activities are about three times less important (~.16), and the rest of 14 activities are similarly less important (<.10).

The *Electrical* (.59) and *Mechanical* (.57) *deficiencies* are clearly the two most important ***Direct causes*** groups, followed by *Hydraulic and pneumatic deficiencies* (.43), *Human factors* (.38) and *Control and instrumentation deficiencies* (.27). The four remaining groups have a score below .14. This is also presented in the Figure 2 (left side).

Four ***Systems*** are top ranked (with score ~.38): *Reactor auxiliary*, *Electrical*, *Primary reactor* and *Secondary (feedwater, condensate and power conversion)* systems. *Instrumentation and control* with *Essential auxiliary* systems are following (~.25). The last five unimportant systems have a low score (<.16). This is presented in the Figure 2 (right side).

Three top ranked ***Components*** are *Mechanical* (.87), *Electrical* (.59) and *Instrumentation and control* (.32). Remaining four component groups are closely low ranked (<.16).

Inside ***Root cause and Causal factors*** grouping four groups are closely top ranked (~.26): *Maintenance, testing and surveillances*; *Procedures and documentation*; *Equipment performance* and *Design configuration and analysis*. The following three groups (~.16) are: *Equipment specification, manufacture and construction*; *Personnel work practices* and *Supervisory methods*. The remaining groups are closely ranked around two scores (nine at ~.10, and six at ~.05).

Sensitivity and uncertainty analysis (not presented here) shows that ranking results are robust. Further investigation is interesting in regards to special importance of certain ranking indexes (e.g., *Trend*).

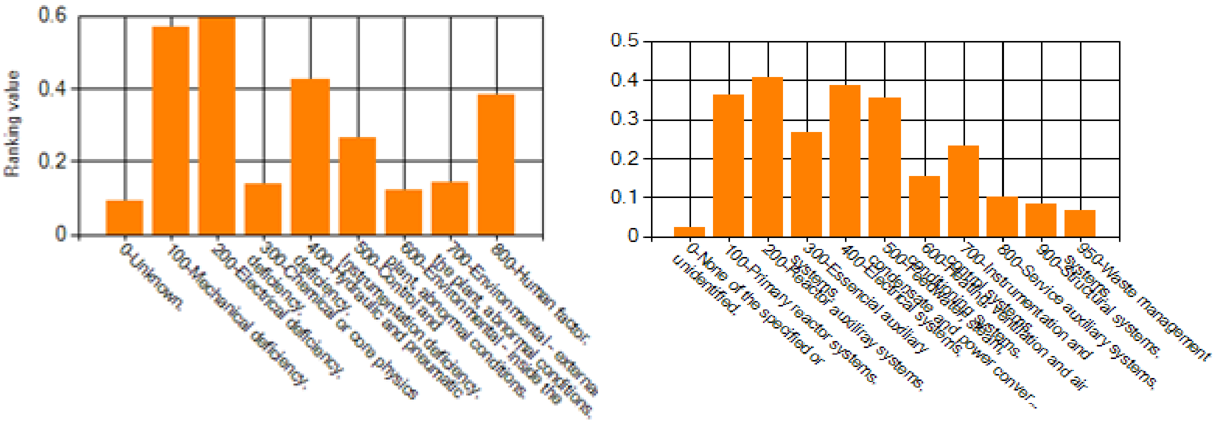

Figure 2. Ranking results example for two groups of events: *Direct causes* (left) and *Systems* (right).

3.1 Other results

Coding scheme allows the creation of many additional reports and some results are presented here.
Distribution of events in time is available on various scales. On the monthly bases average number of events is 24. Three months have 25% more (*April*, *May* and October: 30) and less (*July*, *August* and *December*: 18) events.

During the week events are significantly less frequent on weekend (-38%).

During the day events are also not evenly distributed. They are occurring more frequently between 8 and 18 h, and they are especially rare between 6 and 7 h. The precise time of event is available for ~80% of events.

Duration of event caused shutdown is available for ~40% of events, and majority of events are causing between 4 and 240 h long shutdown.

Reports about number of events per vendor, reactor type and involved staff are also available (not presented here).

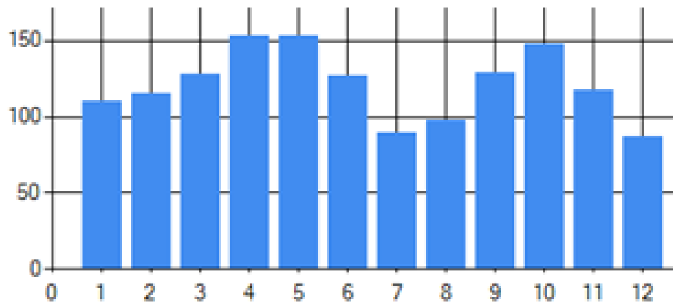

Figure 3. Monthly events distribution – April, May and October are top three months.

4. Conclusions

Proposed method and implemented tool OPERATE allow ranking event groups by importance for decision about further detailed investigation and for providing additional insights into the operational experience events. OPERATE is computing event groups ranking for five categories and creating additional reports as basis for selection and second-level insights into the operational experience events.

Ranking results for different groups could be also viewed together as intersection of different categories (e.g., systems, component and causes, etc.). This will allow for more focused selection of most important events as candidates for detailed analysis.

Further use of this tool seems promising. It is important to realise that OPERATE use relies on the creation of the suitable database where events are fully characterised according to defined coding scheme. Alternatively, tool could be customised to use database with some different coding scheme then used in this pilot exercise.

It also seems interesting to continue with tool functionality development, e.g., separate ranking for different groups of plants and selecting events which are present in the more than one high ranked groups, etc.

The additional value of the OPERATE interactive features is that users could educate themselves about the nature of all events which are occurring in the one nuclear power plants of a group of NPPs for a given time period. This could enhance understanding of different factors related to all events.

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Reasonable recommendations

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Abstract

Accident investigations are executed by e.g. authorities, insurance institutions and companies themselves. The scope and objectives of the investigation depend on who is investigating. The quality of the investigation and the results depend on several constraints, e.g. the knowhow of the investigators. The investigations that aim to improve safety in the future usually include recommendations that are directed to the companies involved and/or the industrial sector where the accident occurred. Sometimes recommendations may even be directed beyond the sector involved.

This paper aims to raise discussion on reasonable recommendations. That is, recommendations that are usable, realizable, and hopefully even measurable. What should be recommended and to whom? The paper presents, with examples, how the ESReDA Cube model may be used to systematically identify recommendations to improve safety on different organizational and societal levels.

Keywords: accident investigation, recommendations, ESReDA Cube model

1. Background

Scenario 1. You're investigating an accident. Writing the report: background, chain of events, causes of accidents, recommendations. What should you recommend and to whom? You list recommendations that are based on both the results of the investigation and your expertise in the field. Are you missing something?

The problem of generating "smart" recommendations is a universal one. One of the reasons is that many of the current accident investigation methods don't give the investigator support in creating the recommendations for improvement, nor in their follow-up.

Scenario 2. You're reading an accident report. You reach the chapter on recommendations. And… you just can't grasp them. The recommendations sound like good ideas, but there is no manual on how to turn the good ideas into practice. Who should utilize the recommendations and how should they be implemented? Should they be developed further?

And, sadly, why is this accident not unique? You've read other reports much like this one, of accidents that were due to similar causes. The previous accidents were also investigated, and recommendations were made to prevent similar in the future. In vain?

2. The ESReDA Cube model

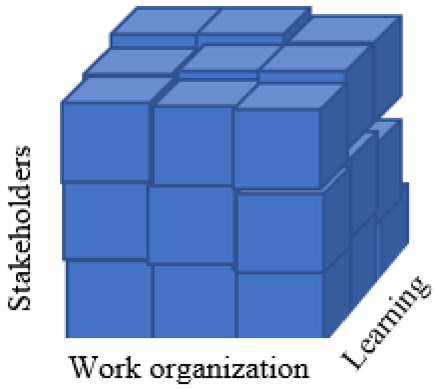
The ESReDA Cube model was created by the ESReDA Project Group on Dynamic Learning and published in 2015. Originally the Cube consisted of a 3x3x4 matrix (hence the name "Cube") with three systemic dimensions representing a) the level of learning, b) the stakeholders involved and c) the work organization where the problem lies. The idea was to use the Cube as an aid to identify and categorize accident factors more systematically.

The Cube was developed to provide the ability to optimize, adapt and innovate sustainable change beyond the level of intervening in the actual accident process itself. Intervention does not only focus on eliminating or mitigating causal factors which were disclosed during the investigation of the sequence of events. Causal factors are answering questions dealing with the what and how, while understanding the why of an occurrence requires additional information about conditions, context, assumptions and simplifications. Such information can only be derived from a diagnosis of the system itself. Applying the Cube enables an investigator to disclose the origin of contributing factors to different phases and states of a system. This can be as early as in the conceptual design, up to operations, both in normal and in safety critical states. In short: The Cube enables an investigator to analyse an event in the context of the system in which it occurs. The purpose of the Cube is to enlarge the scope of recommendations to the system and not restrict recommendations to the sequence of events under scrutiny.

Since its publication the Cube has been utilized in the post-investigation analysis of several accidents and, based on these results, developed further. The original publication introducing the model is available free to download on the ESReDA website[46]. The publication includes a more detailed description of the thoughts and theories behind the Cube than is presented in this paper, and several examples of the use of the Cube.

[46] https://www.esreda.org/projectcasestudy/dynamic-learning-as-the-follow-up-from-accident-investigations/#more-322

The Cube was developed further based on the thought that the model itself and the guidelines to use it need a more simplistic form that will allow to use the Cube more intuitively. The result is a 3x3x3 matrix, see Figure 1a.



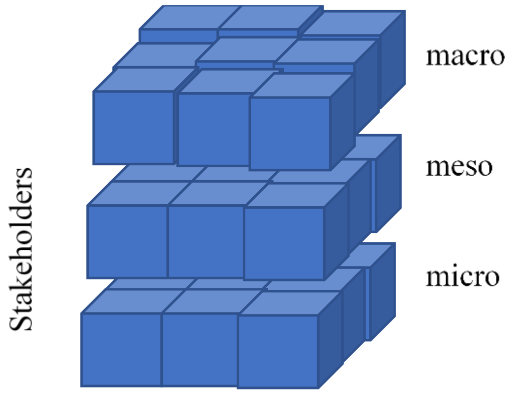


Figure 1a. The ESReDA Cube 2.0. A model with three dimensions and 27 individual cells that represent different possibilities to improve safety.

Figure 1b. The Cube may be sliced into planes. If sliced into horizontal planes, each plane represents a different organizational or societal level where safety may be improved. Slicing vertically (different aspects of work organization) or in-depth (levels of learning) is also possible, depending on the objectives of the analysis.

During the development process it was identified that the systematicity of the Cube may be utilized from several viewpoints. These viewpoints will be discussed in detail in the upcoming ESReDA book on Foresight in Safety (estimated to be published in 2019), and here we will concentrate on only one of them: the intriguing thought that the Cube may be used to create (on-going investigation) or analyse (post-investigation) the recommendations that are generated by the accident investigation results.

In the example figure 1b above, the stakeholder dimension has been cut into three levels. The levels represent different organizational and societal levels, not unlike those presented by Rasmussen and Svedung (2000).

Stakeholders involved (y-axis)

1. MICRO level. Organisations, teams or individuals.
2. MESO level. Industry sectors
3. MACRO level. Governments, agencies, authorities and society

The stakeholder levels must be explicitly defined before the analysis. There may be more than three levels, if needed.

Once the stakeholders have been identified, the factors that enabled the accident to happen may be divided into three categories of work organization. In the original publication there was a fourth category of context, but in the further development of the Cube it was identified that context is best written into the narrative of the accident due to its specific impact on the accident sequence. This does not mean that context, the operations environment, should be excluded from the analyses. Careful consideration should be given to the possibility of existing accident factors that are not included in the three levels of work organization presented below.

Work organization (x-axis)

1. STRUCTURE is about the (re)design of the system architecture: hardware, technology, functionality, organizational scheme (static)
2. PROCESS is about the actions and decisions made in both actual and formal operational conditions (dynamic)
3. CULTURE is about the values, norms and behaviour (inherent/abstract)

The first step of the analysis is to place the accident factors into the grey 3x3 matrix presented in figure 2.

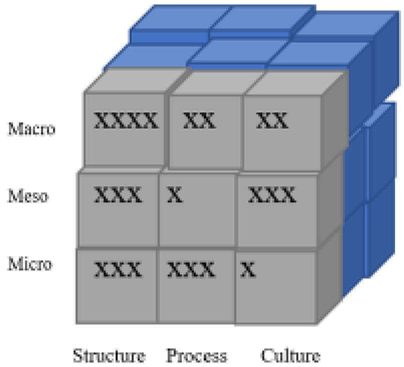


Figure 2. Identified accident factors (x) may be divided according to stakeholder and work organization.

When all the accident factors have been identified, it is time to start thinking about the lessons learned: what can be learned from the accident. How deep have we learned and what lessons have possibly remained unlearned? The depth of the Cube (z-axis) represents the depth of learning, expressed by its rate of change: optimize, adapt or innovate.

Level of learning (z-axis)

1. RULES, single-loop learning: react, improve, optimize
2. INSIGHTS, double-loop learning: adapt, renew
3. PRINCIPLES, triple-loop learning: develop, innovate

More information on single-, double- and triple-loop learning may be found from the original ESReDA Cube publication (2015) and Stoop (2018).

The task at hand is to take the identified accident factors (step 1, figure 3) one-by-one, and think what are the lessons learned (step 2, figure 3) from that factor on the x-, y- and z-levels. What can different stakeholders learn from it? On what levels can learning occur? Can the learning involve different parts of work organization? Take one accident factor and place all the things that may be learned from it into the cells of another empty ESReDA Cube. After this has been done, do the same to all the other accident factors. The results will be a Cube full of lessons learned.

The final step (step 3, figure 3) is to use the full Cube to generate or evaluate the recommendations. You must learn something before you can recommend improvements. Slice the Cube into three planes. Do this first from one direction, then later on from the other two, and target your recommendations to a) different levels of stakeholders, b) different parts of work and c) different levels of learning.

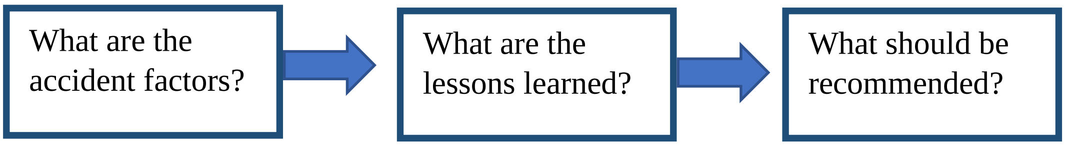


Figure 3. Use of the ESReDA Cube. Utilizing identified and categorized accident factors to formulate precisely targeted recommendations.

The ESReDA Cube may also be used to assess the quality of a former investigation and thus to improve the investigation process itself. It can also assist in tracking which recommendations have been addressed, and with those that have been addressed, could result in a post-implementation reclassification, becoming evidence of good practice to be shared with the safety management communities. Additionally, for those recommendations that were not implemented, the researcher could investigate what the reasons were behind, triggering another research thread. What were the obstacles? Where was the governance bottleneck, etc.?

3. Examples of ESReDA Cube applications

The four examples of use cases presented in this paper represent four very different kinds of accidents: a train derailment, a large petrochemical explosion, a smaller explosion and a large set of recommendations made in aviation. Each example represents a different use case of the Cube:

3.1. Derailing in Romania in 2017

In 2017 a rail crane derailed in the centre of Romania, on the track that runs between Mureni and Beia. The rail crane was one part of a train in traffic, the 4th vehicle after the locomotive. At the moment of accident, the rail crane came out of a small radius curve. The train speed was 44 km/h.

The accident investigation and subsequent investigation report[47] was made by a commission of the Romanian Railway Investigating Agency (AFIGER). The investigation commission concluded that the frontal traverse deformation which was the immediate cause for the derailing must have occurred before the train was composed, and not in this accident. Most probably the deformation occurred during a previous intervention. The deformation should have easily been detected when the train was prepared for circulation.

Figure 4 shows identified accident causes and contributing factors from the viewpoint of the ESReDA Cube. These factors are only a few examples of what was found in the accident investigation.

[47] https://www.agifer.ro/images/rap-finale-ro/117---Raport-Investigare-Mureni-Beia-15-04-2017.pdf

	structure	Process	culture
macro			
meso		no written inspection procedures	
micro	weight of crane	no written confirmation of the technical inspection no inspection before leaving station	lateral wear and transversal level

Figure 4. Examples of accident causes in the cells of the ESReDA Cube. Here the cells represent the single loop learning plane (the light grey plane in Figure 2).

The objective of applying the ESReDA Cube is that the analyst/investigator will think of the accident causes, the lessons learned, and the recommendations from a more systematic viewpoint. Many accident causes may be put into several cells of the Cube. The placement may depend on perspective, but the perspective does not hinder the possibility to learn from all viewpoints of the Cube. For example, the fact that the locomotive driver did not get a written confirmation of the technical inspection is a problem of that railway station (micro) but possibly also a sign of a larger problem of no valid inspection procedures (meso) or not enough conditions (inadequate rules) to establish the responsibility of the person in charge with technical revision (macro).

Through the above-mentioned line of thought one accident cause will result in several lessons learned. Some of the lessons learned concerning the lack of written confirmation are presented in figure 5.

	structure	Process	culture
macro	There are not enough conditions (inadequate rules) to establish the responsibility of the person in charge with technical revision.		
meso		The operating company should have valid inspection procedures	
micro		Written confirmation should always be part of the railway station’s normal operations	

Figure 5. Lessons learned from the accident factor “lack of written confirmation”.

Usually most lessons learned are rules-based (single-loop learning, z-axis), and the question that should be asked is how to learn in-depth, taking into consideration the possibility to gain insights (double-loop learning) or change principles (triple-loop learning).

Once the lessons learned have been inserted into the Cube, the recommendations are based on these lessons. For example, the inspection before leaving the station (and thus written confirmation), recommendations based on lessons learned could be e.g. ”More conditions to establish the responsibility to make technical revision” (macro process cell), ”Ensure the inspection before leaving station” (macro process cell) or ”Valid inspection procedures” (meso process cell). Examples of other recommendations identified in this investigation are presented in figures 6 and 7.

macro			
meso	Practical training of employers when working in abnormal situations, and risk analysis	Establish obligation to perform an activity only in accordance with procedures	
micro			New training for the staff involved in safety control
	structure	process	culture

macro			The regulations for planned reparations
meso	The communication between rail actors at managerial level should be more efficient,	Practical training	
micro	to perform the risk analysis for intervention train activity as well as for its circulation.		
	optimize	adapt	innovate

Figures 6 and 7. Recommendations derived from accident causes and lessons learned.

From the viewpoint of context, the system level (the system as a whole) was identified as a factor that may contribute to such accidents. It was established that the condition of the infrastructure (railroad tracks) affects safety, and that the regulation concerning intervention trains should be reviewed. One of the commission’s main conclusions was that the barriers which could have prevented the accident did not work, and that there were not enough (adequate) barriers to prevent a human error.

3.2 Explosion at BP Texas in 2005

Another use case example presented in this paper is the BP Texas City refinery accident, which took place in March, 2005. A series of explosions occurred during the restarting of a hydrocarbon isomerization (ISOM) unit, resulting in 15 deaths (workers) and 180 people were injured. Most of the victims were near work trailers not far from an atmospheric vent stack. A distillation tower was overpressurised as it was inundated with hydrocarbons, creating a geyser-like release from the vent stack. This release resulted in the formation of a dangerous vapour cloud, which was ignited by an unknown source (could have been a running vehicle engine) and triggered the series of explosions. The refinery was severely damaged.

As the incident has already been thoroughly analysed, neither additional analysis of the accident itself is attempted in this paper nor are the numerous findings of accident causes listed. Instead, as a second use case example we analyse and map onto the ESReDA Cube the recommendations formulated by one of the investigating groups, i.e. the Chemical Safety Board CSB[48]. Furthermore, in this paper we focus our analysis on those recommendations issued by the CSB to the chemical industry as a whole. We will concentrate here on the meso-plane of the ESReDA Cube[49], presented as the middle plane of the sliced Cube in Figure 1b.

Out of the 26 recommendations issued by the CSB, there are six meso-level recommendations, which are mapped in figure 8. It can be observed that of the six meso-level recommendations one occupies the *structure-insights (S-I)* cell, two recommendations are situated in the *structure-rules* (S-R) cell, two recommendations are located in the *process-insights* (P-I) cell and the remaining recommendation is found in *process-rules* (P-R) cell.

	Structure (S)	Process (P)	Culture (C)
Principles (P)			
Insights (I)	2005-4-I-TX-10	2005-4-TX-6 2005-4-TX-7	
Rules (R)	2005-4-TX-2 2005-4-TX-4	2005-4-I-TX-3	

Figure 8. Meso-level Chemical Safety Board recommendations mapped onto the ESReDA Cube.

Because of the length of the recommendations, the recommendations are presented in figure 8 in the original CSB code. A brief explanation of the mapping of each recommendation:

- 2005-4-TX-10 (S-I):
    - *Structure*: mainly a design of Management of Change guidelines;

[48] The recommendations are available at https://www.csb.gov/recommendations/?F_InvestigationId=3515

[49] The meso level in the accident is represented by the recommendations for American Petroleum Institute (API), National Petrochemical & Refiners Association (NPRA), United Steelworkers International Union (USWA) and the Centre for Chemical Process Safety (CCPS).

  - *Insights*: double-loop learning – new insight to monitor changes. Potential for culture change – but not guaranteed.
- 2005-4-TX-2 (S-R) and 2005-4-TX-4 (S-R):
  - *Structure*: mainly a re-design of existing API guidance (recommended Practice 752 and 521);
  - *Rules*: only single-loop learning where a rule has been changed. No evidence of insight change.
- 2005-4-TX-6(P-I) and 2005-4-TX-7 (P-I):
  - *Process*: requires working together towards a definition of a new standards (development of process safety indicators and fatigue prevention guidelines) in a multidisciplinary and multi-sector team. Dynamic.
  - *Insights*: double-loop learning. Development of new indicators to monitor (2005-4-TX-6)
- 2005-4-TX-3(P-R):
  - *Process*: prompt action to alert API members;
  - *Rules*: only single-loop learning – no evidence of insight change.

The mapping of the meso-scale recommendations onto the Cube led to some interesting results and related questions:

- There were no triple-loop learning recommendations.
- There were no culture-oriented recommendations.

Perhaps, when designing recommendations, safety boards should consider to also target recommendations that lead towards triple-loop learning and culture-building at all levels (meso, in this event, but also micro and macro.

Additionally, it would be relevant to check whether all recommendations have been implemented and consequently map the current follow-up situation onto the Cube. Such an exercise would trigger questions such as:

- What were the obstacles encountered at the meso level that made it difficult to implement a given recommendation?
- Which recommendations led to an improvement in the mapping classification onto the Cube?
- How can these results feed into improving safety-related aspects at the meso-level across the given industry?
- How can we design better recommendations that target a triple-learning loop learning level and a culture-building organisation level?

3.3 Explosion in Finland in 2018

An explosion occurred in Finland in March 2018, at a company that makes aerosol products. The explosion was most probably caused by the sudden ignition of a flammable gas or vapour. The explosion and the subsequent fire destroyed about half of the building. One person was injured.

The Finnish Safety and Chemicals Agency (Tukes) investigated the accident with the objective to identify the chemicals that caused the explosion and the ignition cause, the chain of events, and the causes of the accident.

The investigation has concluded that in a probable chain of events, solvent vapours had risen close to the ceiling and ignited. The full accident investigation report is available in Finnish on the Tukes website[50]. Some of the lessons learned from the accident are presented in figure 9. The lessons learned were directed to the industry as a whole.

Meso-level

	structure	process	culture
principles			
insights	Install the gas alarm as a part of the safety automation system		
rules	Ensure that the adequacy of ventilation is measured Install enough gas detectors Pressure relief walls in safe direction Ensure that alarms are noticeable at all entryways	Storage and handling must be in their own fire compartments Systematic maintenance must be carried out	Workers (incl. new and temp.) must be trained to work safely, and they must be told about the plant's hazards.

Figure 9. Lessons learned from most probable immediate cause of accident: flammable solvent vapours rose to the ceiling, and ignited.

This example shows how the Cube could be utilized during an accident investigation. The empty cells in the accident causes matrix will provoke further questions during the investigation, and the lessons learned matrixes may be utilized in targeting recommendations better to specific stakeholders.

3.4 A large set of recommendations in aviation

Karanikas et al (2018) describe an analysis of 82 aircraft accident investigation reports, published by four different accident investigation authorities between 1999 and 2015. In total, 625 safety recommendations were included in the reports. The ESReDA cube was used to analyse the scope of the recommendations with respect to the work organization, stakeholders involved, and the level of learning. The ESReDA Cube was selected for this purpose as it provides a convenient, easy to apply multidimensional reference framework for the comparison of the scope of the safety recommendations. Apart from the work of Karanikas (2016) who classified safety recommendations as Actions, Assignments and Reminders in the context of evaluating aspects of safety management within an organization, the literature reviewed by the authors does not suggest any other categorization.

[50] The Finnish investigation report and English powerpoint-slides https://tukes.fi/onnettomuudet/tutkitut-onnettomuudet/muut

The results of the analysis showed that in the work organisation dimension, the majority of recommendations were made at the structure and process levels, with only a small percentage (smaller than 5%) aimed at the culture level. For most of the investigation authorities the recommendations were evenly distributed between structure and process, but one authority made a large majority (84%) of the recommendations at the process level. The severity of the accident did not influence the distribution of recommendations across work organisation levels.

In the stakeholder dimension, most of the recommendations were made at the micro and meso level, with only a few recommendations at the macro level. Variation across the four investigation authorities was significant: two authorities made roughly a similar number of recommendations at the micro and meso level, one authority made more recommendations at the meso level than at the micro level (20 % micro vs 80 % meso), while the 4th authority made more recommendations at the micro level than at the meso level (67 % micro vs 33 % meso). The severity of the occurrence had a significant influence on the stakeholder level of the recommendation. Fatal accidents were more often associated with recommendations at higher stakeholder levels than incidents with no fatalities.

In the level of learning dimension, most (approximately 80%) of the recommendations were at the insights (double loop learning) level, and this result was consistent across all four investigation authorities. However, two of the authorities made virtually all the remaining 20 % at the rules (single loop learning) level, while the other two authorities made all of the remaining 20% at the principles (triple loop learning) level. The severity of the accident did not influence the distribution of recommendations across learning levels.

4. Results and discussion

The four examples above demonstrate different ways to utilize the Cube. Although the examples represent only a small portion of the full analyses of the cases, they show how the accident causes and lessons learned do not fill the cells evenly. Some cells remain empty or emptier. The investigators may consider whether these cells are irrelevant to the case at hand or if the empty cells represent something that has remained unidentified or unlearned.

Considering the depth of learning, critical questions should be raised about the clarification of

- who is involved
- who is responsible
- who is able to change the system
- who is capable of assessing the validity, efficiency and sustainability of the recommendations made

The example of the application of the Cube to a large set of recommendations resulting from aircraft accident investigations demonstrate that applying the Cube allows the identification of interesting patterns: the majority of recommendations are located near a particular corner of the Cube, there are significant differences across investigation authorities, and the severity of the accident influences the location of recommendations in the Cube. These results may be used to better understand how recommendations are constructed and to subsequently identify best practices for the formulation of effective regulations.

The remaining challenge is to create recommendations that are possible to follow up, and that it is possible to verify afterwards that they have been followed up.

Compared to other accident models and methods of analysis, the added value of the ESReDA Cube is that it is both visual and systematic, allowing simple decomposition into three dimensions. It gives the analyst the possibility to "eat the elephant bit by bit" instead of trying to grasp everything at once, while maintaining a clear picture of which elements have been covered and which are still to be analysed.

5. Conclusions

Putting recommendations into practice seems like a never-ending battle. Another accident occurs and you think how was the risk not identified, understood and/or eliminated? There are several accident reports of similar accidents available and even more near misses known of. This paper aimed to raise discussion on reasonable recommendations. That is, recommendations that are usable, realizable, and hopefully even measurable. What should be recommended and to whom?

The idea of grouping accident factors according to stakeholder is not new. But the idea of categorizing factors according to work organization at the same time is new. Continuing the process by adding levels of learning means the ESReDA Cube model may be used to systematically look at accident factors from several perspectives.

To some stakeholders, recommendations may be seen as suggestions, without an obligation to act upon them. Sometimes recommendations are very abstract, and often they are repetition to recommendations made in other reports. Very seldom we know to what extent the recommendations have been followed-up. As a solution, this paper shows how the ESReDA Cube may be used to assist in constructing more reasonable and better targeted recommendations. In addition, the need to act upon recommendations is discussed. When recommendations are abstract and/or repetitive, they may not be implemented.

The concept that the Cube may be sliced from three directions gives the analyst the possibility to identify accident factors, lessons learned and/or recommendations.

The Cube is a model, not a method, and we believe it is best used as an aid to improve consistency and completeness. The ESReDA project group welcomes all comments for further development of the model.

5.1 Acknowledgements

The authors wish to express theirs thanks to Dr. Nektarios Karanikas and Dr. Alfred Roelen from the Aviation Academy of the Amsterdam University of Applied Sciences for their contribution to this paper – namely chapter 3.4 which was added after the conference and introduces a fourth use case on how to utilize the ESReDA Cube to analyze recommendations. Their investigation on recommendations made in aviation was seen to be so closely linked to the scope of the paper that it would be an asset to add it to the paper for the benefit of the readers.

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SESSION 4:

Lessons learned and historical perspectives

Learning from incidents – the interactive way

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Abstract

Learning from major industrial incidents is possible applying different methods. The approaches demonstrated in various literature can provide a new perspective of learning and implementing the lessons from past events. A completely new way of learning lessons without experiencing the same costly mistakes that could occur during a major incident is possible via interactive case studies.

These case studies used as a training resource, developed by the IChemE Safety Centre are focusing on major incidents from different sectors, such as the oil, mining, space or even nuclear industries. The other advantage of the studies is that lessons from these events can be retrieved and applied across various sectors because the fundamentals are the same. Also, topics such as management systems, corporate government, ethical decision, emergency response, organisational and human factors or safety culture are the core areas which are similar in many operations.

The objective of the paper is to demonstrate the advantages of using interactive case studies to promote an active way of learning from past incidents without repeating the costly mistakes. The paper addresses different areas of interest where various industrial sectors can find relevant learning opportunities that can be implemented in their operation.

Keywords: interactive, case study, learning, industrial sector

Introduction

A key focus area for organisations is to look at what can be learned from incidents to prevent recurrence. Deriving lessons from incident investigation reports is not complicated, but it may not be the case when we try to implement the learnings within the organization. Applying lessons from any incident is a complex task and organisations can fail in implementing them, despite their great effort. The question arises how we can improve the effectiveness of learning? Is there another way than reading investigation reports or watching videos of such events?

1. How hindsight bias can impact learning?

When we review the findings of an incident, we do it with the knowledge of what happened and what were the causes. It is easier to look for a way to rationalise why the incident would not happen to us. This impacts why we fail to learn from others' errors. We justify that we would not have made that decision or taken that action. Finally, we believe that the incident could not happen to us.

We even at times state that we would have known better and made better decisions. This rationale however fails to take into account the full context of the original decisions, or the fact that "the historical judge typically knows how things turned out" (Fischhoff, et al., 1975).

Hindsight bias is a tendency to view the outcome with the belief that you could have predicted it after learning what the outcome is. This hindsight bias makes it difficult to objectively review an incident without second guessing the actions taken by those involved in the event (Fischhoff, 1975).

As highlighted in the Clapham Junction railway incident report (Hidden, 1989) "There is almost no human action or decision that cannot be made to look more flawed and less sensible in the misleading light of hindsight. It is essential that the critic should keep himself constantly aware of that fact." The fact is we cannot "unknow" information. Once we learn about any information, we inevitably know it and it cannot be unknown anymore. Therefore, overcoming hindsight bias can be very difficult.

If hindsight bias is difficult to overcome, what can we still do about it? Let's take an example; cases are widely used in various industries to learn from incidents. They explain the direct and indirect or root causes of an incident, and it makes them a powerful tool to understand what went wrong. When reading investigation reports the temptation to pass judgement on those involved is very strong, but it is flawed. This judgement is made with currently available information that may not have been available at the time.

Hindsight bias inhibits our learning from incidents which means that once we know the outcome of an event, we can see exactly what went wrong in leading to the outcome. We see this information with the benefit of knowing the outcome, and therefore we do not see the events develop in the context under which they occurred. This may cloud our judgement with information that was not known to the people in the event. The question is whether there is a better method of learning from past events.

2. How the case studies work

The case studies developed by the IChemE Safety Centre consist of short videos, with breaks in between for facilitated discussion.

The incidents are presented as a story and efforts have been made to make them generic and anonymous. The reason is to try and prevent the audience from succumbing to the hindsight bias. Real life cases are used as the basis for the videos to address the audience stating 'but that would never happen' as the events unfold. Once the actual incident is disclosed, the story becomes real.

The sessions begin with an introduction to the facility type and the team involved in the facility, as well as introducing the audience to the role they will be playing in decision making. This provides a chance to set the context of the case study. Figure 1 shows the example of setting the context using the Offshore platform case study that simulates incident investigation. In this example the audience plays the role of an investigator.

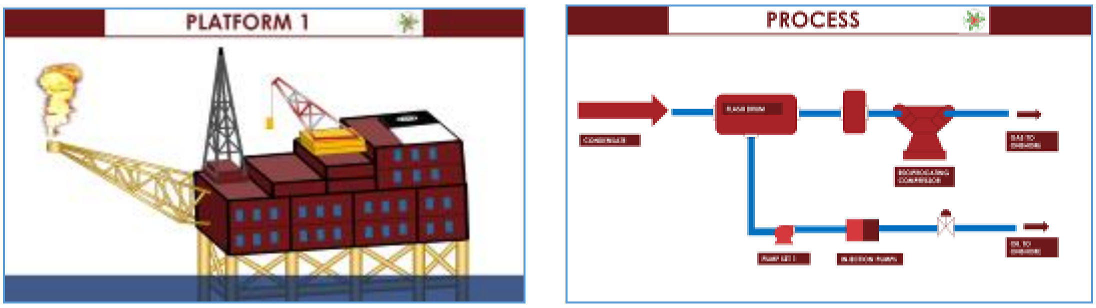

Figure 1: Example of setting the context

Once the context is set, the events that led up to the incident start to develop. At certain points in the story the audience are given a chance to make a critical decision. They obtain the summary information and the video stops for the audience to make their decision (See Figure 2). The type of decision making in each case study remains consistent, so as to create a degree of familiarity with the decision framework used.

As a next step, the facilitator discusses the decision made by the audience before start again the video to see what decision was made by the people involved in the real case. Each case study typically has three decisions to be made. Once the final decision is made that leads to the event, the actual incident is revealed. The learnings of the particular incident are then discussed in the video. Once the videos conclude the facilitator holds a final discussion on the learnings and what people have taken away from the experience.

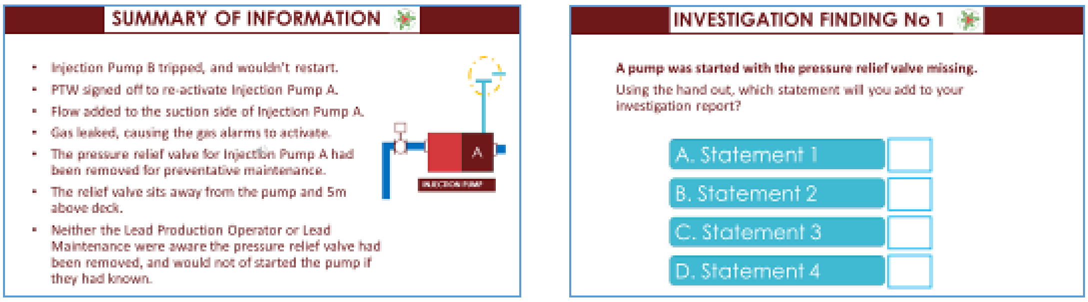

Figure 2: Example of a decision question

The presentation of the material allows us to create some of the initial pressures felt by the individuals involved, such as time delays or financial constraints. For example, with financial constraints, as it is presented in the Coal mine case study it will reference the money spent or cost cutting. This starts to provide some of the original context.

At times this can mean that the study presents additional unnecessary information. This is done not to confuse the audience, but to show some of the information overload that people experienced in the real case. The audience needs to figure out what is important and what is not to be able to make the decisions.

2.1 The case studies

The ISC has released six interactive case studies up to the date of the paper. Those case studies are focusing on the following aspects of process safety and addresses the issues:

1. Coal Mine – simulating design, construction and commissioning decisions
   - This study guides users through the challenging practice of engineering decision making, this time focusing on the design, construction and commissioning of a coal mine. It highlights the pressures of budget and schedule, enabling users to experience how these factors influence vital decisions.

2. Gas Plant – simulating operational decisions
   - In this study the user will encounter a stream of crucial decision making points, which would typically occur while on shift, operating a gas plant. Users will practice managing the tenuous balance between meeting production output targets, while managing a process upset.

3. Tank Farm – simulating operational decisions
   - This study exposes the user to a series of challenges associated with operating a tank farm. They will make ongoing decisions about the operations, comparable to those that could occur while on shift. Users will practice managing the tenuous balance between meeting production output targets, while adhering to essential safety requirements.

4. Offshore Platform - simulating incident investigation
   - In this study the user will play the role of the incident investigator tasked with identifying the root causes. The case study explores the complexity behind the incident and prompts the user to identify the true causes beyond the immediate direct cause.

5. Lift off - exploring decision making
   - This case study takes the user through the process of making critical decisions within a complex organisation as they manage a busy launch schedule. It highlights the ethical pressures of working within existing processes to solve problems.

6. Tidal Wave - emergency response
   - This case study will take the user through an emergency response event as it unfolds. It highlights the different risks and challenges of responding to a natural hazard triggering a technological accident.

2.2 Application of the case studies

A question arises as to how to apply the case studies and what effective ways are possible to transfer the message to the audience. One way to use of the studies could be the application and implementation of the lessons highlighted in the studies.

A detailed discussion with the workforce or the management of the facility would provide further insights as to where it is possible to improve the safety management system. The purpose of the case studies is to promote a different tool to advance learning from past events and learnings found in those real-life cases can be implemented in the policy and system of the organization.

For example, the case study on developing lift off can have applications for senior executives and directors on governance decisions, as well as for front line operators on factors that influence certain critical decisions.

Further to that, these studies take the facts of an incident and simplify them in terms that can be understood by a wide range of people. This makes the application of the case studies very broad. They are also designed in such a way to ensure the delivery of the facts is constant using videos, and have comprehensive facilitation notes, so the discussion can be led by someone from within the organisation, from a manager to a team leader.

Lessons from these events can be retrieved and applied across various sectors because the fundamentals are the same. For example, Lift off is a space shuttle incident and Tidal wave discusses emergency response in case of a Natech event in a nuclear environment. However, operators, managers working in a completely different environment will find the relevant message without necessarily having a thorough knowledge in the field.

Topics covered in these studies, such as process safety management systems, corporate government, ethical decision, emergency response, organisational and human factors or safety culture are the core areas which are similar in many operations.

Conclusion

The case studies have been run a number of times across varied audiences and received positive feedback and both engaging and well presented. Putting the learner in the event as it unfolds and encourages them to make decisions without knowing the outcome.

A completely new way of learning lessons without experiencing the same costly mistakes that could occur in real life. The lack of real consequences for the participants may reduce the experience of learning, but it is still a greater understanding than simply reading an investigation report with the dry facts or watching a video knowing the outcome.

Seeing an incident unfold in the context of what else is occurring at the time can help us understand why people made the decisions they did. This can be more powerful that just questioning the decision that they made. Understanding the why allows us to address similar issues in our facilities.

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Using the 'Knowledge of Accidents' in Normal Operation: a Case Study on the Framing of Organisational Diagnosis of Safety Management

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Abstract

Industrial accidents continue to occur despite prevention efforts of high-risk industries. One can state that failures to learn occur, similar accidents recur in some organisations (NASA, BP), and we observe that similar root causes and accidents patterns recur whatever the industrial sectors, the country, the culture and historical period. This empirical statement opens towards the possibility of accidents' lessons capitalisation into a structured 'knowledge of accidents' (Dechy et al, 2010) that includes the 'pathogenic factors' (Reason, 1997), and 'pathogenic organisational factors' within organisational diagnosis (Dien et al, 2004, 2012, Rousseau et al, 2008). Our goal is to address the challenge of using this knowledge of accidents in normal operations. We will address this challenge through an analysis of a case study. The case study aims at describing how experts used in practice this knowledge to define the analysis framework of a safety management assessment conducted by IRSN for the nuclear industry.

Keywords: Accident, Organisation, Diagnosis, Safety, Learning.

1. Introduction

Industrial accidents and disasters have occurred in every industry and country especially since Second World War and the 30 years of glorious industrial development. After an accident, an investigation aims at identifying lessons to be learned, for instance through the definition and implementation of corrective actions to prevent similar accidents from recurring. The learning process, the risk analysis process and more globally safety management are supporting the implementation of preventive, protective and emergency safety measures.

One could state that an overall reduction of industrial accidents for the last 50 years has been achieved and some authors claimed that some industries reached an ultra-reliable state (Amalberti, 2006).

However, this improvement has plateaued for a few decades, and a "tango on an asymptote" (Frantzen, 2004) is observed on accident statistics. Major industrial accidents continue to occur. Moreover, failures to learn are observed with similar accidents that recur, for example at NASA with the loss of two space shuttles for different technical failures but similar organisational failures; and at BP with a relentless series of accidents with Grangemouth (2000), Texas City (2005), Prudhoe Bay (2006), Deepwater Horizon (2010).

Our working position and research work in such high-risk industries lead us to develop an assumption that the lessons of accidents are neither learned sufficiently nor sufficiently used in practice, especially across industries (Dien, 2004, Dechy et al, 2008). We therefore proposed that the lessons from accidents should be capitalised into a structured 'knowledge of accidents' (Dechy et al, 2010). It follows some conceptual and formalisation efforts of human and social scientists that led to the notions of 'pathogenic factors' (Reason, 1997), 'pathogenic organisational factors' especially for the use within organisational analysis of accident and organisational diagnosis of safety (Dien et al, 2004, 2012; Rousseau et al, 2008; Llory et Dien, 2010; Llory et Montmayeul, 2010).

In developing this concept of knowledge of accidents, we mentioned the necessity to address the challenge of using this knowledge in normal operations. This questions how it can be achieved in practice and how it can be enhanced through different tools, processes, skills and knowledge management provisions.

Several contexts of use of this knowledge of accidents in normal operations should be studied, as for instance the use by operators (workers and managers) in the daily practice of management of performance and safety, as the use by experts during a safety assessment, as the use by regulator inspectors when conducting an inspection, or after a training where lessons from accidents are transferred.

In this paper, we reflect and analyse expert practices in using this knowledge of accidents during a safety assessment performed at Institut de Radioprotection et de Sûreté Nucléaire (IRSN) for the French Nuclear Safety Authority.

In safety and reliability, both applied sciences, two research traditions in human and social sciences are often opposed. The first studies normal operations to identify features of reliability (High Reliability Organisations, e.g. Rochlin et al, 1987; Roberts et al, 1990; Laporte and Consolini, 1991) and of resilience (Resilience engineering tradition, e.g. Hollnagel, 2006). The second considers the 'gift of failure' (e.g. Wilpert, 2011) and that accidents are the 'royal road' to access real organisational (mal-)functioning (Llory, 1996) and vulnerability.

In this paper, we want to address how knowledge of accidents is used in normal operations, in one of its contexts of use (safety assessment). From a theoretical point of view, our study creates an operational link between the two research traditions and could support their articulation rather than their opposition.

In this theoretical context, our specific research question is: How experts can use the knowledge of accidents to frame an organisational diagnosis in normal operations?

After some reference to the theoretical context, we will describe the context of the case study for our research before the analysis and the discussion of the findings.

2. Learning from Accidents, Knowledge, Normal Operations and Organisational Diagnosis

2.1 Learning from events and accidents research tradition

Learning from accidents and failures is an established tradition in engineering, safety and reliability of high-risk industries, for instance since the birth of some industries such as aviation with the first public accident investigation board set-up in 1917 in the UK (ESReDA, 2005; Dechy et al, 2012). Learning from human errors and organisational failures has also become a hot-topic in practice and for scholars since the end of the seventies (e.g. Turner, 1978; Perrow, 1984) with accidents such as Tenerife in 1977 and Three Mile Island in 1979 that changed worldviews on the causal factors of accidents (Wilpert and Fahlbruch, 1998).

Indeed, to improve safety, some researchers conceptualised the approach and advocated for the study of events (incidents, near-miss, failures and accidents) to highlight features of vulnerability (e.g. lack of robustness such as redundancy, safety margins), as they consider not enough attention is given to those events. Wilpert (according to Carroll and Fahlbruch, 2011), considered that undesirable incidents and events, serious and disturbing as they may be, are a 'gift of failure'. In short, events offer an opportunity to learn about safe and unsafe operations, generate productive conversations across engaged stakeholders, and bring about beneficial changes to technology, organisation, and mental models (understanding). Llory (1996) goes further, arguing that accidents are the 'royal road' (referring to Freud's metaphor about dreams being the royal road to access the unconscious) to access to real (mal) functioning of organisations. Indeed, some hidden phenomena, hardly evident in normal operation may become more visible in accidents (especially those in the 'dark side of organisations' (Vaughan, 1999, Llory, 2006)). Studies of accidents help to reverse our perspective: if normal operations hardly show organisational pathologies, accidents help to better understand the risks associated to the banality of the daily life in organisations.

2.2 From failures to learn accident's lessons to the knowledge of accidents

After an accident, an investigation is launched to understand what, how and why it happened this way, why it was not prevented despite safety measures (preventive, protective,…), to identify the direct and root causes, the lessons that could be learned, the corrective actions that could be implemented, to prevent a similar event to recur (here and also elsewhere) (e.g. Frei et al, 2003; Sklet, 2004; Dekker, 2006; ESReDA, 2009; Ziedelis, 2011; Dechy et al, 2012; Dien et al, 2012; Hagen, 2018). Efforts and investments have been made by the high-risk industries in operating experience feedback systems to make the learning process a pillar of modern safety management (Dien, 2004).

Learning is a process that generates outcomes especially changes, in other words 'learning involves a change' (Koornneef, 2000). It can be in the knowledge base, the beliefs, the risk perception and the technical, human and organisational provisions to prevent accidents. It can come from experience and study. After an event, several learning loops (single, double, triple) have been qualified by the organisational learning researchers (e.g. Argyris and Schön, 1996) and multi-level learning is acknowledged (Hale et al, 1997; Rasmussen and Svedung, 2000, Dechy et al., 2004, Svedung and Radbö, 2006, Cedergren 2013; Hovden et al, 2011, Tinmannsvik et al., 2013; Ramanujam and Carroll, 2013; Drupsteen and Guldenmund, 2014;

Bringaud et al, 2016; Blatter et al, 2016). In addition, the depth of change varies (optimise practice within existing constraints, adapt and modify conditions, innovate). This depth of change is one of the three dimensions of the ESReDA cube (ESReDA, 2015) taking into account the learning scope (structure, culture, process…), and levels of sociotechnical system addressed (micro, meso, macroscopic).

However, lessons learned from accidents (e.g. Columbia space shuttle in 2003, Texas-City refinery in 2005, flight Rio-Paris in 2009…) have shown some failures to learn from previous events, weak signals, near-misses and accidents (e.g.; Dechy et al, 2009; Hopkins, 2010; Paltrinieri et al, 2012; ESReDA, 2015). Some lessons on the root causes are not identified especially due to the lack of depth of analysis and therefore jeopardize the relevance of lessons to be learned (CAIB, 2003; Dien et al, 2012, Thellier, 2017). If there were changes, they were 'too late and too little' as said by the chair of US CSB (Merritt, 2006) after Texas City refinery accident.

Beyond these statements, especially the ones on learning loops which may focus the issue on the organisational learning mechanisms from only one accident, the specific challenge we invite to tackle is to broaden the research on learning mechanism in two directions, historical and transversal, in order to integrate other accidents in the perspective (Dien, 2006, Dechy et al, 2008). It requires to consider the opportunity to learn from other sectors' industrial accidents, for example to transfer the lessons from Columbia space shuttle accident to the process industries (Dien and Llory, 2004). It requires also to consider the opportunity to learn from many accidents that occurred in the world over a few decades and that provided several lessons to be learned.

Indeed, several researchers studying industrial accidents observed that similar root causes recur whatever their occurrence context (industrial sector, the country, the culture and historical period, regulation). They found 'echoes' (as said by the former astronaut Sally Ride about Columbia space shuttle loss which echoed Challenger loss) and 'striking similarities' (as mentioned by US CSB chair in front of US Senate about Texas City and Prudhoe Bay accidents) not only in NASA and BP's accidents' patterns, but in most if not all accidents (Dien et al, 2004; Rousseau and Largier, 2008 ; Llory and Dien, 2010; Llory and Montmayeul, 2010; Dechy et al, 2010, 2013, 2016).

Based on this empirical statement and on the assumption that recurrences are meaningful, several researchers provided concepts that have been articulated to form a generic model of accident based on recurring patterns (Dien, 2006, ESReDA, 2009). Indeed, lessons from accidents showed that an accident is a combination of direct and root causes at several levels in sociotechnical systems (Rasmussen, 1997) which have implemented several lines of defence to prevent accidents. In this way an accident is "hard to obtain" (Perrow, 1984). The safety degradation (Dien, 2006) may have started long ago with latent flaws as soon as the design phase for instance (Reason, 1990) that generates warning signs in an incubation period (Turner, 1978), with weak and strong signals (Vaughan, 1996; Llory, 1996). Some signals may be recognised within processes such as audits or investigation of events, or by some actors such as whistle-blowers. But accidents showed that signals of danger were not adequately treated by the organization and management through the implementation of proactive or corrective action (Merritt, 2006; Guillaume, 2011; Jouniaux et al, 2014; Dien, 2014). Similarly, several researchers formalised and conceptualised the recurring root causes of accidents, called 'pathogenic factors' (Reason, 1997), and then 'pathogenic organisational factors' (Dien et al, 2004, 2006, 2012, Rousseau et al, 2008) (see §2.3).

In line with this approach that takes into account this empirical statement about recurring patterns of accidents, the idea of 'capitalisation' of generic patterns of accidents emerged and was formalised in a concept called the 'Knowledge of accidents' (Dechy et al, 2010, 2013, 2016). This conceptual approach assumed that the systematic and cumulative study of several incidents, accidents and crises, provides us an understanding and knowledge, which can hardly be obtained in another way, of the dysfunctional dynamics and pathogenic factors that undermines organisation and the way these factors erode defence in-depth.

This assumption is valid only for some high quality and exemplary in-depth investigations of accidents such as Ladbroke Grove rail accident near Paddington station in United Kingdom in 1999 (Cullen, 1999), Columbia accident investigation (CAIB, 2003), Texas City refinery accident (CSB, 2007) that provide 'thick description' (as defined by Geertz, 1998) of organisation (mal-)functioning.

In our definition, the 'knowledge of accidents' does contain mainly some structured knowledge such as grid of analysis and models of recurring patterns (model of accident, pathogenic organisational factors) and some stories, than can be transferred, memorised and used by safety analysts but also managers, operators, regulators.

2.3 Organisational analysis and diagnosis, pathogenic organisational factors

Methods in human and organisational factors that are used by experts for assessing safety management or investigating an accident incorporate some key principles of human and social sciences approaches such as the reliance on subjective information data collection from interviews and workplace observations, as well as documents. More specifically, some researchers developed some methodologies for conducting organisational diagnosis of safety and organisational analysis of accident (Dien et al, 2004, 2012; Rousseau and Largier, 2008; Llory and Dien, 2010; Llory and Montmayeul, 2010, Dechy et al, 2011a) that integrate some methodological lessons from exemplary organisational analysis of accidents such as the three investigations mentioned in the previous paragraph (Cullen, CAIB, CSB). They are also inspired by lessons from organisational diagnosis in normal operations when conducting an assessment of management of safety (Rousseau and Largier, 2008).

One of their key characteristics is to rely on the so-called 'pathogenic organisational factors' which formalise some knowledge about the recurring root cause of accidents at a rather generic, global and macroscopic level. Within this method, the pathogenic organisational factors can be used by an analyst to support the framing of its assessment, to support its lines of analysis and to audit their presence and severity in an audited organisation. Here is a list extracted from the following references (Dien et al, 2004, Rousseau and Largier, 2008, Llory and Dien, 2010):

- Poor recognition of critical components, of critical activities or deficiency in anticipation and detection of errors,
- (Excessive) production pressures,
- Deficiency of communication or lack of quality of dialogue,
- Excessive formalism or proceduralisation,
- Organisational complexity, obscurity and compartmentalisation,
- Learning deficiencies (operating experience feedback, closing feedback loops, lack of listening of whistle-blowers),
- Lack of accountability,

- Inability to develop and maintain individual competencies, and to develop and use collective competencies,
- Lack of adequate human resources (in numbers),
- Lack of organisational culture of safety,
- Deficiency of daily safety management,
- Complacency or deficiency of control authorities,
- Failure to re-examine design basis and operations assumptions.

2.4 Some limits of the approach relying on lessons from accidents

This learning from accidents research tradition and our theoretical proposal cannot ignore the challenges raised by other researchers in safety. Firstly, some researchers are cautious about the relevance and validity of the lessons learned from accident investigations, either due to political pressures, resources constraints or biases. One of the most critical comment is that the hindsight bias influences accident report findings. Accident investigators could hardly avoid the wisdom after the event (Reason, 1990) and would explicitly or implicitly develop harsh judgment of human actions and decisions, knowing the overall story. In search for accident explanation, investigators would pay more attention to relevant signals that became meaningful in retrospect and would not be in the position to be “comprehensive” to the people facing blurred and contradictory signals masked by the daily noise, ambiguities and uncertainties in the course of events. To the extent that Vaughan (1996) concluded that some weak signals could not be understood before the accident because they were normalized in NASA’ culture.

On this aspect, we have also been critical considering that although the risk of bias is serious and has to be managed by investigators and human and organisational factors analysts, empirical data from several major accidents showed that some people in the system did detect some safety issues, did recognise some early signs of danger, did alert of potential accidents (Dechy et al, 2011). Furthermore, audits and learning from event processes can capture such warning signs. For instance, the Texas City refinery accident in 2005 was preceded by several events, even serious incidents of 30 million dollars, by claims from managers, by internal and external audit alerts and investigation alerts (CSB, 2007; Hopkins, 2008; Dechy et al, 2015).

In addition, some researchers (e.g. Bourrier, 2005) considered that accident reports are secondary documents whereas research based on ethnographic studies of the daily life of organisations would provide more reliable data.

To this point, we opposed that though it can be indirectly collected data rather than directly collected data for a researcher, major accident and disaster investigations are often analysed by large teams, sometimes with human and social scientists, and are provided important resources that both support the quality and depth of findings and lessons. Their reports, made of hundreds of pages, provide “thick descriptions” (Geertz, 1998) of the practices. They are not perfect, and may contain under-investigated issues but are valuable pieces of knowledge.

2.5 Normal operations research tradition

A second research tradition advocates for the studies of normal operations, the so-called High Reliability Organisations (Rochlin et al, 1987; Roberts, 1990; Laporte 1991; Bourrier, 1999, 2001, 2011). Instead of explaining accidents and defining strategies to prevent them based on lessons learned, those researchers would rather concentrate their understanding effort on the surprise of a rather lack of accidents and high reliability of some organisations operating high-risk systems. In this research tradition, we would add another research group that formalised Resilience Engineering concept and more recently with Safety II concept (Hollnagel, 2006, 2014). Those researchers have been seeking factors, practices, and "best ways", especially remarkable to explain how success is obtained daily despite adverse conditions. In such a way, they would grasp features of reliability, resilience and safety.

These research approaches have emphasised as well but in a different manner the need to learn from experience, from events, from adaptations when unexpected events show up, especially minor events as no major accident often occur and offer opportunities to learn.

On expert judgment activity, stories of internal events incidents and external accidents are sometimes used by managers to support decision-making in high-risk industries in normal operation and to mentor younger colleagues (Hayes and Maslen, 2014). In the context of crisis and unexpected events, Weick and Sutcliffe (2007) insisted on the dual role of experience that supports sensemaking but that can lead to excess of simplifications based on the recognition of similarities between present and past that are in fact superficial. These last points open the possibility to support expert judgment with stories of past events such as accidents, with knowledge from the past, though it can bring biases.

2.6 Research gap: the challenge of using knowledge of accidents in normal operations

This review of the scientific literature leads us to point that we have little evidence on how the knowledge of accidents is used in normal operations. Indeed, one of the goal of the knowledge of accidents is to enrich safety analysts, prevention actors such as decision-makers, operators and inspectors, with some background knowledge references and to support the expert knowledge 'black-box'. More precisely, we lack of evidence on how knowledge of accidents can be used in practice by some analysts in the framing of an organisational diagnosis of safety management in normal operations.

As a matter of the fact, as the two research traditions (normal operations, accidents) in safety management are often opposed, we propose a way to connect them in the safety practice. By doing so, we also aim at fostering the theoretical debate between these two research traditions.

3. Approach

The research approach is qualitative and, in a first step, relies on first-hand data as researchers who participated to the development of these concepts of knowledge of accidents and pathogenic organisational factors and as analysts who implemented it in practice as experts within an institution (IRSN) for a case study of organisational diagnosis of safety management in normal operations. To understand the case used for our research, some context is provided on the safety assessment process.

3.1 The context of the research case

3.1.1 Assessing management of safety by experts at IRSN: generic principles

In France, the nuclear power plants' licensee, Electricité de France (EDF), remains responsible for ensuring nuclear safety, radiation protection and occupational safety on its 58 nuclear reactors in operation on its 19 nuclear power plants (NPP). External control is carried by the regulatory body that is composed of the control authority, the nuclear safety authority (Autorité de Sûreté Nucléaire, ASN) with the support of IRSN which is the Technical Support Organisation (TSO). This control is regularly performed through inspections checking regulation compliance that are led by ASN inspectors with the support from IRSN experts. Comprehensive safety assessments are performed by IRSN experts. Both approaches are complementary.

The goal of safety assessment is to provide a robust basis (facts, findings) to support a rigorous analysis involving collective expert judgment to aid a decision-maker. For IRSN, the decision-makers that will use the conclusions of the analysis are the control authority (ASN) and the operator (Electricité de France). Both will use the findings, the criteria developed, the recommendations proposed to define regulatory requests or safety management provisions.

A nuclear operator has to submit to the regulator a report about a “safety case” to obtain a license at different stages of its life cycle: for constructing, operating, and dismantling. Different report types can be distinguished, as the report about the safety case can be the safety options report, the safety analysis report that formalises the safety demonstration. In addition, and more often, the case is an object related to safety engineering but with a reduced scope such as a modification of a manufactured equipment item, such as a safety equipment, or such as a safety calculation for a demonstration of robustness of a building. But a case can also be an object related to management of safety, such as an activity performed by a person or group of workers, an organisational change, the real functioning of an organisation or the real performance of some safety barriers and provisions. The real functioning implies to consider its observable performance when implemented by people within the constraints and resources of a work organisation. To report on the real and daily performance of the sociotechnical system, data collection methods such as observations in the field, interviews of workers, records and documents are required.

IRSN is then requested by the control authority to provide a technical expert opinion. To support the collective expert judgment process, a key activity is to be able to confront the case with some criteria. The criteria to support expert judgment can come from norms, design and safety rules, analysis guidance with criteria and threshold or from scientific knowledge and research, lessons learned from internal events or international events, experience and experiments... For example, for a safety case to justify the mechanical robustness of an equipment, an analysis is performed to verify that the equipment can sustain a load to some threshold and that the conditions of operations will not create loads that overcome the thresholds. Sometimes, especially at the beginning of safety assessment on new issues, criteria are blurred and not really fitting the expertise need; problems are sometimes ill-defined rather than well-defined; thus, a decision-aiding process is required for the expertise itself that is rather an exploratory process than a standardised activity (Merad, 2010). To support its independent assessment, often some additional data about real performance of the sociotechnical system is collected in the field by IRSN experts which complements the case report provided by the operator. This normal operation field data is collected within the established framework and should provide evidence on the identified criteria for assessment. In practice, especially in human and organisational factors safety assessment, it is not a linear process and is rather complex and iterative as the case (e.g. the real observed performance) can help to define as well the framework and criteria.

Before starting the safety assessment, it is necessary to address its key shaping factors: the risks related to processes, activities and management provisions, the stakes, the scope of the assessment, the delay to report findings and conclusions, the type of decision to be taken by the decision-maker, … Then, the generic question to address: is the information about the real performance satisfying the assessment criteria to develop with reasonable confidence the judgment that the provisions implemented by the operator are sufficient to manage risk? In other words, how safe is safe enough?

3.1.2 Assessing management of safety and radiation protection during outages: building a specific analysis framework

Maintenance on NPP reactors is mostly performed during planned outages, either for preventive and curative maintenance. A planned outage is organised every year or eighteen months depending on the reactor design and nuclear fuel management. Around 5 000 maintenance activities and sometimes up to 15 000 maintenance activities are scheduled. All these maintenance activities are performed during the outage in one to six months. Though the preparation of the outages starts years before with support from central engineering divisions, a dedicated outage project team is set-up for a year and staffed with more than 50 engineers and technicians. It is coordinated by a group of twelve to fifteen people. The maintenance activities are executed by hundreds of workers, mainly subcontractors but also internal maintenance technicians and operators.

To define the scope of analysis for the assessment of safety and radiation protection management of maintenance outages and to build the framework of analysis, IRSN experts addressed several issues in initial and preliminary studies (Dechy et al, 2014):

1. What is an outage? What are the risks in outages? What are the risk management provisions?
2. What are the lessons learned from outage events?
3. What were the past vulnerabilities (found in former audit, assessment and inspections)?
4. What are the changes implemented? Are they introduced to treat past vulnerabilities?
5. What are the lessons from outage management benchmarking?
6. What are the lessons from industrial accidents?

In addition to the studies conducted to identify potential recurring vulnerabilities in former events, inspections, safety assessments (questions 2 and 3), a benchmark (question 4) was conducted in North America to three nuclear operators that implemented the outage control centre (OCC) that the French operator wanted to transfer as a new organisational model. OCC are open-floor offices where the group of twelve to fifteen coordinators manages the outage on a continuous basis (up to 24 hours basis) with shifts. They are equipped with many screens and computers like in crisis centres. This benchmark helped experts to confirm the analysis framework, to provide other questions and a more critical view on the “best way” to organise outage management. In addition, several international guidelines on outage management were consulted and some relevant research were reviewed to support the understanding of the risk management provisions, the human and organisational issues (Bourrier, 1999; Reiman and Oedewald 2006; Grusenmeyer, 2002).

To conduct this assessment of management of safety during outages, the approach implemented by IRSN experts relied on extensive fieldwork investigations with: 150 interviews of operators, managers, subcontractors, technicians, engineers from maintenance and operations; 70 days of normal operations work observations performed on three French NPPs at several stages of the outage preparation, execution and learning; hundreds of documents reviewed; technical discussions with engineering and management headquarters. It involved a team of mainly four HOF analysts, supervised by two HOF managers, supported by three engineers in nuclear safety and two engineers in radiation protection and one retired nuclear plant operator. The final report is about 185 pages and IRSN recommendations were submitted to the French nuclear Advisory Committee of Experts in charge of nuclear reactors (Groupe Permanent Réacteur) the 13th of June 2013.

3.2 Methodology, data collection and analysis

The research goal was to establish a case study that provides a narrative that enables an understanding of the performed uses of knowledge of accident especially in the context of an organisational diagnosis in normal operations. The assessment of safety management during maintenance outages is the case with the most systematised used of ‘knowledge of accidents’ though it is not the first (Rousseau, 2008) nor the only one at IRSN. In other words, the focus of this paper is to address how the sixth question had some effects on the assessment. Though every aspect (answers to all six questions) had its impact in the definition of the framework of analysis and on the interpretation of some data found during investigation, the case study we describe in this paper on the use of knowledge of accidents and analyse hereafter is only a small story in the bigger story of the IRSN safety assessment of outage management.

In the team of twelve experts involved all along the safety assessment and at various degrees, the coordinator of the HOF analysts and its line manager were the two experts who explicitly used the knowledge of accidents and are the two first authors of this paper. This specific situation enables to have access to first-hand data as participating observers. Another specificity of this context of use is that these two analysts in charge of this safety assessment by IRSN are among the researchers who participated to the development of the concepts of knowledge of accidents, pathogenic organisational factors, and organisational diagnosis of management of safety. This second specificity highlights their role of ‘research-intervention’. One could notice that these two specificities implies a major bias as the two analysts are experts and researchers, and are at the same time judge and stakeholder, by being in this case study the users and the developers.

The case study relies on a retrospective analysis of some expert work conducted from 2011 to 2013 that implies a loss of memory. The reliance on tracks of expert activity was a key, achievable in practice with records of text documents produced at that time. With these biases and limits in mind, data collection focused on the initial analysis that was the key step to justify the launch of a safety assessment by IRSN under the request of the control authority. Indeed, the issues raised about outage management, the definition of scope of analysis, the identification of the framework of analysis were formalised within a twenty pages document. The presentations of the document enabled exchanges within IRSN with other analysts involved, with internal managers of safety and radiation protection engineering. It enabled as well to agree with the most critical lines of investigations with the control authority and the NPP operator. To support the establishment of this analysis framework, studies to address the six questions mentioned in § 3.1.2 were conducted by IRSN experts. Some available knowledge from accidents was reviewed for this purpose. When necessary further researches on lessons from accidents were initiated to produce knowledge of accidents for further use. However, the knowledge and lessons from accidents, used as references to support the definition of analysis framework, were primarily discussed by the main analyst and its supervisor and not systematically communicated and discussed with other analysts, engineers and managers.

4. The case study on the use in practice of the knowledge of accidents in organisational diagnosis of safety management

For the IRSN assessment on "safety and radiation protection management during maintenance activities in outages" (IRSN, 2013, Dechy et al, 2014), 'Knowledge of Accidents" and organisational diagnosis methodologies was particularly useful (Dechy et al, 2016) at three stages of the safety management assessment : (1) a planned use to define the scope and framework of analysis ; (2) for the interpretation process to support expert judgment ; (3) for rhetoric purpose during interactions with stakeholders to convince them about the potential impact of the risk and the relevance of IRSN recommendations. The first type of use is further analysed in this paper to get a detailed analysis.

In this chapter 4, we aim to describe the experts' practices, putting light on the analysis processes and the tools that supported them. With the following case study, we look at the small story of the use of the knowledge of accidents in a bigger story of the IRSN assessment of management of safety during NPP maintenance outages. Therefore, the way lessons from accidents supported the analysis are presented after some explanations on the other data, factors and clues that shaped the definition of analysis framework. In other words, our preoccupation was to deal with our own biases, of being researcher and expert, and to avoid an effect of presentation as well that would exaggerate the influence of lessons from accidents. The initial analysis enables experts to identify the key topics to investigate in order to frame the assessment. The issues raised in outages are numerous and were prioritized. The selecting and prioritisation process are not discussed in this paper but only the use of knowledge of accidents for the six main lines of analysis from § 4.1 to 4.6. Indeed, 'Knowledge of accidents' helped to identify the scope of the assessment, to better justify the most important risk management provisions to audit and assess, and the key likely potential deficiencies that could be found.

4.1 The use of the generic accident model and the dynamic of risk management

High-risk systems have a history and so do their risk management and the regulatory requests to enhance safety. In other words, though the focus in this paper is limited to one case of IRSN safety assessment, it is connected to previous ones and does not start from scratch. Indeed, two key previous IRSN safety assessments were conducted from 2006 to 2008 and their findings pointed several vulnerabilities. In this perspective, to establish the analysis framework of a safety assessment, past vulnerabilities can provide investigation paths and assessment lines.

Indeed, in 2008, IRSN completed its first large scale HOF assessment of management of safety in a competitiveness context after EDF's partial privatisation in 2004 (Rousseau, 2008). Several weaknesses were already identified on outage risk management: practices of overburdening the schedule, operation asymmetry towards outage project, inadequate human resources (in numbers) for field actions by operations. Other issues were found in identification and use of lessons, the position of the independent safety line, management of organisational changes and their interactions. In parallel, in 2008, IRSN also completed another large-scale safety assessment on maintenance policy: among the deficiencies, one can mention skills management (in house contractor oversight, at subcontractors), understaffing of in-house control of subcontractors, outages preparation difficulties due to their proximity and overlapping at sites level.

After the IRSN safety assessment in 2008, ASN requested the nuclear operator to strengthen the operation team' position during outages with complementary organizational provisions in order to adequately respond to outage project' requests. In addition, it was requested to establish an analysis of schedule pressures and operation staffing. To these regulatory requests, the French NPP operator mentioned it would start to implement in 2009 Outage Control Centre (OCC) which objectives are to improve all performances (safety, radiation protection, availability of plant, and cost). This change in outage management was aimed at solving former deficiencies and was part of a large-scale program of changes to improve all performances of the French nuclear operator a few years after privatization.

The end of the OCC implementation was scheduled for 2012 outages but its efficiency had not been assessed so far and the first feedback from the regulator inspections showed heterogeneous implementation in 2010. In addition, inspectors of ASN had contrasted lessons on first plants where OCC was tested: at the same time, it was limiting some overtime in daily work hours, but also enabling a "double day" for managers, meaning that after OCC shift, they would continue to work at their office.

In this context of warnings from the past vulnerabilities to be solved and the contradictory signs received from implementation, it was worth to inquire in order to provide evidence. To this purpose, for the current 2011-2013 analysis on outage management a set of general questions was framed to wonder if risk management was improved with OCC or not: Does the new organisational model to manage outage enable the risk management in outage to become more efficient than in the past? Do the performance factors introduced by these new organisational provisions compensate past vulnerabilities? Are they creating new vulnerabilities? This approach, this rationale and those questions were written and developed in the initial analysis document as a basis to launch the IRSN safety assessment.

Though no clear references to the lessons from accidents were explicitly made for this point in the initial analysis document, the underlying rationale was influenced by the knowledge of accidents. To support this approach, the coordinator of the analysis and its direct supervisor clearly referred to their background knowledge on lessons from accidents. In particular, they both referred to a generic model of accident causation (see § 2.2). From this perspective, both analysts assumed that 'history is a cause' as the Columbia Accident Investigation Board (CAIB, 2003; Starbuck and Farjoun, 2005) clearly recalled the limits of safety improvement after Challenger accident in 1986 and the safety degradation that are connected to the NASA management policy 'Faster, Better, Cheaper'. The policy was aiming at improving performance, specifically doing more with less in a constrained environment set-up by US Congress that was translated into budget and staff reductions and increase transfer of activities to private sector.

In addition, the two analysts considered that the historical dimension is one of the three key dimensions of an organizational analysis of safety (Dien, 2006; Llory and Dien, 2010; Llory and Montmayeul, 2010). Having this accident model, this historical approach and these stories in mind helped both analysts to remain pragmatic and critical about the potential impact of changes. One should note that this view challenges continuous improvement motto and beliefs associated with changes and the quest for forever higher performances. Indeed, the effects from changes can be negative (see hereafter in the next § about management of change). This knowledge (of accident model, historical dimension and stories) helped to formulate the questions to wonder if this program of changes solved former safety issues and if they generated perverse negative effects.

In other words, and more generally, rather than a photograph of risk management, one of the purposes of a safety assessment on safety management, is to situate it in a historical perspective. The safety assessment should provide evidence in order to appreciate the global trend of the system, the dynamic of risk management. So, in addition to the generic goal of a safety assessment and associated question (how safe is safe enough?), a second generic goal is to wonder if safety is improving or degrading. The outcome is often to look for provisions to enhance safety that provide an increase of safety margins. This generic mindset helped to share a broader and longer-term view which was the key overarching rationale to establish conclusions beyond the five-key topic of the analysis discussed hereafter.

4.2 The use of lessons from accidents to address management of change

In addition, the program of multiple changes set-up by the NPP operator was aimed at improving all performances (production, safety…). This ambitious program could require from IRSN some investigations on the conduct and implementation of all changes which could provide evidence for a potential conclusion on management of change. However, within the resource constraints of the assessment (e.g. the delay to conclude) which scope was rather on safety and radiation protection management during outages, it was considered relevant to focus only on the conduct of the outage management change related to the implementation of OCC while addressing the effects of other changes during outages.

In high-risk industries, the risks generated by technical modifications have been monitored for decades by engineers and operators. The risks introduced by organizational changes have been widely recognized since the nineties in some industries and since the early 2000s in the nuclear industry by institutions such as IAEA and OECD that edited some recommendations and guidelines to assess risks (IAEA, 2003; OECD, 2004). In France, specific requests were made in the early 2000s by ASN and IRSN to the NPP operator to develop methods to address human and organisational factors impact of technical modifications and later of organisational changes. The operator had developed a method for that purpose and the implementation of OCC was the first organisational change to be analysed using this method (Le Guilcher and Carballeda, 2011; Dumont et al, 2011).

In this context, a set of general questions was framed and formalized in the initial analysis document and the final report of the IRSN safety assessment to consider if this approach was efficient: How risks were assessed? How was OCC designed? How was change conducted? How were the interactions between changes taken into account? What was the support provided by the central engineering departments to the local plants? What adjustments have been required?

The framing of this approach could be performed by most HOF analysts and would not need in a first approach to look at the insights from accidents. However, some issues in the program of change let the analyst and its supervisor to reactivate some knowledge of accidents and infer some potential analogy with some stories of accidents such as NASA before Columbia accident. Indeed, for both analysts, some key sentences seem to echo with the case. Indeed, the CAIB (CAIB, 2003) entitled a chapter “Turbulence in NASA hits the space shuttle program”. Indeed, Daniel S. Goldin, NASA’s Administrator, self-proclaimed that he was an “agent of change”. In order to obtain “administrative transformation” of NASA, Goldin engineered “not one or two policy changes, but a torrent of changes. This was not evolutionary change, but radical or discontinuous change.” […] “His tenure at NASA was one of continuous turmoil, to which the Space Shuttle Program was not immune”.

Though no clear written references to the lessons from accidents were made in the final version of the document formalising initial analysis prior to the launch of the safety assessment that was shared with other analysts, engineers and managers, an explicit effort with this perspective in mind was made to model the risk induced by an ambitious program of changes to improve all performances (see figure n°1).

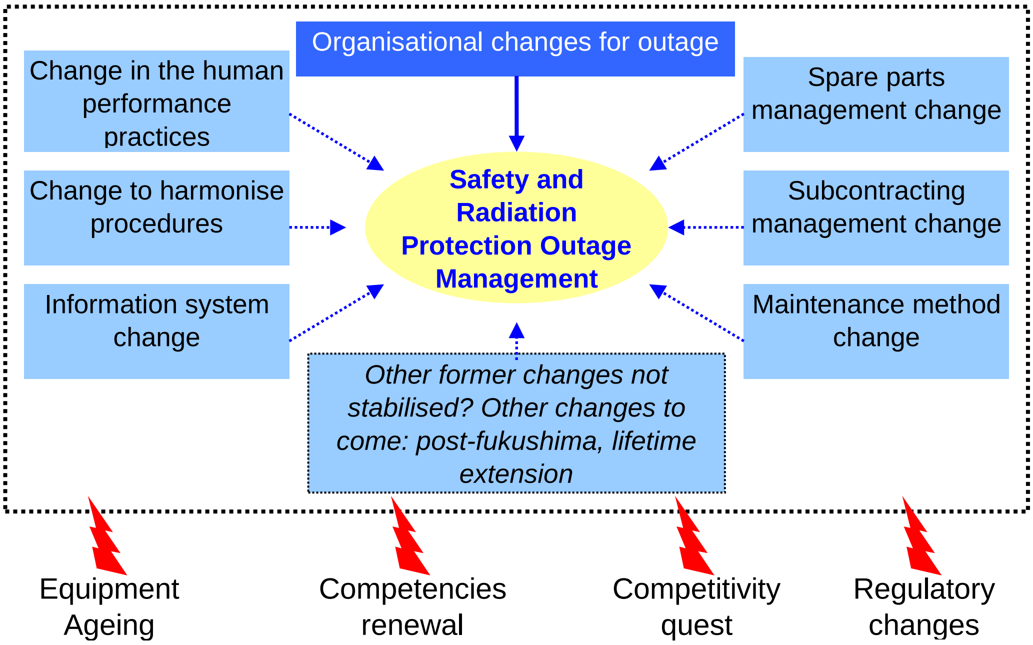

Figure 6 : Safety and radiation protection outage management at the intersection of changes

This modelling effort – in figure n°1 - has been in retrospect one of the most useful tool to communicate to the operator and regulator, the risks induced by the multiplication of changes as observed in accidents and helped to raise the challenge upon the analysis of their interactions.

In addition, during the initial analysis in early 2011, a dedicated review of lessons from accidents was conducted in order to sensitize our lenses of analysts. It focused on the management of change as a root cause of some accidents (e.g. Columbia, Texas City, Paddington…) and the goal was to identify further issues, questions, and to formalize a grid of analysis. Among the lessons gained from this knowledge generation approach that were published and presented in May 2011 (Dechy et al, 2011), it appeared that very few changes motivated for safety reasons were the root cause of accidents. Though, they could complexify a system's safety (Sagan, 1993, 2004), organisational changes to improve safety were often implemented after events. To the opposite, changes motivated by performance goals are a recurring cause of accidents. This research work was useful to consider that effects of change can be positive and/or negative. Therefore, a pragmatic and critical approach was determined as relevant for the safety assessment in coherence with § 4.1. With these insights, and rather than focusing only on the risk analysis, the time dimension appeared to be a key aspect of change and an opportunity to consider, implying that a proper monitoring of effects of change would be relevant to gain empirical evidence of their effects. These lessons from accidents impacted more broadly the rationale for the conduct of the assessment.

4.3 The use of lessons from accidents to address organisational complexity

The previous assessment of management of safety in 2008 focused on how decision-making was impacted by the privatisation of French NPP. This analysis on the production pressures was explicitly referred to be influenced by lessons from accidents (Montmayeul, 2006, Rousseau, 2008; Dechy et al, 2016). So was the level of analysis, which shifted from human error to flaws in decision-making processes which are indeed often mentioned in accident analysis (Vaughan, 1996; Llory, 1996; Morel, 2002, CAIB, 2003). Some flaws were found by IRSN during 2007 outages and recalled in § 4.1 (asymmetry of power relations between project and operations, staffing issues, over-burdening the schedule). The OCC was for the NPP operator a new organisation that would cope with those vulnerabilities.

In this context, an analysis on the scope of organisational complexity was considered as it articulated also with the two formers (production pressures, decision-making). Indeed, the initial analysis enable to grasp the complexity of outage management: thousands of activities have to be prepared within a project team for months by several tens of maintenance and operation specialists and with subcontractors in order to be executed in a few weeks by hundreds of actors from maintenance, operations and subcontractors that are coordinated for about a year by a dozen of engineers. The interface management (communication flows, coordination, cooperation) between multiple actors (OCC, shift operations, maintenance, subcontractors, safety, radiation protection, logistics…), internal and external, at different level of hierarchy, in different space, territories and time all along the organisation chain from preparation years and months before, to the execution (territorial complexity and time complexity with synchronisation issues at different phases) challenged the continuity of decision-making processes. It enabled also to address how trade-offs integrate safety concerns beside the schedule, production pressures and other concerns. In this context, the new outage project coordination organisation (OCC) was introducing new interfaces with new communications lines and with new people who had to understand and take ownership of the outage preparation. In such context, one could wonder about the effects on information reliability and decision-making.

The relevance of this scope of assessment was confirmed by the benchmark performed in North American NPP where interface issues between operation and maintenance were familiar, and OCC was indeed considered as adding an interface to solve an interface problem which would increase the complexity of the organisation.

Topics like organisational structure, processes of coordination, communication, cooperation are widely addressed in the human and social sciences literature and familiar to HOF specialists. However, here again, the two analysts considered that there were strong echoes with accidents, especially the Paddington rail collision in United Kingdom in 1999 and the Columbia space shuttle loss in 2003). Organisational complexity (internal, external with subcontractors), interface issues and fragmentation after privatisation, were at the origin of several accidents which the analyst and supervisor were familiar to as they had produced knowledge such as grid of analysis related to these accidents. Complexity was in this sense defined as a pathogenic organisational factor that could be analysed within an organisational diagnosis (see § 2.3, Rousseau and Largier, 2008; Llory and Dien, 2010).

In addition, similarly that for the topic of management of change, an additional and dedicated effort was made to review several accidents with these root causes to establish more detailed knowledge of accidents. A paper has been prepared in parallel of data collection and analysis for IRSN safety assessment all along 2012: on organisational complexity (Dechy et al, 2012;

Dien et al, 2013). Additionally, at the end of IRSN analysis, a paper was made on organisational fragmentation (Dien and Dechy, 2013). This research showed that complexity can help to some extent safety (for instance with automated sequence, additional safety devices), but it was observed how adverse can become the trend to increased organisational complexity through division of labour, hyper-specialisation, bureaucratisation, matrix organisation to communication channels, blurred responsibilities and increased the challenges of coordination, cooperation and integration.

4.4 The use of lessons from accidents to address subcontractor's integration

Along the previous line of assessment on organizational complexity and interface management, a specific room was considered for the external interfaces involving subcontractors. Indeed, in some type of maintenance activities, up to 80% are subcontracted. The new outage organization provisions aimed at better integrating subcontractors in preparation work but as well in decision-making processes for instance at interface with OCC. In this purpose, some questions were prepared to define the analysis framework like the reality and level of integration at the level of the work organisation, the impact of these relationships with oversight, the effect of the different type of structures… One should notice that the depth of analysis was aimed to remain limited in this safety assessment as it was agreed with the ASN to launch in 2012 a dedicated safety assessment focused on the subcontracting process. In this case, the assessment was therefore more focused on the interface and integration of subcontractors.

Subcontracting is often looked as a risk for safety and health conditions though it is used by companies to improve performance. No extensive review of academic literature in human and social sciences was directly performed by the coordinator analyst as it was specifically performed for the purpose of the safety assessment on subcontracting process that was launched during the outage assessment. However, the issue of subcontracting has been highlighted in several accidents in France such as DC-10 crash at Ermenonville in 1974 (Llory, 1996) and AZF in Toulouse in 2001 (Dechy et al, 2004), in Macondo oil spill in Gulf of Mexico in 2010 or in the case of Challenger shuttle loss in 1986 with communication flaws between Morton Thiokol engineers, their management and NASA regarding the fatal decision to launch the shuttle.

Similarly, a specific review of lessons from accidents which root causes involve subcontractors was undertaken to produce some insights, questions, issues to address and was formalized in a publication along the analysis in 2012 (Dien et Dechy, 2012) and after the finalization of the assessment on fragmentation issue as an articulation of complexity, subcontracting and privatization (Dien et Dechy, 2013). Among these, the knowledge gained by this analysis of lessons from accidents showed an increase of complexity with the divergence of interests which challenge communication at interface for instance during preparation work, under-investments in skills, under-reporting of field issues in the learning from experience. The fragmentation of organizational network with less interactions challenged the relationships, the skills at interface and favour insular attitudes.

4.5 The use of lessons from accidents to address human resources management

The topic of human resources was particularly identified for integration in the analysis framework as it was impacted by the organizational change and the implementation of OCC. Indeed, to operate 24h/24h and 7 days a week in other to reduce outage duration and provide availability of outage project decision-makers for issues that arise overnight and over the week-end activities, it required staff in quantity and quality. The operator had identified the risk of stressing the staffing capabilities in numbers and in competencies to operate OCC and the ASN had already observed adverse consequences. Indeed, it would require to set-up shift hand-overs with enough competent engineers in maintenance and operations. However, the request for staffing occurred at a time where the French NPP workers were about to retire with 30 to 50% leaving in 5 years. Within this context, several questions were prepared to support the analysis framework on human resources management: as the OCC requires staffing in quantity and quality, how is it implemented? What are the side effects? How are the skills acquisition managed? What are the effects of the human resources policy?

Human resources management is an important issue in management, human and social sciences that is often addressed when conducting a HOF analysis within high-risk industries as it started several decades ago with the ‘human error’ concept. IRSN had completed in 2006 a thorough assessment of competencies management. Indeed, the skills acquisition and maintenance were an important issue in perspective of the retirement wave. In addition, human resources management was already one of the pathogenic organisational factors that was formalised in organisational diagnosis framework (Rousseau and Largier, 2008; Llory and Dien, 2010). Therefore, no complementary analysis of lessons from accidents was found necessary and enough lines of assessment could be raised. However, the lessons from root causes of accidents with under-staffing at Texas-city refinery in 2005 and years of workforce reduction at NASA in the nineties were in the background references of the coordinator analyst and its supervisor.

4.6 The use of lessons from accidents to address learning process from outages

Learning from events, often called operating experience feedback in the nuclear industry, is recognized as a priority in risk management, especially since Three Mile Island accident in 1979. It was found that an incident could become a nuclear accident implying a nuclear reactor meltdown. This accident had precursors in the US at Davis-Besse NPP in 1977 and in Switzerland at Beznau NPP in 1974 (Llory, 1999). The NPP operator was also looking at improving learning from outage unexpected events by setting-up within the outage project team a dedicated team called “high-impact” team. This team’s goal was to capitalize lessons to avoid the recurrence of the same unexpected situations as these kinds of events challenge the outage team capabilities and the duration of outage project. Within this context, the questions prepared for the assessment were about the process to identify and capture lessons, the overall efficiency of learning and the efficiency of the use of lessons in outage preparation. Moreover, the French NPP operator made in 2009 an internal audit which pointed some deficiencies in the operating experience feedback processes and benchmarked the north American NPP which implemented a so-called ‘corrective action program’. A reform of the learning device and organization was in progress and its support to outage learning was raised.

Operating experience feedback performed by NPP operator on around 10 reportable events per year per reactor are challenged on a continuous basis since the eighties by IRSN and ASN. In addition, the integration of HOF in the event analysis has been regularly investigated by IRSN since the nineties. It was known that some accidents were partly caused by failures to learn, for instance since Three Mile Island accident (Llory, 1996, 1999). In addition, prior to this safety assessment, a review of several industrial accidents was made and enabled to formalize a grid of analysis that articulated numerous learning deficiencies (Dechy et al, 2008, 2011, Dien et al, 2012). This specific knowledge of accidents provided more than 30 lines of questioning and in this context of an assessment on management of safety a more limited focus to the main issues was necessary. The questions raised focused mainly on two key issues such as the formalisation of lessons and their use. However, the numerous learning failures remain in the background knowledge of the two analysts.

5. Conclusion

This case study helps to make more explicit how lessons and 'knowledge from accidents' were used in the context of normal operations, specifically to support the framing of a regulatory assessment of safety management in nuclear power plants. As researcher mobilising in retrospect our embedded experience of expert, as analyst and supervisor at IRSN, special attention was first given to the summary of the main performed expert activity dealing with the bigger story of the assessment of outage management. It therefore provides the narrative of the main expert rationale that lead to establish the framework of analysis. And, it was indeed in this context that the small story of the use of accident knowledge in the safety assessment occurred. Our research aimed at discussing some underlying factors, conditions that facilitated this process and the barriers we had to overcome at the analyst level.

At this stage of the research, it shows that for four of the five main lines of analysis selected (interface management, integration of subcontractor, human resources management, learning from experience), some pathogenic organisational factors (POFs) were available before the IRSN assessment in some scientific publications or along the analysis (management of change). Labelled in positive terms, they could constitute five items of risk management provisions, but they may be affected by deficiencies or pathologies. Although, other POFs could be activated by this case, an implicit prioritisation effort lead to focus on the key ones for this safety assessment. Similarly, the sixth line of analysis, on a broader issue of potential safety improvement or degradation is connected to the formalisation of a generic model of accident.

This background accidents' knowledge and the memories of stories of accidents were part of the references of the analyst in charge and its supervisor. These references were appropriated because at the same time the experts conducted research on lessons from accidents. However, these background knowledge references are activated during the initial analysis when there is a confrontation to other sources of information such as the provisions implemented by the operators, the lessons from events, the lessons from ASN inspections, the lessons from previous safety assessment of IRSN. This activation may trigger either some structured knowledge on pathogenic organisational factors either some memory of specific accidents' lessons for instance with echoes of Columbia when thinking to multiple changes or organisational complexity. At this stage, this kind of knowledge of accidents, either as a list of POFs and as a memory of some lessons already helps the analyst to raise the issue, to be critical, to sensitize its grid of reading, to identify a few questions for further analysis. In other words, it helps to focus the analyst' mindset to a preoccupation with failure (Weick and Sutcliffe, 2007).

Indeed, knowledge of accidents is supporting reflexive processes. In other words, using a POF in this context was not a paste-and-copy exercise but was rather activated after initial analysis of the case of the nuclear operator. Therefore, this knowledge should be used as a starting point of the investigation not as an ending point. In addition, POFs are rather macroscopic and generic which implies a loss of context. The investigation consists in analysing the relevance and intensity of the POF with regard to the context and determine the potential adverse impact on safety.

However, the level of abstraction related to the knowledge of accidents remains limited if the analyst can only rely on generic POFs. In other words, it was found necessary to establish a more refined grid of analysis by using the standard approach of reviewing lessons from several accidents with a narrow focus on one POF in order to elaborate a more structured and refined knowledge of accidents with analytic and synthetic conclusions. Some of the lessons were formalised before the IRSN assessment on production pressure by another researcher and on learning from experience in association with the analyst. However, some topics such as organisational change, complexity, subcontracting and fragmentation were not analysed in-depth before the safety assessment. In this context, and in a role of research-intervention, specific reviews of lessons from accidents were performed in association with other researchers to provide a structured knowledge of accidents ready for use. Being an active participant researcher in these reviews that lead to four scientific publications in French definitely helps the assimilation as an analyst.

So, in summary, the use of the knowledge of accidents was favoured by available publications on POFs that were part of the analysts' background knowledge on top of the memory of accident stories acquired by reading and researching on reports of lessons from accidents. The appropriation of this knowledge was favoured by the cumulative role of researchers and analysts who themselves produced some of this knowledge for the specific use in the situation to support their expertise for assessing the management of safety. This configuration will likely contrast with other configurations of knowledge generation and use. With this double hat of knowledge producer and researcher and analyst, we played a role of acteur-pivot (Journé and Raulet-Crauset, 2005) with a dedicated responsibility in the framing of the analysis.

Finally, this case study on the use by experts of accidents' knowledge to support the framing of an assessment of safety management in normal operations starts to show how we can build a bridge between two research traditions, relying on lessons from accidents and normal operations. It was beneficial to analysts to get more references to support choices, to sensitise the lenses of analysts and to support the analysis framework. This on-going case study already provides its first lessons but it is too early to define generic mechanisms, to generalise and to pave the way towards some engineering and management proposals. Further research is required, more in-depth and with other cases and other actors.

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Are structural weaknesses limiting the capacity to learn from incidents?

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Abstract

This paper is about the capacity to investigate and learn from incidents. Capacity is seen as the outcome of individual practices and facilitating social structures. Practitioners create practices that fulfil their goals in a specific work context. To the extent that a practice succeeds, it could be deemed a 'good' practice. Practices are shareable in principle, but there are many conditions. Creating and sharing 'good' practices depends on the social structures— stable and enduring social institutions, organisations or arrangements that make up the social world—that facilitate or limit practitioners. This paper considers structures under three broad headings: lifelong learning, empiricism and cooperation between practitioners and academics. These structures offer opportunities for improvement.

Keywords: Values, context, empiricism, cooperation, good practice.

> "There is base[51] labour, and noble labour. There is base sorrow, and noble sorrow. There is base joy, and noble joy. But you must not think to avoid the corruption of these things by doing without the things themselves. Nor can any life be right that has not all three. Labour without joy is base. Labour without sorrow is base. Sorrow without labour is base. Joy without labour is base."
>
> John Ruskin, 1867.

1 Introduction

The present authors noted the following passage in the *call for papers* for the 55th ESReDA Seminar:

> *"There are major challenges in bringing into practice a body of existing knowledge on accident investigation and learning to generate system change for safety improvement. This requires better understanding of the obstacles to practical application of* ***good practices****. Given differences in histories, technologies and culture, these obstacles are*

[51] In nineteenth century usage, 'base' could be used as an adjective to mean low value, or unworthy.

> *sometimes sector-specific, or peculiar to certain countries, or more generic. New strategies need to be identified to overcome the obstacles to sharing of good practice and improvement of the quality of safety investigations."* [Emphasis added] (ESReDA, 2018.)

The present authors agree that *practice* is a helpful focus for improving the quality of investigating and learning from safety incidents[52]. Furthermore, improvement will depend in part on describing what the to-be-adopted practice is. However, this paper argues that the value of that description depends on knowing why the practitioner does it this way, how they vary their practice in different situations, and what constrains their choices.

The concept of 'good' practice is itself contentious, as is *sharing* of 'good' practices. The *call-for-papers* (ibid.) mentions obstacles to applying 'good' practices. Sometimes it will be that a 'good' practice requires facilities that are absent elsewhere. For example, the ergonomics of some charting methods need wall space, and not all offices have that. However, physical reasons aside, 'obstacles' suggests that merely removing an impediment would allow a 'good' practice to flow into practitioners do. The implication is that 'good' practice is somehow self-evident and transferable. However, what is 'good' in one context, might not be so 'good' in another—hence the use of inverted commas. Therefore, although there may be obstacles, another factor affecting application may be differences of goals and constraints between one situation and another. Sensitivity to context will be a recurring theme in this paper.

To the extent that contexts have shared characteristics, sharing of practices is possible. This is in contrast to an extreme constructivist stand, which is that "phenomena can be understood only within the context in which they are studied; findings from one context cannot be generalised to another; neither problems nor their solutions can be generalised from one setting to another" (Guba and Lincoln, 1989; p.25). However, if the contextual aspects of a good practice can be understood, then perhaps that practice could be generalised to other settings that share those aspects. Later in the paper, examples are given of 'good' practices of interviewing. Some aspects of practice that are claimed to be 'good' in the independent investigation setting may not be tenable in the self-investigation or regulatory investigation settings. On the other hand, some other aspects of interviewing 'good' practice, such as the PEACE model in law enforcement (Clarke and Milne, 2001) seem to be truly generic. One of our conclusions about empiricism in this area is the importance of accounting for the conditions under which a practice can be claimed as 'good'.

The present authors agree with the implication made in the *call for papers*, that developing, identifying and sharing 'good' practice could happen to a greater extent than at present. The interviewees (investigators, and managers of investigation programmes) who contributed to this paper often voiced frustration about this. To an extent, this frustration points to limited

[52] While discussing this with a French speaking colleague, it became clear that this wordy phrase 'investigating and learning from incidents' needs some explanation. The English word '<u>investigate</u>' has two senses. The first sense is of inquiring into something unexpected, the second sense is to look into a case of misbehaviour (e.g. a crime). In practice, these two meanings interfere with each other. Sometimes while the investigators believes that they are inquiring into causes, other stakeholders anticipate blame and recrimination. The word 'incident' is in the wordy phrase because 'experience' or 'events' are neutral, whereas 'incident' has the connotation of being both unexpected and unwanted. The neat French phrase 'Retour d'Expérience' seems to avoid a lot of problems.

agency[53] amongst practitioners to develop their practice as they see fit, as well as limited structures to share and learn from others.

If 'good' practices originate in the work of the individual practitioner then what governs this creativity and what enables others to learn from it? The very general answer is *structures*—"stable and enduring social institutions, organisations or arrangements that make up the social world, and that appear to exist independently of individuals and their agency." (Mythen, 2012; p.125).

The title of this paper asks whether structural weaknesses are limiting the capacity to learn from incidents. By *'capacity to learn from incidents'*, we refer particularly to the practices of investigating and learning from incidents. Insofar as the capacity to investigate and learn from incidents is produced by the practices of individuals, that capacity is structurally determined. For example, a structure like a training course enable practices to be shared, but will also limit the scope of what is shared. And because the definition of *structure* is wide, we are entitled to look into how different forms of structure constrain and enable creating, identifying and sharing 'good' practices.

This paper looks at the impact of three, interrelated structural weaknesses on practices of investigating and learning from incidents: (i) the cooperation between practitioners and academics; (ii) empiricism in safety management, and; (iii) lifelong learning structures.

The issue of structural weaknesses reflects the current agenda of the NRI Foundation. NRI was founded in 1998 to improve safety management practice. Its Board, reflecting on its future contribution, recognises untapped potential for cooperation between practitioners and academics (NRI, 2017). Hence, the hypotheses presented here concerning 'structural weaknesses' do not arise out of thin air, but are born out of reflections about how safety practice can be advanced. The ESReDA seminar has been a welcome focus for discussing these ideas with practitioners and for reviewing the literature.

This paper is an exploratory exercise. It is written to inform discussion rather than arrive at conclusive findings. It reports what the authors learned from discussions with a purposive sample of respondents—all involved directly in investigating and learning from incidents—about the relevance of the structures mentioned to identifying, developing and sharing 'good' practice. The interviews were semi-structured and lasted between one and five hours. The ten respondents are, or have been until recently, investigators and managers of the investigative function within their respective organisations. The organisations include independent safety investigation bodies, safety regulatory agencies, and large businesses. The businesses are in diverse sectors—food, chemicals, and transport— but all of the businesses have programmes for self-investigating safety incidents.

[53] Agency, in the social scientific sense "is the capacity to act freely according to one's own choices, intentions and desires." (Mythen, 2012; p124)

2 Good practice: what is meant by the term?

The term 'good practice' does not have a settled definition. During the interviews held for this paper, the present authors paid attention to the different meanings attached to the phrase. Two meanings seemed particularly close, yet distinct: method and 'good' practice. In the area of incident investigation, *method* usually refers to a formalised procedure, invariably written down somewhere or encoded as software. Practice, on the other hand, seems often to mean a habitual action. The 'good' prefix appears to endorse a practice, marking it as approved or respectable. An example from one of the interviews may help to illustrate the distinction between methods and 'good' practices.

Interviewer: *We have been talking about 'good' practices, but what do you think those words mean. Is Tripod a good practice?*

Respondent: *Tripod is a method, to me. What's a good practice? We use good practices for a lot when we have requirements, so when there's a certain requirement or a lifesaving rule and it's more or less the way we make this happen, the way we comply with that rule, and we call it a good practice. A good practice most of the time is more or less a toolkit of things.*

Although distinct in their meanings, practices and methods are related. For example, the ECFA+ method[54] is a procedure for creating timelines. In the preface of the ECFA+ manual, Kingston and Koornneef (2014) explain that "*This is the second edition of the ECFA+ manual. It contains the insights gained by the authors during the last seven years of applying, reviewing and teaching ECFA+*." Most of those insights stemmed from observations of how people actually worked with ECFA+. The authors incorporated into the ECFA+ procedure, rules derived from practices that they evaluated as 'good'. Similarly, when training people to use the EFCA+ method, the expectation is that users will incorporate ECFA+ principles into various aspects of their practice, as well as being competent to apply the method 'as taught' if needed.

2.1 'Good' practice and practitioner's discretion

In keeping with the above, the word *practice* is taken to mean how a practitioner does their work, or some aspect of it. Furthermore, 'practice' is taken to be discretionary; the practitioner is free to do their work this way, or another way. What makes a practice 'good' is that doing the work that way achieves the goals of the work, in ways that fit within the constraints of the context in which the work is done.

Practice also implies the freedom of the practitioner to experiment, to find better ways of doing their work. This also means having the freedom to experiment when it produces negative results. As some costs and some outcomes may be unacceptable to stakeholders, this freedom, like all freedoms, is relative. Between acceptable and unacceptable boundaries for experimentation is the space where 'good' practice can develop. A mandatory behaviour is better referred to as a method, procedure or simply as a 'rule'.

[54] Events and Conditional Factors Analysis.

2.2 Values define practice as 'good', 'good enough', 'poor', or 'corrupt'.

The word 'good' implies values, and one of the issues about 'good' practice is that it is not always clear which values are promoted by a practice that is claimed to be 'good' (Everitt and Hardiker, 1996). As values are to some extent subjective, we should expect there to be some scope for disagreement about which values define 'good' practice and, even if there is consensus about that, differing views about their relative priority. Furthermore, if it useful to talk about practices as 'good', we may also find ourselves discussing practices that are 'good enough', 'poor' or, if they represent a betrayal of values, 'corrupt'.

Lewin (1946) notes that one cannot improve one's practice unless it is clear what one is trying to achieve.

> *"In a field that lacks objective standards of achievement, no learning can take place. If we cannot judge whether an action has led forward or backward if we have no criteria for evaluating the relation between effort and achievement, there is nothing to prevent us from making the wrong conclusions and to encourage the wrong work habits. Realistic fact-finding and evaluation is a prerequisite for any learning."*

(Lewin, 1946; p.35)

In an organisational setting, explicit criteria are also useful for monitoring quality, to ensure that goals are pursued consistently and standards maintained. However, not all values will be equally clear, or understood and valued by all stakeholders in the same way. Full consensus about what is good and about priorities, as Everitt (1996) points out, is unlikely.

A further complication is that an organisation's espoused values are not always identical to their implicit values (so-called 'values in use') that guide actual practice (Argyris and Schön, 1975). For example, an organisation might prize the scale and inclusiveness of its investigation programme whilst also valuing depth of investigation. However, with finite resources, an investigating organisation cannot maximise both the volume of incidents investigated and the depth of each investigation. According to some of the interviews with practitioners working in self-investigation programmes, volume usually wins in that setting. One interviewee stated that allowing enough time to investigate properly is a condition imposed by the business:

> *"Time is a critical resource in an investigation and, in commercial world, you will never get away from that completely."*

Therefore, the number of investigations is likely to be explicit and monitored, while depth is left implicit and unmanaged (which is what we have heard from interviewees working in organisations that conduct a high volume of investigations).

2.3 The overlap between the 'good' and 'best' practice concepts

In this paper, the term 'best' practice is put aside. Definitions vary, but 'best' practices are notionally "those that will lead to the superior performance of a company" (Camp, 1989; cited in Davies and Kochhar, 2002). In their extensive review, Wellstein and Kieser (2011) conclude that 'best practice' is "*a buzzword launched by consultants out of marketing* *purposes*" (page 686). Farrell (2002) echoes those remarks, and notes that there are types of organisation, such as standards bodies and software houses, that also use the term to advocate their products.

There is no consensus about the level of abstraction at which a 'best' practice can be described. A 'best' practice may sometimes be little more a stylised interpretation of practice, or even a philosophy (e.g. 'Lean Production', Womack et al., 1990), rather than a detailed description of practice observed in context. Wellstein and Kieser (2011) conclude that 'best' practices cannot be objectively identified, and the ability to transfer them between organisations is fundamentally contested.

There is no neat dividing line between the concepts of good practice and best practice. As overlapping terms, all the criticisms just made about 'best' practice may also apply to 'good' practice. Perhaps, because 'good' is a more modest claim than 'best', the criticisms apply to a lesser degree. However, the prudent advice is that each practice claimed to be good must be examined on its particular merits and compared to its goals.

2.4 Context and the objectification of practice

In the area of incident investigation, there has been a tendency to objectify practice; to 'distil' its essence and to 'bottle it' in tools and guidelines. Perhaps this is done in the interests of writing clear procedures. Perhaps combining the words 'good' and 'practice' conveys the idea that a way of doing something is intrinsically good, and therefore separable from the practitioner and the context. However, the effect of the distillation is to remove the contextual details that allow practitioners to assess the value and suitability of the practice. Wellstein and Kieser (2011) found attempts to transfer practices by stripping them of their original context to be "highly problematic" (p.692). Even if practitioners in a new setting, perfectly emulate a practice, it may not measure-up as 'good' using the yardsticks that apply in the new situation. We take it as axiomatic that 'good' practices are a function of their context and are good only to the extent that the constraints and values in the new context are shared with the old.

The NRI Foundation has acted both as poacher and gamekeeper of objectification. As gamekeeper, its board members have presented warnings in past ESReDA seminars that investigation tools "are servants not masters" (Frei, et al., 2003) and that practitioners should beware of "methodolatory", that is, of treating a tool or a method as universally applicable and intrinsically valuable (Kingston and Mertens, 2007). As a poacher, the Foundation maintains in the public domain a number of user manuals (e.g. MORT Tree Analysis, Events and Conditional Factors Analysis, Energy Trace and Barrier Analysis) but has not so far published any case studies that document how practitioners apply these methods. Wellstein and Kieser (2011) demonstrate that good documentation is not itself sufficient to achieve the transfer of a practice. Even so, as a necessary condition to sharing, it seems that writers need to do a better job—not merely documenting the activity of a practice, but also the salient aspects of context, including the viewpoint of the practitioners that enact it. In other words, the writer must understand why that particular practice works well in that environment.

2.5 'Good' practice: a cliché?

Any term used very often is in danger of becoming a cliché; the phrases *'good' and 'best' practice* are used a lot. A Google search returns 19.9 and 49.7 million hits, respectively. One of the properties of clichés is that sheer repetition deadens the critical sense of readers and listeners. Hence, rather than merely offending norms of literary style, some clichés may be rather more pernicious. In this case, the property of being a cliché makes it easier to have implicit claims to 'good' practice accepted uncritically.

Lifton (1961) argued that the regime in Maoist China used clichés as a means of mind control. He describes coining clichés as a process in which,

> *"The most far-reaching and complex of human problems are compressed into, brief, highly reductive, definitive-sounding phrases, easily memorised and easily expressed."*. (Lifton, 1961, p.429).

Lifton describes this kind of cliché as 'thought-terminating', and an example of language that is

> *"... prematurely abstract, highly categorical, relentlessly judging and to anyone but its most devoted advocate, deadly dull: in Lionel Trilling's phrase, "the language of non-thought."* (Ibid.).

Although the present authors do not argue for a different term (e.g. 'effective' practice), users of the term 'good' practice need to be alert to the ease of its abuse[55].

3. Practices in investigating and learning from incidents

This paper is about the capacity to investigate and learn from incidents. The present paper looks at capacity as a function of individual practices and social structures.

To ensure that the present authors and interviewees had a shared definition of incident investigation, the Kingston et al. (2006) description was used. According to that description, incident investigation is composed of 34 tasks. Taken as a whole, the list defines 'what' investigation is. The practices associated with these generic tasks comprise 'how' a practitioner investigates an incident.

Kingston et al. (2006) researched the list with investigation in mind, rather than learning from incidents. Nonetheless, some of the tasks mentioned appear to be implied in learning from incidents, according to their numbering: items (29) Develop remedial actions, (32) Debrief affected staff/others, and (33) Manage recommendations. For the purposes of this work, including briefing the interviewees, learning from an incident was defined as preventative change in at least one level—from individual learning to change of organisational policy and

[55] The term, '*lessons learned'* risk being another thought-terminating cliché in this area. One of the present authors (Kingston) witnessed recently a presentation in an organisation given by a member of its safety staff. One of the slides shown was titled "Familiar lessons learned from recent incidents".

strategy. Corrective action on its own was not considered as learning, because this kind of action is usually isolated in time and place.

3.1. Examples of 'good' practices of investigating incidents

Although the interviews were about capacity, some specific examples of 'good' practice were asked for to ensure that everyone was talking about the same subject. A selection is presented in **Table 4**, below. These were typically discussed in a fairly general way, more as goals than actions, but with enough familiarity to assure that the interviewees had detailed knowledge.

- Making shareable, reviewable models of the incident (e.g. ECFA+, STEP type descriptions).
- Reviewing the context of the investigation *during* the investigation.
- "Timeline is the bedrock, because it shows how conditions combine with events to produce the accident".
- Evidence must be accurate (e.g. actual heights, weights etc., measured by reliable, calibrated instruments).
- The 'chain of custody' must be maintained.
- Through discussion, the Health, Safety & Environment team decide their priorities for supporting specific investigations.
- Investigator's awareness of the context for victims and next of kin.
- Laser-scanning to quickly and accurately record positions (before the accident scene is disturbed).
- Actively managing stakeholders' expectations of an investigation.
- "Terms-of-reference serve two purposes. Inside your investigation is to steer your investigation. Outside your investigation is for them to have control in your investigation."
- Identify improvements needed in safety management.
- Identify the witnesses as early as possible.
- Review, by investigators and by stakeholders, is critical to self-investigation.

Table 4. Examples of investigative 'good' practices volunteered by interviewees

3.2. Examples of 'good' practices of learning from incidents

As with investigation, interviewees were asked for examples of 'good' practices for learning from incidents. A selection is presented in **Table 5**, below.

- Use of plain language in reports (because the boss may be non-technical, and the report may be read by others who are non-technical)
- Analyse events with similar outcomes because causation will differ (the danger is treating is treating 'similar' as the same)
- The rate of safety alerts can improve learning by giving the statistical picture (this is learning based on the mass of initial reports, not the final investigation outcomes).
- Reviewing the findings of an investigation at a meeting representing the different stakeholder groups, allowing each representative to identify the learning points.

Table 5. Examples of 'good' practices in learning from incidents

3.3. Examples of 'good' practices that overlap investigating and learning from incidents

Schreuder (2017), discussing the goals of investigation, points out that learning from an incident often competes with other goals, such as apportioning liability. Therefore, it is not safe to assume that all investigative 'good' practices will also be 'good' practices of learning from incidents—the interviews produced some examples of this:

- An interviewee from a regulatory agency: *"The aim of investigation is to improve safety; that's what they all say! The only goal? I have hundreds of goals here!"*
- An interviewee from an independent investigation body observed that *"If the people involved in an accident were involved in the investigation, they might learn a lot more than they would just by reading report. However, conflicts of interest exist."*
- An interviewee from an airline noted that aviation has a strong culture of *"findings must be fixed"*. Therefore, on the strength that recommendations reliably lead to actions, this appears to be 'good' practice with respect to learning from incidents. However, the interviewee pointed out some drawbacks both to investigation and to safety management more widely. The *"findings must be fixed"* culture encourages investigators to produce 'fixable findings' but not to take opportunities to understand the sources of the problem found. He saw *'finding must be fixed'* as a form of normalising deviance, and that it creates complex patchworks of fixes that may actually weaken control and resilience.

3.4. 'Good' depends on context

Only in some contexts are specific practices seen as 'good'. For example, in the UK, after suffering technical criticisms in prosecution cases, regulators have tightened their arrangements for chain-of-custody during investigations. Maintaining a chain of custody means securing and controlling access to material evidence in a way that demonstrates that the evidence is reliable and free from tampering. However, in all but the most serious self-investigation cases, maintaining a chain of custody is irrelevant.

Another example was given in respect of witness interviewing. One of the respondents interviewed by the present authors recounted an experience on an investigation training course for airline managers.

> *"I was in an interviewing session and the interviewee—the actor—was going to script but was going a little bit aggressive, and ... I thought: 'I am an airline investigator: if we're in the same airline, then I can't hold the interview to the point that it actually breaks down to a complete catastrophe'. He [the trainer] came back and said "you had the guy on the ropes" (those were [his] words with regards to this battery) "you should have gone in for the kill". And if I was an external investigator, and this is my only opportunity to speak to this person, then maybe I will 'go in for the kill', but if I'm in an airline, this person has got a day job and he is my colleague. Am I destroying them or am I educating them or am I trying to find the facts? So, I didn't get the same take as other people from all these things".*

3.5. Instrumental use of the phrase 'Good practice'

Some interviewees voiced caution about how the term ‘good practice’ is used, particularly because of the unsubstantiated claim to effectiveness. One interviewee voiced scepticism as follows—

> *“…we’re very good at that ‘cut and paste’ kind of approach to things here” […] “It usually involves—quite a lot of the time—involves cut and paste of some sort of documentation or some sort of report or whatever. But we’ve never had this means of coherently and consistently making judgements about whether whatever is presented is actually good. We don’t have any panels of experts to think about, pontificate over these examples.”*

Some of the interviewees mentioned that 'good' practice can sometimes refer to methods that are advocated externally or even imposed on investigators.

> *“The more skilled the investigator, the less dependent on a method. For a bad investigator, a method can help as a guideline, but it will not lead to a 'good' investigation and learning.”*

> *“In an investigation you never really know what the outcome will be. You make a plan and you have to be able to adjust that plan. That's a bit where those methods are against me, I do not like to force myself into a harness and those methods create a harness if you take [it] literally. To begin: You become very heavy. It impedes your freedom of movement. You often have such a flap for your eyes with such a harness. Your ears are often sealed and, if you have to urinate, it runs along your legs. That intrusiveness (of such harness) in an investigation is exactly the opposite of how you can come to learning.”*

The quotation is given in its entirety to preserve the parallel it draws between practitioner discretion and self-respect. For that interviewee, mandated investigation methods derogate, even vitiate, professional responsibility, and are counter-productive to the investigator’s role as a learning agent.

A wider point here is the underlying power balance between the practitioner’s discretion and their organisations’ priorities. As discussed earlier, the term *'good' practice* is redolent of practitioner-led empiricism. There will be occasions, as the ‘cut and paste’ scenario suggests, when this is misleading—perhaps intentionally. Practitioners are justified, even professionally bound, to treat claims of 'good' practice with scepticism. Later on, in section 7, this point will be returned to when discussing evaluation of practice.

4. Social Structures and 'good' practice

Mythen’s definition of social structures is paraphrased below; the phrase ‘individuals and their agency’ has been replaced by ‘practitioners and their discretion’.

Social structures are stable and enduring social institutions, organisations or arrangements that appear to exist independently of practitioners and their discretion.

Adapted from Mythen (2012)

We have argued that *practice* is discretionary. However, the practitioner's freedom of choice is relative, not absolute. Practitioners do not work in a social vacuum: they rely on the resources of others, chiefly those of their employers, and work towards achieving goals that are shared by other stakeholders, at least in part. Furthermore, how the practitioner can achieve these goals is constrained by numerous contextual factors. Therefore, to understand how 'good' practice might be better created, identified and shared, it is necessary to look at the social structures surrounding practice.

The present authors suggest that structures both limit and enable the development of 'good' practice. In principle, an investigation training course is designed to enable the practitioner. Similarly, a debrief with investigators might aim to identify potential 'good' practices and points to improve. The training course and the requirements for the debrief can both be considered as structures that enable practice. Conversely, investigators may be given limited time in which to conduct investigations, thus ruling out relatively time-consuming practices that might be otherwise valuable. Another example is adversarial juridical structures that rule out certain practices that might otherwise promote learning from an incident.

All of the examples just given are of structures with fairly direct impacts on 'good' practice. However, understanding structures that have indirect impacts may also offer insights into how to improve capacity through creating and sharing 'good' practices. For this reason, the present authors have adopted quite broad headings under which to consider social structures: lifelong learning, empiricism and cooperation between academics and practitioners. These broad categories overlap, but for clarity they are discussed separately.

5. Lifelong learning and the capacity to investigate and learn from incidents

Lifelong learning empowers individuals to contribute to the goals of the institutions in which they participate. This section looks at how lifelong learning contributes to the capacity to investigative and learn from incidents.

The aim of lifelong learning is defined by Eurostat (2016) as the

> *"Lifelong, voluntary and self-motivated pursuit of knowledge for personal or professional reasons. The overall aim of learning is to improve knowledge, skills and competencies".*

Various authoritative publications (e.g. UNESCO, 2010; Eurostat; and, the European Commission, 2012) define lifelong learning. In general, these agree that lifelong learning includes a range of formal, informal and non-formal learning. These terms are subject to various definitions, but Smith's is indicative:

> "*Formal education is linked with schools and training institutions; non-formal with community groups and other organizations; and informal covers what is left, e.g. interactions with friends, family and work colleagues."*

Smith (2008)

Smith's definition is helpful, but very coarse grained with respect to the structures at work in lifelong learning. It is convenient to think about learners attending courses offered by organisations, and then returning to their workplace more knowledgeable, competent, and skilled. But even if we thought of learners as robots to be programmed, rather than as practitioners with their own intentions and values, there are numerous steps between creating knowledge, running a course, and enacting behaviour in practice; as well as complexity throughout. It is questionable how structures like educational and training courses affect 'good' practice. There appear to be large discontinuities and assumptions.

5.1. Education and training structures aimed at competence in incident investigation

One example was given earlier (page 158) in respect of interviewing (*'you had him on the ropes'*). Colleagues in most workplaces can't pin each other 'on the ropes', not if they want to work together afterwards. Neither can law enforcers (in the UK) cross the line into oppressive interviewing, not if they want interview evidence accepted by the Courts. But the interesting thing about this example is that a university course advocated practice that would be 'poor', even 'corrupt', if applied in the work settings of the students for whom the course is intended.

Another example is drawn from the experience of the present authors. By 2002, one of the Competent Authorities, applied Events and Conditional Factors Analysis (ECFA+, Kingston and Koornneef, 2014) widely in their investigations of incidents on major hazards sites. Using ECFA+ was not a procedural requirement, but its inclusion in practice grew from a handful of inspectors to most of them. However, in 2003, on the basis of theoretical research it commissioned into investigation methods, the regulatory body in question mandated that <u>all</u> its inspectors must use ECFA+. Many inspectors in this widened group reported that they found the analysis a burdensome task that did little to help them secure the goals of their investigations. On reflection, although it was the same regulatory organisation, the investigative settings of its directorates were often dissimilar. The Competent Authority's process safety investigations often needed inspectors to describe long chains of cause and effect, and to find gaps in their understanding of how these were manifest in the engineered processes in which the incident occurred. Inspectors found ECFA+ to be helpful for this. However, inspectors investigating occupational safety accidents are often focussed on finding (enforceable) conditions that were thematically relevant to the accident, but not necessarily causal. For example, an up-to-date risk assessment might not have prevented the accident, but an out-of-date risk assessment is a breach of legally enforceable requirements. Applying ECFA+ adds little value to that, but takes time nonetheless. As with most organisations that conduct investigations, there was a corporate aspiration towards rationality, as exemplified by evidence-based policy-making. However, in this instance the evidence-base was at quite a high level of abstraction: theories of accident cause and general methods of accident investigation, rather than theories of regulatory investigation born from observation across a variety of regulatory investigative settings.

A third example is the UK police investigative interviewing course—PEACE.

The PEACE course was based on an earlier evaluation study of 400 videotaped police interviews with suspects. A training course based on that study was developed in 1992. This provided instruction on interviewing victims and witnesses as well as suspects. (How the content on witness and victim interviewing was developed is not described in the documents seen by the present authors). Clarke and Milne (2001) report that the course, intended for officers with 5-10 years experience, was held in such "high regard" that it was made available to all police officers from the mid-1990s. However, an evaluation study done in 1998 found only limited positive impact on practice. Nonetheless, by 2001, 70% of officers in England and Wales had been trained. Clarke and Milne's 2001 evaluation study also found disappointing results. Paradoxically, there is plenty of support for the PEACE model (e.g. Shawyer and Milne, 2015), and for PEACE training. However, the well-documented experience with PEACE shows that training alone is not enough to cultivate 'good' practice.

As well as opportunities for instruction, and to experience simulations, courses also serve as structures for lateral sharing of knowledge between the participants. The extent to which this happens in general is a moot point. However, speaking as trainers, the present authors note that promoting this aspect of knowledge sharing is expensive in time, unpredictable, and although appreciated by most learners, is not appreciated by all.

Interviewer: *"Did you feel there was scope for the students [of the investigation training course] to share their experiences about what works and what doesn't?"*

Respondent: *"No, not really. Actually, the debriefs were quite weak. After a two-day simulation I got a ten-minute debrief. And the ten-minute debrief was quite one-way from the course/simulation leader: What you 'might like to think about'... "when 'PC Plod' stood all over your evidence", or... "when you interviewed 'Mavis Whoever', you kept asking 'was it a white aeroplane,' instead of asking 'what colour was the aeroplane?'". But <u>not</u>: "What did you think about it all? or "Joe Bloggs, what did you think about it all?" Because, bearing in mind that those people have probably been investigating already elsewhere, they could not only have fed-back into the course content, but fed into all the other years of students in the classroom. They've definitely got the balance wrong there. And they always running behind, anyway. It's hard to keep those things on time."*

Proponents of lifelong learning urge formal and non-formal learning to "move away from the structured, directed, content-led implications of 'education' towards a more actively engaged process of 'learning'" (ETUI, 2009). However, whereas practitioners are adults, formal and non-formal learning structures seem often to apply design principles optimised to educating children. The countervailing philosophy is andragogy[56], which asserts that,

> *"adults should be involved in the learning process, must perceive a need to learn something, are oriented towards problem-focused and immediately valuable learning, and possess reservoirs of experiences– both successes and failures – that are resources for learning. Additionally, andragogy prioritizes adults' internal motivations to learn over external motivations."*
>
> Carpenter and Linton, 2018; p.57

If 'good' practice is shareable, then courses play a role. Courses create opportunities as well as providing instruction and experience via simulations. However, if they are relied upon as the main means of sharing 'good' practice, they are almost certain to disappoint. Education and training courses can do better—by better attention to context, and by creating opportunities for lateral sharing among practitioners and with teachers—but they are a limited means of increasing the capacity to investigate and learn from incidents.

5.2. Structures, learning-to-learn and the development of practice

If we accept that practice is defined as the way people do their work, then practice is to a great extent developed by the practitioners themselves. Therefore, we need to think about how they are enabled to develop their own practices as investigators and learners from incidents. To an extent, business as usual enables practitioners; they learn to investigate by doing investigations, and 'learn to learn' from incidents (e.g. how to spot trends, evaluate information, overcome defensiveness, influence colleagues, etc.). This can be very productive if there is freedom to experiment, opportunity to reflect and power to affect how resources are allocated. However, some practitioners will be better at this than others, and this is due to their competence as lifelong learners, and the structures that support/limit their capacity to learn.

Lifelong learning policies in Europe emphasises individual responsibility. In essence, these policies assume that you are in charge of your learning (Volles, 2016). However, formal structures (which tend to be associated with education and training organisations) can only partly fulfil the development of adults as lifelong learners, and only partially resource their learning from 'cradle to grave'. Therefore, there is a shortfall between the assumptions of lifelong learning and the extent to which it is provided for by formal structures.

Not everyone is equipped equally to learn throughout their working lives. Looking first at practitioners in organisations that investigate their own incidents; some of the time, these practitioners will be people in professional occupations. However, in many cases, practitioners are people who have achieved promotion in the operational parts of organisations. Even if maintaining their technical qualifications, such individuals may have

[56] *Androgogy*—leading adults, in contrast to *pedagogy*—leading children.

limited competence as lifelong learners with respect to underpinning investigating and learning from incidents. The present authors continually encounter examples in their work of men and women who seem to be marooned on an island of technical qualifications. Their core competence gets maintained (until promoted into senior managerial positions where even this is discontinued) while many analytical, creative and evaluative competencies remain relatively undeveloped. Creating 'good' practice in investigating and learning from incidents depends, it is contended, on these more general competencies[57]—competencies that are less developed by the lifelong learning experiences of operational staff. This is discussed further in section 7.

The problem of being 'marooned' on a lifelong learning island is part of a larger structural problem in lifelong learning. As Busccher et al. (2018) points out, "The new foundations of the 21st century depend on people who lack learning ability, and who are not able to adapt and become proficient in new insights and techniques." … "our production workers do not see themselves as professional managers and will not take to this as easily"…"Maybe they were never treated as a professionals." (Busccher et al., 2018; p14. *Translated from Dutch by the present authors*).

The present authors do not have objective data about the professional backgrounds of practitioners in independent investigation bodies and regulatory agencies. However, some of the respondents in our interviews were members of that population. Our impression is that, although they possess the educational background and attitude to learning that Busscher talks about, maintaining lifelong learning is not plain sailing for them. One of the interviewees, a professional investigator, mentioned a methodological reflection forum in which he participated. This was set-up with a university and allowed the investigators and academics to reflect on how investigations were done. Unfortunately, this stopped meeting after staff changes among the key staff who sponsored it. The respondent pointed out that this was one of the few routes he had to a wider world of learning beyond his organisation.

The forum mentioned by the respondent is an example of a kind of lifelong learning structure that the present authors feel is lacking. The closest term is *informal learning*. Whereas formal and non-formal learning are characterised by reliance on pre-established knowledge structures (e.g. text books, fixed syllabus, fixed instruments of verification and qualification) the knowledge structure of informal learning is situationally determined (Livingstone, 2006).

Smith explains:

> *"The key dimension, in many respects, is intention. Education is a conscious activity; learning isn't necessarily. People may not have a clear idea of the knowledge or skill they want to acquire, but they are committed to a process. This focus on intention in education allows us to explore different ways of organizing and articulating this. My own preference is to separate those approaches that depend upon the planning and*

[57] The present authors suggest that the list of competencies proposed by Nixon and Braithwaite (2018), although relating to investigators in the UK's Air Accidents Investigation Branch, would be relevant to practitioners of self-investigation. They list 19 general competencies, including: addressing development needs; awareness of bias; presentation skills; writing skills; empathy; evidence-led approach to investigation; imagination; leadership skills; objectivity of analysis; openness to discussion and challenge; organisational skills; self-insight; team working; understanding the organisational mandate; and, working to standards.

> *sequencing of learning (via something like a curriculum) and those that are essentially dialogical or conversational (and hence hold little prospect of pre-organizing if we to stay true to their nature). The former can be seen as formal, and the latter as informal, education.*
>
> Smith, 2008.

Nixon and Braithwaite (2018) recognise practitioner 'self-insight' and 'addressing development needs' as among the various competencies needed by (professional) investigators. They go on say that developing those and the other competencies they describe "can effect transition from the good to the great investigator" (p.160). Perhaps the evidence of the great investigator is that their practices are judged as good by all stakeholders.

The impression given by the interviews conducted is of unmet needs. Not specific, predictable, easily defined needs that might be met by formal or non-formal courses. Nobody, not even the practitioner, can predict exactly what they will need to know next week, or what scrap of recalled knowledge or chance conversation will suddenly be important in their work. The question is how uncertain, situationally-defined learning can be structurally supported.

Informal learning, unlike formal and non-formal learning, has "no sustained reference to an intentionally organized body of knowledge" (like a syllabus or textbook). It is characterised by learning situations that are "incidental and spontaneous […] such as acquiring job skills". Teachers and mentors may well be involved in informal learning situations, but when they are not, terms like "self-directed or collective informal learning" convey the idea that informal learning can be intentional. (Livingstone, 2006; 249).

The words "incidental and spontaneous" make it unsurprising that informal learning is a difficult matter for policy makers to get much traction on. It is excluded from EUROSTAT's reports about lifelong learning. Informal learning does not line-up easily with things that can be counted, such as the courses, hours, enrolments and other attributes of formal and informal learning. Nonetheless, Van Dam (2017; p.68) reports some statistics about informal learning in The Netherlands:

- "38 percent of people learn a lot or quite a lot by just doing their job."
- "18 percent of people learn nothing and 44 percent just learn a little bit by just doing their job."
- "People learn significantly less on the job after age 35."
- "Informal learning supports the development of competencies that are required in an existing role but don't prepare people for a very different role in the future."

According to the figures above, we should assume that the majority of practitioners are learning little, especially if they are aged 35 or over. Actually, for practitioners in self-investigation settings, matters may be worse than in the general case. First, their skills are less often practiced than those of the full-time investigators in the regulatory agencies and independent investigation bodies[58]. Second, as noted in the previous section, practitioners in the self-regulatory setting may at a further disadvantage if they happen to belong to the group that Busccher et al. (2018) claim “lack learning ability”. Therefore, if we wish the development of 'good' practice to be more vibrant with respect to investigating and learning from incidents informal learning seems to be the area to look at.

5.3. Lifelong Learning Structures: Summary

Practitioners create their practices. They operate at the interface between the working context (of investigating and learning from an incident) and the experience and resources they can call upon to innovate 'good' practice. Formal and non-formal learning appear to give impetus to developing practice, but have limited value as a direct ‘source’ of 'good' practice. Informal learning appears to be the main forum in which 'good' practice is developed and shared. However, the bias is towards formal and non-formal, and away from informal learning structures. The general picture is that only a minority of workers benefit from informal learning, and this depends in large part on their own competence as learners. It is argued that learning competence enables practitioners to innovate 'good' practice, to identify them and to share them with other practitioners.

As Ellis (1990) points out, formal, non-formal and informal learning do not have hard boundaries, it’s a question of finding the right blend for different learning needs. The impression formed in the interviews, and in conversation with practitioners more widely, is an unmet need for lifelong educational opportunities to which practitioners can bring their vast store of practitioner knowledge and particular issues they wish to explore. Rather than delivering a scholarly, one-size-fits-all product, these opportunities would see academics as educators enabling a learning process in which they and the practitioner were equal partners. For some academics this would mean a change of approach, and perhaps a change in how academic resources are funded.

6. Empiricism as a determinant of the capacity to investigate and learn from incidents

To summarise the discussion so far. The premise of this paper is that various structures support the development of 'good' practice and may hold the key to improving it. The first set of structures was grouped under the heading of lifelong learning. Within lifelong learning, informal learning appears to be of particular importance to developing and sharing 'good' practice. However, informal learning and learning ability seem relatively marginal as a resource in the lives of most workers, according to Dutch statistics. For the present purposes, informal learning is suggested as a useful source of challenges to the assumptions of formal and informal learning (e.g. the ‘blended’ approach mentioned earlier). However, informal

[58] *The situation with respect to practices for learning from incidents (rather than investigating them) may be different. Firstly, learning from incidents is a necessary function in the self-investigation setting, but not of the regulatory and independent setting. Secondly, the practices of learning from incidents may be shared with learning from events that are more frequent than safety incidents.*

learning remains rather intangible. As Livingstone (2006) puts it: "the various forms of informal learning "constitute the most elusive and shifting domains of adult learning".

In this section, the concept of ***empiricism*** to identify structures that support, or limit, the creation of 'good' practice. Empiricism describes the creation of knowledge through experiment and observation, and this is one way of looking at the creation of 'good' practices. There is a good deal of overlap between the concepts of empiricism and informal learning; central to both is the idea of learning from experience. Empiricism allows us to consider how 'good' practice is discovered by individuals, and by groups, at different levels of formality. These variations are discussed in the sub-sections that follow.

Overall, the interviews conducted for this paper, suggest that empiricism is mostly commonly experienced by practitioners working in a relatively isolated capacity, and rather less so when working as a group. This section will also indicate the scope for empiricism of a more systematic, scientific type, as this seems to happening very little in this field.

6.1. Empiricism and the individual practitioner

Earlier, practitioners were described as the *engines* of creative practice. By acting in context, practitioners find ways that meet goals while respecting the constraints of situations that are never twice exactly the same. One might even say that practitioners are profligate innovators, always experimenting. Whether doing an investigative task, like taking a photograph, or participating in a learning activity like taking part in a debrief, each new occasion brings new challenges and another opportunity to refine skills and try new approaches. When something new works, a 'good' practice is born. It might be very similar to the previous 'good enough' practice, but the new version has some advantage over the old. It is quite possible for this experimentation to happen 'wordlessly', beneath the level of conscious deliberation. This is a form of informal learning, as mentioned earlier, but focussed very much in the head of the individual practitioner. As Schön puts it,

> *"Practitioners themselves often reveal a capacity for reflection on their intuitive knowing in the midst of action and sometimes use this capacity to cope with the unique, uncertain, and conflicted situations of practice."*

(Schön, 1983; p.viii)

Reflecting 'in the midst of action' is a powerful means to improve practice. However, it is limited by competing with the work itself for the attention of the practitioner. However, the sheer volume of work experience must go some way to compensate for this. It is not for nothing that Schön (1983) placed so much emphasis on reflection-in-action. Rolfe (2014) notes that for 'wicked' problems that "resist and defy our attempts to formulate, tackle and resolve them" the dynamic, unrelenting quality of reflection-in-action has great strength.

6.1.1. Reflection and the practitioner

At the level of the individual practitioner, a number of assumptions of reflective practice are already visible. The first of these is opportunity, which means a conducive pace of work (i.e. not too fast) or time enough to permit reflection. Correspondingly, the first structure governs how time is allocated and work prioritised. Although most of the interviewees had large degrees of control over how they used their time, they all reported large workloads. Unless a task produced a surprise that demanded their reflection, very seldom would the practitioner make time for reflection after action.

At the level of the individual, reflection appears to involve several elements, chiefly: awareness of emotions, availability of data, awareness of values, an understanding that relates causes and effects (a 'causal model'), and the ability to reflect. All of these, visible in the Cambridge dictionary's straightforward definition of reflexivity, can be thought of as necessary conditions.

> *"The fact of someone being able to examine his or her own feelings, reactions, and motives (= reasons for acting) and how these influence what he or she does or thinks in a situation."*

Feelings are part of reflection, but can sometimes be a reason why practitioners do not reflect. As one of the interviewees describes it:

> *"I'm almost cringing at looking at the examples that have gone on with the different things. But why am I cringing? I should pick them up. Those are the things that I have to take through and say 'why are they cringe-worthy?' and, 'what don't I want to repeat from these things?', 'what am I trying to step away from?' Then I'm clear from that 'case study' that I don't ever want to be in this situation. Why? Because I want to be in this situation. Why? Because it does this for me. And it's played its benefit*."

Practitioners may also unwittingly sacrifice reflection to avoid dissonance. Argyris (1999) proposed that practitioners are strongly motivated to see their actions as always consistent with their espoused values. Skilled-unawareness is a psychological means that individuals use to cover-up inconsistencies from themselves. Arguably, adherents preserve their dogma (or more likely, the dogma that they have internalised) through skilled-unawareness, which enables them to overlook the misfit between the action supplied by the dogma and the needs of the situation to hand. As Young notes,

> *"reflexivity in any dogmatic culture always presents the possibility that the whole scheme of things will simply fall to pie*ces."

(Young, 1991; p.15)

Investigator's reflection-in-action is an engine for developing practice, whether 'good' or otherwise. When the pressure of work is very great, and inquiry is not rewarded, one would predict practice to develop towards fast and shallow investigation. In this respect, it is a species of Rasmussen's stop rule *"Keep investigating until you find a familiar cause to which you know the cure; then stop"* (Rasmussen, 1988). Whether to avoid dissonance, or simply in the rush to the meet deadlines, any conscious reflection on values is likely to be truncated. This also is empiricism: the practitioner is learning how to meet the demands of their work, and tacitly defining values like 'learning from incidents' in ways they can live with. Organisations that investigate large numbers (i.e. thousands per year) of incidents, tend to use categories against which frequencies are monitored. Coupled with high individual workloads, categorisation provides a simplification that can dominate the approach of both the investigator and those who are to be informed by the investigation.

> *"For example, if from experience we say it's a short landing, it starts now to have hints of an unstable approach, all of a sudden it doesn't matter what really happened in the event, it starts to become an unstable [approach] and then gets labelled as 'the unstable approach into…' but then all the other elements of the investigation are lost. […] But that is one of the points, post-investigation, as part of that debrief of the event, with the inquisitive mind, you [the manager receiving the input from the investigator] should be looking at from a different perspective. Yes, you want to hear the story, but you should be then relating it back to your organisation as a whole. And also, the investigation process as whole, appreciating that it has its limitations, and questioning where it could have been stronger. But that doesn't happen. Once we talk 'unstable approach' we then focus in the learning bit on 'unstable approach'. That's where we live."*

Unless actively opposed, structural constraints such as high workload, short deadlines, and cultures that prize action over inquiry, will drive investigative practice away from reaching goals such as learning from incidents. Disabling reflective practice means more than stalling the creation of 'good' practice, it may also make it harder to avoid the corruption[59] of practice.

6.1.2. Reflection through review and debrief

So far, the discussion has focused on practitioners reflecting in isolation. However, reflection on practice by groups offers obvious possibilities for sharing practices. In the interviews, debrief and review were the overt activities most associated with reflection. What came through the interviews was that these activities often had a dual focus: on the goals of investigating the incident and the goals of learning from the incident.

> *"[There are more or less obvious things that an investigation will pick up] that were directly linked to the event itself. But if you are clear on what investigation brings to the table, about what part it plays in your overall management of safety/risk management system, you should then also be taking a system view of it: as in has it performed? Has it [the investigation] given you what you want it to give you as a process? So, as well as the event, and working out why the [risk management system] didn't pick up this issue, you have also got to take it back to the matter of how to improve the investigation process itself […] as a result of what has come out of this. There are two strands to the learning."*

If combined into one activity, there appears to be a focus on the content issues (the incident) at the expense of discussing how the investigation was done. One of the differences between self-investigations and those by independent investigation bodies and regulators, is the extent

[59] The word 'corruption' is harsh, and tends to be reserved for deliberate wrongdoing, dishonesty, and the like. However, as Wardhough and Wilding (1993) argue, corruption is a justifiable term for conduct that betrays values. What should we call it when an organisation has the espoused value to learn from incidents, but enacts structural constraints that systematically reduce the scope and depth of learning?

and frequencies of review during the conduct of the investigation. In self-investigation, review is a limited managerial resource allocated on the basis of the safety risk, and more often, actual consequences of the incident being investigated. This is sometimes manifest in the presence of *terms-of-reference* for the investigation; a common practice for investigation of 'serious' events, but uncommon for anything 'less' serious.

> *"If you look at an internal investigation, it [a terms of reference] would only be needed if otherwise you would not get those results [the right questions answered in the right way]. So, it is good to use them [terms of reference] for reflection and what I still want to do, although in the SHE management team they did not continue with that but I want to use them internally and have some reflection. These people sometimes ask '[are] we doing the right things?' So more afterwards using [terms of reference]: "OK this is what we could get out of incident investigation. Do we get it out of it? If not, are we doing something wrong?" That might be a more feasible, I'm not saying better use, but more feasible to use in that way than to say: hey guys, make up your terms of reference."*

The issue is how to engage reflection on an investigation in a timely way that does not interfere with reflection on the findings about the incident. If only done in serious (and therefore relatively infrequent) cases, the effect on practice is likely to be slight, and secondary to discussing the safety implications of the serious incident.

Still on the subject of self-investigation, an interviewee contrasts the duty of an accountable manager (in whose activities the incident happened) with those of the safety manager.

> *"The accountable manager has got a duty to take a holistic view, balancing the business interests with a whole load of other things. The person responsible for the production or the activity should have the system view in terms of 'how does this fit into the system, how does this help me make sure everything is working?', whereas, the safety manager is trying to make [it] that the investigation that's just occurred followed the right sort of process […], and that the organisation has taken it into consideration, but also [to ask] 'does the investigation process itself need to learn from this event?' The intent in the way we've set ourselves up is that the 'safety manager'—that's [a function] made up of an individual and several other individuals—should be looking after those processes and making sure that they continuously improve.*

In the work setting, the dual focus appears to be hard to sustain, when specific incidents are discussed, safety lessons have the priority over investigation improvement. Schreuder (2017) also found a paradoxical relationship between perceptions of these goals. In his study, practitioners identified learning from incidents as the main goal of safety investigation in their company, "yet, not a single evaluation criterion was proposed for this goal" (Schreuder, 2017; p.29). Whatever the reasons, the goals of learning safety lessons and learning investigation lessons are difficult to achieve in the same review or debrief.

6.2. The Case for Case Studies

Several interviewees mentioned case studies as a missing ingredient from empiricism in their organisations. However, they saw it as an asset to assist in the sharing of knowledge.

"It is more the power of the case study for me, really." ... "For me it was how you share the experiences and then also key with whom you share those experiences." ... "If I can talk to someone like [colleague's name], who understands what I'm saying, give him the practical example and he sees it and now he can make the relation, then he can go and interpret [for] them: he can go in and give the message better in the language [of his department]. He can translate it much more effectively. I need him to understand what it is I'm trying to achieve by it, but then he's better equipped to make or help his community understand it in those terms. So, it was about how information's cascaded and how learning is actually [done]."

"I think that's the key— being able to say what makes this good, because if you have that sort of statement this is good because it does "duh, duh, duh, duh, duh," it does this and then it does it this way and it does it with minimal whatever. If you can make those sort of statements then it becomes a bit…it lives a little bit more for people." ... "And so, I still come back to my view which is that you don't say whether something is 'good' practice or 'bad' practice, what you say is this is how we do it here. And […] our experience is positive in the sense that ..."

"[…] you were asked to write a 'no more than three hundred words' example of a piece of work that you'd done that was challenging; and in this three hundred words you've got to say what the challenge is, you've got to say what you did, how you overcame those challenges, whether you had any success, [and] if you didn't, what you did to re-correct, and what the ultimate outcome was. Now, actually, for some of the things we did, three hundred words is nothing for the complexity of some of these things. But invariably what I found was […] that there was very little how and a great deal of what. And, at the end of the day, that's because it's the what that the organisation values. They don't care about how you do it, as long as you get the result that they're looking for. […] but I think what it was really about, I suppose, is the 'how'; it's less about the how you did it but more about how you did it bearing in mind the constraints that you felt existed or perceived. […] And I think that's the piece [about context] that often gets missed in the example. So, because people haven't said the constraints, they were under, that's at least fifty per cent of the context, maybe more, so when you then see that example of good practice, your constraints are different. They will always be different and so does it look that good to you? Well maybe not. Or maybe your constraints are significantly more [limiting].

Practitioners can see great potential in case studies, but appear uncertain about how to create them and are daunted by the work they suspect may be entailed.

"But there's a lot of effort that would have to go into that and therefore I think people are less [likely to document it]—unless they're tremendously committed to doing that and doing that well. [That's why] it probably doesn't get done well, and so therefore you end up with something that is less than it should be."

But 'case study' sounds LONG. If I'm honest, I think when I first used to hear it being mentioned I did not know how it would be applied. And I'd hear my colleagues say it and I'd think 'they're saying 'case study' and they want to do a case study', and they've produced what the case study is: here's an investigation that was done. What was missed? What could have been done better? [But] ... what <u>are</u> we doing? We look like we're criticising someone's work." ... "But I think the use of case studies, as silly as it sounds or as ironic as it sounds, is you need a good example of how a case study's been used to solve a case study approach."

The use of case studies seems to be a tangible, untapped potential for communicating about 'good' practice.

Related to case studies, in the sense of documented 'practices' is an idea mentioned by one of the interviewees. The suggestion was for descriptions of practice accompanied by 'Amazon' style reviews. The interviewee described how a Sharepoint area was set up by a group of regulatory agencies.

"They could upload examples of good practice. So that might be a campaign that they'd run or it might be prosecution they'd taken or it might be some research that had been undertaken, or whatever it was it might have been some sort of local guidance that they produced for distribution centres or restaurants or whatever it was. And we would ask them to upload it. And the idea was that then there would be a panel of experts [from the regulatory agencies] who would then make some judgements about how good this good practice was. And those judgements would also be about what was it really demonstrating. Was it demonstrating, 'yes, this is a good example of a campaign', or is it a demonstration of 'this is a great way of communicating', and 'this is an example of how to communicate with a particular niche audience', or whatever it might be. Because there's different ways of looking at those. [...] Getting people together to think about those sort of things at the same time was tricky because if you're dispersed and remotely located you look at it as an individual and I think there's a value in looking at it as a group, and having that dialogue between the members of that group. Because I think you probably approach a greater proximity to the truth. But we found that very difficult [...] to do that, to be perfectly honest. And just getting people to assign the time and commit to doing that became very difficult. So we ended up going down the lines of 'actually, do you know what, sod it, why don't we just do like Amazon?' And we gave people the possibility of scoring up to five stars for whatever gets produced. And writing a short text piece about why they think it is so good or so bad or so mundane or ordinary or whatever it is, but it would give them that opportunity, and then give other people the opportunity to read those reviews. [...] I think the key thing is the currency of those reviews. The thing you don't have any control over is the expertise, how insightful the person making the review is. To some extent that risk is offset by the quality of the text that you ask them to add, so if somebody's marked something five stars out of five and then look at the text and it's gibberish you might think well maybe this person hasn't actually got the judgement skills after all. And I think the individually poor reviews—I don't [mean] bad reviews, but poorly written or poorly thought-through reviews—the [...] sheer number of the reviews starts to reduce the impact of the poor nature of some of the reviews."

6.3. Continuous improvement and learning from incidents

One of the fundamental tenets of empiricism, according to Shelley (2006) is that "knowledge is tentative" and therefore subject to continual revision[60].

Some of the interviewees, recognising that shifting priorities are normal their organisation, mentioned the importance of an explicit strategic approach to improvement. A strategic view accepts that current practice is usually something less effective than the ideal, but that it is improving along defined lines. In this way, a strategy provides a structure that helps to secure a set of values within which practice can be assessed. As one of the interviewees explains:

> *"The 'Safety Plan' should be supporting and endorsing our future, where we're going, so when someone at whatever level in the company asks the question you say to them 'this is what we're doing about the here and now', 'here's all the effort and activity'; 'the things that you're paying for us to do today'; 'you may not be with the company in ten years, but you want to hand over something responsible, and this is what we've outlined for the next few years, and we can even tell you next year how much we intend to spend and where we intend to go with it'; 'from what you're seeing, is that right'? Then you can have a management conversation where they'll say to you 'can we look at this in year two?', 'push that down to year four'. And then at least you're aligned with company thinking and you can work those things, and then they can see that if you've got some innovation you can test it. You can bring it forward, innovate and test with [a specific operational department] but the plan will say it will be in the organisation in 2020. And I think people can live with that. As long as you show material movement, but you don't have to do it across the board. So it's also from the practitioners point of view, it's what am I doing with this monster of information you're giving me. And the practitioner needs to be in a position on how do you implement such new methodologies and new approaches, and that sort of thing.*

It was noted that most of the recommendations in the evaluation of PEACE interview training were for implementing structures outside of the classroom. In respect of supervision, they recommended:

> "*... that a Nationally agreed policy on the supervision of interviews be developed. This should include (i) that interviewing and communication skills be an integral element of annual appraisals for all staff, (ii) that the priority be attributed to supervision by the service, and (iii) that subordinates' performance become a criterion in the annual appraisals for all supervisors and managers."*

Clarke and Milne, 2001; p.97-120

In one way, it is perfectly clear that implementation involves creating structures that sustain activities at every level of an organisation. However, what appears to be widespread in investigation and lesson-learning is piecemeal, hesitant managerial attention on high level

[60] As the French say: *"Il n'y a que le provisoire qui dure"* (only that which is provisional endures).

policy ambitions. Meanwhile, for better or worse, practice evolves a long its own lines according to local goals and constraints.

6.4. Mentoring and coaching practitioners

The interviews were not designed to specifically look into structures that enable peers to learn from each other. It is likely that these are relevant in the development and sharing of practice.

In the experience of the present authors, practitioners help each other on an ad hoc basis, and through informal 'shadowing' arrangements. However, in some organisations, practitioners are spread quite thinly across several locations. In examples of those organisations, we have seen attempts to set up structures where practitioners pair-up for key tasks like interviewing and analysis, and act as critical friends providing reviews of reports.

The interviewees did shed some light on how safety departments involve themselves during investigations.

> *"...So, I think they had the right qualities in the sense that they were very approachable. People respected them. People understood where they were coming from and they gained that respect through good intervention in the past. So that's what their reputation was built on. And they were also proactive, so they would hear about an incident and actually: 'do you know what, that's down on despatch again. We've had three in despatch in the last six months; I'm going to go down there'. And so they would be very active in that way. But it was very ad hoc, which is not necessarily a bad thing. [...] But what that also meant was it was also related to just how stretched they were, and so it was always a balance between yes I should go to despatch but actually I've got all of this other stuff to do, or actually no, this is a more serious event at despatch after we've had three less serious ones, and despite all of those other pressures this is actually taking priority. So exercising that judgement is what they would do. Now the way they would do that, and this was the maturity of the team, is they would discuss it amongst themselves. So it wasn't just a decision of the [Health, Safety & Environment] manager or them as individuals, they would discuss it amongst themselves and they would come to some sort of alignment or consensus. So I think that's how good [Health, Safety & Environment] team works and functions. It doesn't come down to the decision of an individual. There is that maturity about 'well let's see what all our views are on this and where this sits in our overall or ever lengthening list of priorities that we have'. So I think that was a good thing and I suppose you could say that is a good practice.*

Interviewer: *So how does it start?*

Respondent: *"[...] my boss helps me: 'We have a situation here and we'd like to look more into it. Could we get more deep into it?' So not: 'it's all wrong!', but 'there's an interesting situation and we need to learn from it as a business group and not [only] as a site, can you help us with that?' And then we dig into that and then you start talking with the site manager: 'what do you* *think of it?', 'who's the best guy that can help me with this because it's rather complex?' So he [the site manager] knows that he needs to do something there because I'm not there just for fun. So getting the team together with him. And I know these people, and I know who are the good ones. You get the good people to work with you and they already know it. They just have to tell you. So it was wrong, but we need to learn. And we go into this and tell me what it is and during the process you get feedback, and every evening you walk by the site manager: 'so we are <u>here</u> and we are learning <u>this</u>, and did you know that <u>this guy</u> knows a lot about the process, and what we learn <u>here</u> that's new, and this and that'. And most of the time not always all is new for the site manager, but he's very happy to learn what you all learnt in here. Getting insight together."*

Interviewer: "[So, a very light] vertical exercise of power – there's a little bit because you're saying [to the site]: 'we're interested, and we have a right to be interested'.

Respondent: "You have the right to be supported"!

Interviewer: "Very good [laughs]. It seems remarkably diplomatic".

Respondent: "To be honest, it doesn't always work".

Interviewer: "What happens when it doesn't work"?

Respondent: "When it doesn't work then people are really defensive."

The interviewee went on to explain that once practitioners are defensive, only very limited progress can be made. The interaction becomes an exercise in limiting the damage to the relationship. As another of the interviewees suggested, if an organisation wishes to contribute to the lifelong learning of the workforce, it may first need to create shared understandings about defensiveness and face-saving, as these are fundamental obstacles. Van Dam (2016), citing the work of Dweck, makes similar comments. He advocates Kegan and Lahey's model of the 'Deliberately Developmental Organization' as a means to normalise the ideals of lifelong learning for all workers in an organisation.

6.5. Post-investigation critical review of investigation practice

Interviewees mentioned critical reflection on investigation practices. These, however, need to be specially organised and resourced. One of the respondents—a board member of an independent investigation body and a professor in a university department—explained that,

"He [Adrianus De Groot) introduced the idea of a Forum as the regulative mechanism of the normal scientific process. In the context of scientific work this Forum is an abstract that relates to all kinds of evaluation and feedback in the academic world. That is normal. But applying scientific procedures/methods outside the world of

research thus not give immediately a critical context. You have to organize that yourself." … "and I could practise it because of my position [in a University]"

However, these apparently technical concerns appear often to be connected to power relationships and imbalances. The interviewees from independent and regulatory investigative backgrounds mentioned a structural lack of critical self-reflection on methodology.

One interviewee described a situation in which a regulatory body was not willing to meet with a defence lawyer despite his repeated offers to give them insights (gained though some 60 incidents) into the recurring weaknesses of their prosecution cases.

Equally, and perhaps surprisingly in the case of regulatory agencies, respondents mentioned a lack of criticism from outside. In the words of three interviewees:

"Even in the press there is no critical voice! [The investigation body's] insights and statements are sacrosanct!"… "In a democracy a permanent discussion on the value of an insight must be possible – it is essential."

"Professional investigation bodies never hear criticism, it falls on deaf ears."

"[This investigation body is seen as] whiter than white".

In the self-investigation setting, a lack of critical reflection can be driven by various forces, and not straightforwardly positional power[61]. One of our interviewees explained a dynamic in his organisation which he attributed to carrying-out actions identified after audits and investigations. These actions might be identified at one location but then required at all comparable locations throughout the company. The speed to implement actions has become a KPI for managers. As one might anticipate, managers have found ways to report actions as completed that might, in fact, be only at the planning stage or implemented only partly. In any event, this has created a culture in which:

"Senior leaders think that everything can […] be done that quickly, so their assumption is that whatever goes in there will be done within a quarter [of an hour]. So, their expectation has grown. We haven't managed that very well at all. And then woe betide you if you are that sort of person who turns around and says 'no, I'm not going to play this game', because then the full furore of the organisation is focused on you"

This creates a double-bind that is corrupting of practice: a belief amongst senior managers that all problems can be cured quickly by simple actions, and an intolerance of information to the contrary. Critical review has no place in this scheme, and such contradictory data have to be explained-away as exceptions.

[61] *Charles Handy (1981, Understanding Organisations) identifies six sources of individual power: (1) Physical ('might is right'), (2) Resource, (3) Position (such as the legal authority to do certain things), (4) Expert, (5) Personal (charisma) and (6) Negative (any of the first five powers used in an abusive way to stop or delay things, or to distort them).*

6.6. Systematic study of 'good' practice.

The foregoing sub-sections have been presented in order of formality. It started with the individual practitioner learning from experience in relative isolation from their peers. In this sub-section, empiricism is considered in terms of attempts to identify 'good' practice through research activities.

What constitutes a research activity is a moot point. However, the present authors were very broad. Any activity aimed at finding out how some practitioners do some aspect of investigating or learning from incidents, would have qualified. Then inquiries could be made about the aims of the research, its results and so forth. The first point to make is that among the organisations contacted, admittedly a very small sample, we heard of no examples. (The next section considers the motivations of practitioners towards this kind of research).

Assuming that there is little research going on into 'good' practice of investigating and learning, we need to ask whether there a need for it. What kinds of knowledge might be useful to practitioners, investigating organisations and investigation stakeholders? Looking back over the issues discussed in this paper, research into 'good' practice of investigation and learning could aim to:

- stimulate practitioners' development by identifying current 'good' practices elsewhere;
- inform competence by identifying knowledge underpinning 'good' practice as observed in the field;
- manage better the conditions found to drive 'corrupt' practice;
- specify structures needed to develop practice "in the direction of the good[62]";
- challenge current ideas by identifying 'good' practices in investigation that constitute 'poor' practices for learning from incidents;
- identify values held by stakeholders that are not currently reflected in practice;
- discover the contextual criteria that qualify or limit a 'good' practice;
- stimulate research into practices that will better fulfil goals and constraints that are currently met poorly;
- in general, improve selection, training and management of practitioners.

Turning to the form of research, if 'good' practice is 'what works' we have to ask about the criteria for judging success, what evidence is used, and who gets to judge. It is also necessary to think about the method for doing this kind of work. It brings to mind the start of Feynman's famous commencement address on joining Caltech as a professor:

> *"During the Middle Ages there were all kinds of crazy ideas, such as that a piece of rhinoceros horn would increase potency. [...] Then a method was discovered for separating the ideas which was to try one to see if it worked, and if it didn't work, to eliminate it. This method became organized, of course, into science."*

Feynman, 1974; p.10

[62] (Everitt and Hardiker, 1996; p.171)

A scientific approach, in the Feynman sense, certainly has a role here, but it is not assumed that science is the only approach that is helpful, or that there is only one valid scientific paradigm in which to assess 'good' practice.

Given that value comes supplied in the term 'good' practice, evaluation research clearly applies. As well as medicine, evaluation is frequently used in public services, but appears to be largely unused in the field of investigating and learning from safety incidents, in either public or private organisations. The current authors are not aware of any reasons for this (beyond the general ones given by Niven, 2004).

If evaluation research were to be made use of in this area, we should be careful to avoid some its traps, both paradigmatic and political. Discussions of evaluation research often rehearse the long-standing debate between a realist/positivist standpoint—that reliable knowledge can only come from objective observation of physical reality—and a social constructionist/relativist standpoint which maintains that "foundations and knowledge are value-laden, and, contra positive realism, that the distinction between objective and subjective knowledge is unclear" (Marks, 2002; p14). In an area where context, values and the practitioner are often of decisive importance to any claim of efficacy, an extreme realist position looks unfeasible. It may only be tenable only for evaluating some aspects of handling and analysing physical evidence, but not much else. Even in areas that have more scope for them, such as medicine, advocates of positivistic approaches (e.g. randomised controlled trials—RCTs) recognise that practitioners should be empowered by their expertise. For example,

> *"Good doctors use both individual clinical expertise and the best available external evidence, and neither alone is enough. Without clinical expertise, practice risks becoming tyrannised by evidence, for even excellent external evidence may be inapplicable to or inappropriate for an individual patient. Without current best evidence, practice risks becoming rapidly out of date, to the detriment of patients."*
>
> Sackett, et al., 1996; p71.

Similarly, in their most recent guidance from the UK's National Institute for Health and Care Excellence (NICE) distinguishes between 'context-free' and 'context-sensitive' scientific evidence, and states that these may be complemented by what it calls "colloquial evidence: including "evidence about values (including political judgement), practical considerations (resources, professional experience or expertise and habits or traditions) and the interests of specific groups (views of lobbyists and pressure groups)". (NICE, 2012)

The general aim of evaluation is to identify 'good' practices, and in order to do so, make explicit the values that define good. As stated earlier (Section 2.2) there may be a variety of views about what constitutes 'good'. Everitt and Hardiker (1996) is a notable attempt to apply evaluation to identifying and sharing 'good' practice in social work. However, most of their arguments and much of their advice appears to be applicable more widely. They list seven principles "which any evaluation system should adopt to ensure 'good' practice". These are:

- *"the importance of moral debate and everybody, irrespective of power, status and position, having the right to legitimate opinions;*

- *scepticism of rational-technical modes of practice;*
- *the recognition of power, powerlessness and empowerment;*
- *the development of genuine dialogue between users and those within the organisation, and within the organisation itself;*
- *attention to be paid to the fundamental purpose of the organisation and caution about becoming diverted into demonstrating productivity;*
- *the encouragement of openness, questioning, complaints and criticisms from outside and within the organisation;*
- *the removal of 'otherness' that may be attributed to those lower in the hierarchy, to users and to those relatively powerless in the community."*

Everitt and Hardiker, 1996; p.35

Evaluation research tends to be done by social scientists for organisations as a means for the latter to demonstrate (e.g. to funders) that their goals are being achieved as advertised. Everitt and Hardicker (1996) recognise this summative aim, but have suggested that it can be shared with formative purpose. However, if we make that formative goal central to the research, other research approaches start to suggest themselves. Among these options are various forms of 'action research'. These will be discussed in the next section.

6.7. Structures that support empiricism: Summary

Everitt and Hardicker's principle of the "encouragement of openness, questioning, complaints and criticisms" echoes a theme in many of the interviews. Usually, this was demonstrated by negative examples: stories of individuals being defensive, senior managers that accept only 'successes, and professional investigation bodies content to 'rest on their laurels'. However, the principle stands—the readiness to learn has to be encouraged and led.

Lack of time/work pressure is an issue. While useful to motivate productivity on certain operational tasks, when learning how to improve safety, pressure of work is inimical to 'good' investigative practice and its development. However, even without these pressures, there needs to be a structural gradient that influences practice in the direction of the 'good'. Supervision, mentoring, peer-review need to have values defined in a meaningful way, such as though plans and strategies that show how the ideals of policy are being pursued.

Debriefs and reviews are opportunities to discover 'good' practice. These need to be planned for and resourced. Furthermore, as learning about safety and learning about investigation may be difficult to combine, separate arrangements may be needed.

There is an argument that investigating organisations need to be more 'research-minded', valuing more the 'how' things are done and not just the outcome of doing them. As well as debriefs and reviews, the 'how' could be made more visible though case-studies. How to document case studies is a moot point, and itself a research need. One possibility, more to complement case studies than as an alternative, is computer supported collaborative review of documented practice experiences.

An underlying theme in this section has been the relative weight attached to knowledge created from practice compared to that created from a positivist interpretation of scientific method. As Rolfe (2002) pointed out, *"If you apply the criteria of positivism to reflective practice, then it deserves to be at the bottom of the hierarchy of evidence, just as if you apply the criteria of reflective practice to positivism, then the RCT will be at the bottom."* This distortion in our views of what works can be compounded by scientific evaluations in which 'good' is defined unilaterally by a powerful group. If evaluations are to be used more in this area, then these are traps to avoid.

7. Cooperation between practitioners and academics as a factor of the capacity to investigate and learn from incidents

This section presents some views of the current situation and the potential benefits of closer cooperation between academics and practitioners. Many of the issues described in this paper—the obstacles to 'good' practice alluded to in the call for papers—could be addressed, at least in part, by better cooperation between academics and practitioners.

'*Could be addressed'* is the point, because the interviews revealed so few examples of close cooperation. During the research, the authors have asked themselves whether they are in the position of the person who emerges from the Ironmonger's shop disappointed by the lack of pork pies for sale. The Ironmonger *could* start selling food, but, in general, ironmongers do not. We have often asked ourselves if we are making a category error. However, whereas the hungry shopper can find satisfaction elsewhere, the choices for the needy practitioner appear to be quite limited. The nearest option seems to be consultancies—these have their place and serve well some needs. However, cooperation on 'good' practice seems to require the objective research, and educative skills of the academic, rather than the sectoral subject matter expertise of consultants.

7.1. Definitions of 'cooperation' and an 'academic'

Based on the Wordnik dictionary entry, *cooperation* could be defined as: active help from a person or organisation involving the orderly sharing of resources which are mutually beneficial. For reasons, which will be explained, the present authors suggest that the word *meaningful* needs to be added in there somewhere.

While on the subject of definitions, an *academic*—for the purposes of this paper—is a scholar who is most likely working at an educational institution, where they have the overlapping roles of educator and researcher, mixed in various proportions.

7.2. Practitioners' expectations of cooperation with academics

The practitioners interviewed during the research for this paper expressed views about cooperation with academics that, for the most part, were close to those expressed by Schön twenty-six years ago.

> *"There has been, on the one hand, an erosion of practitioners' faith in the ability of academic research to deliver knowledge usable for solving social problems-indeed, a growing suspicion that academic research may actually exacerbate social problems. In*

this sense, practitioners may feel, in relation to the academy, a sense of having been seduced and abandoned. On the other hand, when practitioners accept and try to use the academy's esoteric knowledge, they are apt to discover that its appropriation alienates them from their own understandings, engendering a loss of their sense of competence and control."

Schön, 1992; p.120

A selection of illustrative quotations gives a flavour of the responses, including one from a practitioner who recounts a master's degree project that gave him insight from the academic 'side of the fence'. (Most of the interviewees had post-graduate qualifications).

"The practitioner will look at the scientist and say, 'all that nice data you're collecting, how is it actually helping this situation?' And the scientist says:' this is the basis of science: we need baseline information;' 'we need to be able to…'. They've got the whole reasoning around their activity. And it's probably lost in how each of the parties will use what actually comes out of their interactions. And I've met some really clever people trying to do some things, and half of me says 'we've got a responsibility to feed this sort of activity because otherwise where will it be done?'"

"We went to [the academic] and we were saying 'we'll pay for him to give human factors briefing to the senior managers within […]' and he produced a whole ream of slides. And we said 'what are you going to do?', and he says 'I'm going to talk to the slides'. Well, no; hang on! 'We're giving you access to our senior management and you want to take them through some sixty slides?' […]. So the expectations of the two worlds were [quite different]."

"Anywhere I've worked in aviation, other than at […], there has never been any kind of direction [towards]: 'I think we should get some academic help here'. Other than at […], and I suspect that was only because of [a senior manager], and I think his reasoning was 'I want to make sure that I am bullet-proof in court'. But looking anywhere else across aviation, no links at all.

"[concerning an industry group set up by a regulatory agency] academics used to visit that group. They'd typically be PhD students who had finished or were coming close to finishing their PhDs. [I'd characterise it as] here's something you might want to use, boys. 'I've created this method; I've created this way of thinking. It would be two-way: 10 minutes to present something, then questions at the end.

"It was hard to get access to the organisation and the data. Two reasons really. Most organisations didn't really seem interested or see the point. And secondly because they were worried about where the data might end up; in what form it might be in the public domain. It was about a predictive tool, […] for predicting maintenance error. I compared the areas that were predicted to have problems in, with the areas they were actually having problems in. In terms of working with industry, it was quite hard. I went

into to 2 or 3 organisations, it was hard. None of them saw any benefit in it. It was an arduous task to get [their] time. And then there was the data issue: they were really frightened where the data was going to be used. They were very, very cautious about that."

"So, when [the Regulatory Agency] put out the call, all these organisations started trying to put together cases to get funding. [The company] are experts at doing this, to try and secure funding from [the Agency]. And in essence their R&D part of their business is funded for a bit. Even then, when they put out these 'what do you think about what we want to do here?', and 'what we're looking at', in many ways they're not really clear on the end game. They've kind of got like 'I want to look into an airport and an airline interface and it needs looking [at]'; I agree, but then to what end?"

"And sometimes I think the conversation [is not] clear. Maybe it is that element of politeness when they first come together. So, this lady at [...]—who's now at [University]—heard we were interested in MOSS, which is a version of LOSA used in maintenance. We said we were interested. She said she's done it with [an airline]. All of a sudden, we were both excited: from her point of view, [a large airline] is interested; for us, someone's done it. And we're really excited, to the point that we formed an agreement off being excited about the same subject [up] to the point that when we started getting into actually 'what are you going to do?', 'how are you going to help us get this going?' [and] to her then saying 'what are you going to give me access to?' Then it started not looking good; we were not on the same page. Although there was common interest, I don't think the expectation was explicitly laid out. [...] And I think anyone that's doing a PhD or a Masters and they want to approach an airline in particular, I think just being aware of some of these things – I don't think it's exclusive to an airline, and [applies] maybe to some other industries, I don't know."

"But working with the likes of [University] it is a little bit frustrating but there has to be something in it for both, in that if it's a student from [University] they have a PhD or something they're doing. But they could, as university, work with you because you pay them to do the thing. But there's always something attached to it where there's someone developing something out of it and then it's at that point, when you've got conflicting objectives, that it starts to then become a bit of a problem where—if I was hiring any other supplier, in the most black and white approach to this—they would provide a service to specification. But in this case, it's almost like I have to, and it's not my view, I like the learning, but from an implementation point of view I'm entertaining what someone needs and paying for it as well at the same time [laughs]."

In balance, there were some positive stories also. Two respondents, who had little other cooperation on research, nonetheless described how they valued reflective dialogue sustained over a long period with an academic. And another practitioner, who was unaware of any research relationships on the subject of safety, nevertheless mentioned two occasions of contact between academics and senior management in his company.

> *"The only time recently I would say is 2016, which is summer 2016, when there was a safety symposium that was organised in the U.S. and a number of […] senior leaders went along to that and it was presentations from a series of academics to them. I think the most impactful one, or most visibly impactful one, was […]. And that led us, I remember, that led us to the […] and that whole process which then led on to the serious incident review board kind of approach. So that was a positive outcome from that. […] But then the other one was a few years ago when we had a different composition for the [Health, Safety & Environment] leadership team and we had a presentation given to us by […]. He was utterly brilliant. He was a fantastic speaker [laughs]. He was very vocal. So, there was only about fifteen of us in the room so he was very, very [effective]."*

These quotations are given here only as illustrations, but are suggestive of a more general picture. Even so, the authors do not claim this to be a reliable representation, and are tentative about analysis presented here. Nonetheless, the interviewees included practitioners from global businesses, large European airlines, and regulatory agencies from the UK, Europe and the Middle East. In short, organisations whose scale and complexity would make them likely candidates for relationships with academic institutions. And indeed, there were relationships, but these appeared to be limited to formal education and, to a lesser extent, non-formal education. These relationships appeared to be largely one-way: purchasing places on courses, or providing students with access to data. The impression is that academic institutions set the terms of these transactions, with practitioners acting as gatekeepers, not equal partners.

7.3. What might academics expect from cooperating with practitioners?

All but one of the respondents interviewed for this paper were practitioners. The present authors would have liked to have heard more about academics' perspectives on these issues. In particular, we wanted to hear stories of cooperation that defined success from their point of view. However, it takes two to tango, and the practitioners we spoke to seemed used to be being 'wallflowers[63]' at this particular dance.

The authors considered whether the topic of investigating and learning from incidents defines a group of academics who see their role quite conservatively. By *conservatively*, we mean limited to providing formal and non-formal education, and conducting research that they control unilaterally. Again, better data is needed before reaching any firm conclusions. However, there is at the least prima facie evidence in the literature that what we are choosing to call 'conservative' is actually normal—most academics tend to follow the pattern described and explained by Schön many years ago.

> *"there is a dilemma of rigor or relevance, which comes to bear especially on those who consider themselves researchers. A topographical image helps to convey the feeling of this dilemma. One can imagine a cliff overlooking a swamp. Researchers may choose to say on the high, hard ground where they can conduct research of a kind the academy considers rigorous, though on problems whose importance they have come increasingly to doubt. Or they may go down to the swamp where they can devote themselves to the social problems, they consider truly important, but in ways that are not rigorous in any*

[63] Wallflower is defined, in rather sad terms, by the Merriam-Webster dictionary as "a person who from shyness or unpopularity remains on the sidelines of a social activity (such as a dance)"

> *way they know how to describe. They must choose whether to be rigorous on the high ground or relevant in the swamp. Over the past twenty or thirty years, the social and personal costs of this dilemma have become increasingly apparent. In the same period, technical rationality, which is at the root of the dilemma, has come under vigorous attack on the part of such philosophers of science as Thomas Kuhn, Imre Lakatos, Jürgen Habermas, and Paul Feyerabend. In these circles, hardly anyone wants any longer to be considered a positivist. Nevertheless, in everyday institutional life, technical rationality is resurgent. One has only to observe the deliberations of hiring, promotion, and tenure committees in the research universities, deliberations on which the future of the academy largely depends. One has only to observe the behavior of students who anxiously vote with their feet to acquire "hard skills" like statistical analysis and computer programming. Indeed, the contemporary academy is the scene of an epistemological battle, albeit a battlefield of snails (one has to look very closely and patiently in order to see it). As a result of this and related trends, the schools of the professions-not only the ones Nathan Glazer calls "minor," such as education, city planning, and social work, but the ones he calls "major," such as medicine, law, and business—are in a state of ferment.”*

Schön, 1992; p.119-120

In the sectors that Schön mentions—education, city planning, and social work—academic involvement in informal learning and research of practice is visible in the literature. The upshot of this is that, indeed, there are models for cooperative work between academics and practitioners. Furthermore, these models are relatively mainstream in many areas of public service provision. Not that the grass is necessarily ‘greener over there’—the ferment that Schön describes still seems true in public services, as are his remarks about the resurgence of technical rationality.

7.4. Technical rationality, and the risks created by limited cooperation

As Rolfe (2014) explains, Schön used the term *technical rationality* to describe a situation in which “*university-based technologists generate knowledge for practice-based technicians to apply. Technical rationality is a useful model for practice when situations are simple and straightforward and where the same solution can be expected to work in every instance.” (Rolfe, 2014; p.1180).*

The concern shared by many social scientists is threefold. Firstly, technical rationality oversimplifies complex situations. The simplification is partly to make problems amenable to research methods, and partly to reflect the problems defined by the policy-makers who commission research. Secondly, practitioners’ knowledge and values (and those of other disempowered stakeholders) are under-represented in defining these problems, the research design, and the requirements of solutions. Thirdly, that if the resulting solutions are enforced as rules, practitioners will not be able to adjust their practice to fit the needs of particular instances. As a result, some needs may go unmet. As Kingston and Dien argued in the ESReDA seminar last year, when monitoring is also defined by this process, unmet needs, which sit outside of the definition, may remain invisible to policy-makers. As they put it:

> *"the simplification implicit in the models which underlie most measurement schemes, may not be recognised as an over-simplification, in the sense that some relevant aspects of the system measured are not represented in the measurement"*

Kingston and Dien, 2017; p11.

7.5. The divide between academics and practitioners

Our discussions with practitioners have left us with a profound sense of opportunity. Academics and practitioners in this area could benefit from working together in the ways that their counterparts in other areas are working together.

However, there are structural issues to overcome. One is the cultural inertia of the current patterns of behaviour (including funding): 'it doesn't happen now, so it need not happen in the future'. Another is the implicit and explicit assumptions of academic life—some academics may see these proposals as a threat to their reputation and identity. Then, there is the mutual confidence and understanding between the two groups, which the interviews suggest needs building-up.

Darroch and Toleman (2007) looked at the gap between academics and practitioners working in Information Systems. Their literature survey identified several factors, of which three, paraphrased below, appeared pertinent to this paper.

- **Communication.**
  - the *research* community, *'is in danger of talking mainly to itself about itself'.*
- **Academic promotion, reward and tenure mechanisms.**
  - promotion and tenure processes are based on *"publication in academic journals and evaluation from academics (to the exclusion of practitioner journals and evaluations);* which result in,
  - *"institutional pressures that foster irrelevance" […] "rather than reward interaction, it actively sustains the divide;"*
  - *The "structure is inflexible and does not reward innovation or state-of-the-art thinking.*
  - The mechanisms also discourage *"the PhD experience from making a greater contribution to industry"*
- **Academic journal publication.**
  - *"Academics are most rewarded for publishing in highly-ranked academic journals, but are poorly rewarded for publishing in practitioner publications"*
  - *"It is widely accepted that practitioners do not have access to, or do not read academic publications. This represents a significant, lost opportunity for engagement, and thus further erodes the relationship.*

Absent from Darroch and Toleman's list, is practitioners' perception of academics as **inflexible**, a recurring point voiced in the interviews that informed the present paper. The authors interpret this as a reflection of the paradigmatic position(s) of academic researchers. As Rolfe (2002) explains:

> *"the dominant paradigm defines how the knowledge-base of a discipline is built and maintained, what is to count as knowledge, and importantly, what are to count as valid ways of generating knowledge."*

As well as creating obstacles to interdisciplinary work, adherence to a paradigm also reduces the flexibility available for cooperation with practitioners. Freidman, et al. (2015) relating this issue to problems in organisational learning, argue that the most likely way forward is to ground research "in the requirements of workable intervention"; a strategy that "blurs the line between research and practice, encouraging researchers and practitioners to act as partners" (Freidman, et al., 2015; 27). The implication of this is that in the cooperative generation of knowledge, it is the academics will have the most distance to travel, conceptually speaking. They are entitled to ask: what is in it for them?

7.6. Models for cooperation between academics and practitioners.

This subsection presents two general approaches, not recipes, for cooperative work—evaluation research and Participatory Action Research—PAR. The aim of cooperative work could be to identify 'good' practices, to create new ones, and to document rich descriptions that allow others to develop their practice. However, although these outcomes would be something to celebrate, the larger agenda of such work would be to enable these two groups to shape each other, both in respect of both domain knowledge and learning to learn. Much of this benefit is likely to arise in non-linear, unplanned ways; similar in its principles to the reflective dialogue between academics and practitioners described by Mårtensson and Lee (2004). (Indeed, their approaches are another promising model that could be applied in this area.)

7.6.1. Collaborative evaluation research

In some areas of practice, such as education and social work, academics are involved in research of 'good' practice. Usually, these pieces of work are carried out in the form of evaluation research, as already mentioned (section 6.6). The usual situation is for the practitioners' organisation, such as a government department, to contract a team of academics to evaluate some aspect of its service to the public.

Evaluation research is both a source of inspiration for how this kind of co-operation can be done, but also a fund of cautionary tales. Concerning the latter, the main complaint is about who has the power to decide what is to be measured and how. In essence, this is the power to define what constitutes 'good' practice and, by the same token, to classify all other practices as less than good. Evaluation research has been widely criticised as empowering senior managers at expense the practitioners. (Everitt and Hardiker, 1996). As an academic recently remarked to one of the present authors [Kingston], *"Often the evaluators are not greeted particularly warmly; I remember turning up for a first meeting with local authority officers … to be told: I expect you are regarded as only slightly less welcome than the auditors."*

The value that the academic brings to the practical setting is:

- **theoretical knowledge of the practical domain** (e.g. of education). This can be a source of criteria for practitioners, and also a fund of diagnostic frames that academics are more likely than practitioners to be aware of.
- **a knowledge of practices gained from earlier evaluations**. Academic evaluators are in a position to get insights into the practices of others that they can use to inform the

development of practice in a new setting. However, a certain degree of contractual prudence is needed to ensure that they share only that which previous partners agree can be in the public domain;

- **writing skills and publication routes** for that portion of generated knowledge which can be shared with, and tested by, other academics and practitioners;
- **knowledge of research methods and technology** with which to perform the evaluation, including the ability to enact the seven principles listed on page 178;
- **'objectivity and neutrality'** to the research (Everitt and Hardiker, 1996; p46).

7.6.2. Participatory Action Research—PAR

For about ninety years, researchers around the world have been identifying what they do *"using terms like 'action research', or participatory research', or a combination of these. Some have stressed the action component, while others have focused more on the participatory process. Still others have come from the field of social science and have identified it as a means of inquiry or research, per se."* (Wadsworth, 1998; p.1)

Interviewees mentioned something that appears essential to cooperation, that it be meaningful to all the parties, not just the academics. This seems to be integral to Action Research and a key difference from what one might call conventional, academic-centred research. The participants in Action Research consist of stakeholders in the system that is the context of the research, working together with an academic. As a group they "organise the conditions under which they can learn from their own experiences and make this experience accessible to others." (McTaggart, cited in Wadsworth, 1998). Schön (1992) found that academics tend to dominate relationships with practitioners, often redefining problems to suit their theoretical and methodological predilections. In contrast, the degree of agency possessed by the non-academic participants in Action Research—their level of control—is much greater than in 'conventional' academic research.

Unlike evaluation, which is characterised by questions about what works, Action Research usually starts with a problem. In the business setting, practitioners are used to working on problems through PDCA (plan-do-check-act) cycles. This is very close to the meaning of the 'action' part of Action Research—finding out what the problem is by acting on it, learning from these interventions, and then acting on it some more, etc. The difference is that PAR brings to PDCA is the sensibilities of academic research—inquiring, self-critical, rigorous, and well-documented. In this respect the academic educates the group by leading them, rather than training them—*educere*, rather than *educare*[64].

The description of PAR provided by Wadsworth (1998) reads rather like an ideal incident investigation in terms of its principles. The difference is its inclusiveness of stakeholders, and that it is intimately connected to action, rather than making recommendations. In respect of

[64] Citing, Craft (1984), Bass and Good (2004), note "that there are two different Latin roots of the English word "education." They are *educare*, which means to train or to mould, and *educere*, meaning
to lead out. While the two meanings are quite different, they are both represented in our word "education." Thus, there is an etymological basis for many of the vociferous debates about education today. The opposing sides often use the same word to denote two very different concepts. One
side uses education to mean the preservation and passing down of knowledge and the shaping of youths in the image of their parents. The other side sees education as preparing a new generation for the changes that are to come—readying them to create solutions to problems yet unknown. Bass and Good, 2004; p.161.

'good' practice, PAR might be most useful as a means develop practices for learning from incidents, as well as a model for learning specific lessons from incidents. In other words, the problem(s) would be identified by prior incident investigation, but PAR would be the way of further defining and alleviating the problem. The potential advantages are:

- Stakeholders stick with a problem for longer, rather than finding only rapid fixes. This would be appropriate for those incidents that investigation, or monitoring[65] reveal to be symptoms of 'messy' or 'wicked' problems;
- By bringing together participants from different parts of the system, the PAR group own all parts of the problem and the solution, leading to deeper insight into goals and constraints;
- Occupational ill-health tends to be the 'poor relation' compared to safety incidents. Whereas safety incidents are more visible and their localisation in place and time means that are more tractable. PAR has already been used in this area (e.g. "Barefoot Research", Keith, et al., 2001)

7.7. Cooperation in lifelong learning

Since the European year of lifelong learning in 1996, the European Commission has recognised that co-operation between all the relevant actors must improve if lifelong learning is to flourish.

> *"... All relevant actors, in and outside the formal systems, must collaborate for strategies to work 'on the ground'. Gaining insight into the needs of the learner, or the potential learner, along with learning needs of organisations, communities, wider society and the labour market is the next step." ... " There is a clear need here for the formal sector to recognise and value non-formal and informal learning. Creating a culture of learning depends ultimately on increasing learning opportunities, raising participation levels and stimulating demand for learning."*

(European Commission, 2001)

However, Volles concludes that there "are considerable implementation gaps between the education and training goals set by the EU and the actual – often disappointing – outcomes achieved by the member states." (Volles, 2016; p.360).

Perhaps the area of investigating and learning from incidents, serves as a microcosm of this wider problem. Cooperation seems to be marginal and hesitant. It is characterised by a lack of lifelong learning mindsets[66] among practitioners (van Dam, 2016), a lack of mutual understanding between the actors involved in lifelong learning, and coloured by the tendency for academics and practitioners to undervalue the other's knowledge.

The lifelong learning competencies of the practitioner are equally an issue. As already discussed, the skills assumed of adult learners do not, however, spontaneously appear at age 18, and practitioners will vary in their current level of competence as learners. Hence, 'learning to learn' is as much a feature of lifelong learning as 'content' knowledge.

[65] which was the approach taken by Daltuva et al., 2009

[66] Van Dam (2016) does not use mindset as a way of referring to an all encompassing attitude, but instead describes many different forms of mindset that each contribute to lifelong learning.

Both PAR and evaluation are forums for development as learners—both for the academics and the practitioners. One of the claims of PAR is empowerment of the research participants, not only in terms of equalising power imbalances in the research setting, but by enabling the participants to take an active role in their own development. In the cyclic nature of PAR, developing learning ability increases, as it were, the individual's capacity to acquire capacity. A similar benefit is claimed for evaluation, if performed according to the principles set out by Everitt and Hardiker (1996).

There are likely to be innumerable ways that a more cooperative approach could improve lifelong learning. But, ironically, it seems likely that a higher degree of cooperation will needed if these ways are to be found and made to work. Some pump-priming will be needed to find these ways and make them work.

8. Conclusions

'Good' practice is a clichéd term. However, the problem of the cliché is not the language, it is the lack of critical reflection on implied claims to efficacy. This can make it harder, not easier, to reveal the values that define good and the causal theory that makes a practice effective. When 'good practice' is used as a cliché, claims efficacy remain implicit, especially when said by someone with more power than you. But it is a risk: the practice might not be 'good' in the context of your work; it might be a distraction from more deserving ideas. And it is also a lost opportunity, for practitioners and academics alike, to discover what 'good' is, and to understand the dynamics of 'corrupt' practice.

Generalisation of 'good' practices is possible, but it depends on understanding the goals and constraints of the context. Documenting 'good' practice means also describing the context, rather than stripping it away to leave only the procedural steps. How to produce case studies is itself a research need.

Practice is created by practitioners, sometimes in relative isolation, sometimes working in groups. As with 'best' practice, it is not possible to objectively identify 'good' practice. Furthermore, the values that define 'good' may not be a matter of consensus in a group of stakeholders. Influencing practice 'in the direction of the good' requires the group to recognise their values through reflection and research of practice. Organisations need a strategic view of the longer term development of investigation programme towards goals of learning (for safety) amongst others. It is not true that an investigation performed to high technical standards will induce learning. Stakeholders will need to be prepared to resolve conflict between 'good' practices of investigation and those of learning from incidents.

Lifelong learning is often talked about in terms of its most tractable parts – formal and non-formal learning: courses, for the most part. These have a role in 'good' practice, but perhaps more as a focus and inspiration than as the main means for achieving competence or innovating practice. For these, the emphasis is on informal learning, which is a much more complex set of structures. In general, informal learning is not flourishing in organisations and, as a result, that practitioners' *capacity to acquire capacity* is limited. In this respect, investigating and learning from incidents is a microcosm of wider problems in lifelong learning.

Rather than practice being in the margins, this paper has argued for it to become a focus for empiricism. As individual practitioners, and as groups, there are structures that can be built on. The accent is as much on relational work as much as technical skills. At these individual and group levels, pressure of work appears to be the main inhibition to developing and sharing 'good' practice. There is scope for structural adjustments to help this: planned debriefing, critical review, and the use of ‘terms-of-reference’ in both of these.

The paper has discussed the role of systematic research approaches to the question of what is 'good' practice. The most available ‘model’ for this is evaluation research. However, insight in 'good' practice will require an approach to evaluation that addresses power imbalances and is sceptical about rational-technical outlooks on practice.

The authors have argued for a larger academic role in the development and sharing of 'good' practice in investigating and learning from incidents. For the most part, this enlarged role is in research, but also in education—especially with respect to informal learning. We are mindful of Lewin’s advice[67] that “action, research and training is a triangle that should be kept together for the sake of any of its corners.” Rather than more of the same, the argument here is for more academic activity enacted in collaboration with practitioners. Research designs consistent with evaluation studies and participatory action research, examples of which exist in the public sector, could be applied to investigative and lesson-learning practices in safety. The ambition would be for better, faster development of 'good' practice; and more grounded theorising of safety management.

There are very strong constrains that limit our structures. However, the present authors see in this area abundant opportunity for projects that elucidate 'good' practice while demonstrating the art of the possible.

After word

In this paper the authors have tended to look at learning from incidents through the lens of investigation. This means that we have seen the issues of investigation first, and learning second. This paper is not so unusual in this respect, but this bias can be a problem. Organisations investigate accidents for lots of reasons, but if learning safety lessons is the pre-eminent goal, we should remember look at investigation through the lens of learning, not the other way around.

9. Acknowledgements

Safety investigation, and being critical of one’s organisation, are sensitive matters. Our respondents were generous with their ideas, their time, their information and their trust. In return, the present authors promise to maintain confidentiality.

[67] Lewin (1946); p.43.

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SESSION 5:

Methods

Do not repeat old mistakes in learning from accidents: It`s better to prevent a run away than be ready for it

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Abstract

The article returns to more than twenty years old, but very serious, accident from the Czech railways. It briefly reminds WHAT happened that time, and analyzes HOW and WHY the causal factors leading to the accident were combined. Lessons learned from the analysis are compared with available data. It turns out that surprisingly, in the course of the lessons learning, the possibilities for the prevention of initiating the basic hazard, which realized in the accident, have not been thoroughly analyzed.

Therefore, it cannot be said that the accident was properly used as information to prevent similar accidents. Two recent media reports confirm that the basic hazard keeps being urgent and that the appropriate lessons are still missing.

Therefore, the answer to the question from the seminar "what are the remaining challenges?" is: In the accident analysis, it is especially necessary to consistently accept and implement already known approaches to the analysis of causes and to the accident response, including the application of known principles for inherently safer solutions. Consistent work with existing tools is often everything what is necessary for satisfactory lessons learning. In the case described, it should not be forgotten that „When the scenario cannot be initiated, then no need for its mitigation."

Keywords: Railway safety; Root cause analysis; Inherently safer design.

1. The incident

The incident occurred on Saturday, June 24, 1995, at the end of the afternoon, during the disconnection of freight cars at Čachnov station. Four cars run away. Two cars were loaded with wood, one with iron scrap and the last car was a service one. On a nearly five-kilometer downhill journey with slope over 20 per mille, the cars reached a hundred-kilometer speed. At a neighboring village of Krouna they hit a small passenger train (railbus) moving at a speed of about 40 km per hour in the opposite direction. Of the 23 people present on the train at the time of the crash, 18 died, 4 were seriously injured, one died later in the hospital, and one woman survived with smaller injuries. See [1, 2].

Figure 1 shows the situation at Čachnov station shortly before the incident. The four freight cars represented the rear part of the train, which stopped at the main track to the left of the station building (the black rectangle indicates the locomotive). This quaternion of cars should have stayed in Čachnov. It was disconnected so that the locomotive together with front four cars could carry out other planned shunting operations in front of the station building. In the end of the shunting, the quaternion was planned to be parked on the track south of the main track, ie on the track closest to the building to the left. All shunting operations were to be completed before the arrival of a passenger train from Krouna. Four persons participated in the shunting operations: train driver (locomotive engineer), trainmaster, and two freight car conductors. Also a dispatcher was present at Čachnov station, but she did not participate directly in the manipulation.

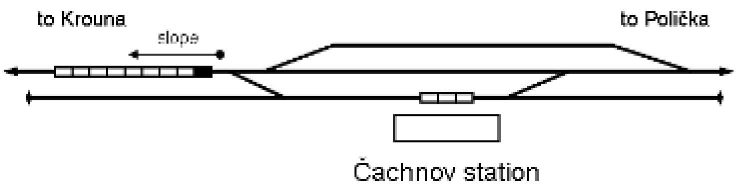

Figure 1. Railyard in Čachnov shortly before the incident.

The quaternion that run away later stood at a place where the track was already falling towards Krouna with a gradient of more than 20 per mille. The conductors did not brake three of the four cars with a handbrake and did not use mandatory hand rail shoes, which were to be laid on the track directly to the wheel of the first car down the slope. They did so with the consent of the trainmaster and in violation of safety regulations. The impulse generated by the disconnection and the sloping position were enough for the standing quaternion to start move downhill in the direction of Krouna. The two conductors tried to stop with the help of brakes, but they did not succeed. The attempt of the dispatcher to alert a passenger train driver by calling the previous station served by a dispatcher was unsuccessful, too. When she was calling, the train had already left the station. Other posts occupied by railway personnel were not available on the 10 km journey to Čachnov. The collision could no longer be prevented by the available means. The quaternion travelled from Čachnov to the place of crash about 5 km.

According to the first reports, the cars travelled to the crash site about 20 minutes. This has led to speculation that if the railway staff was equipped by means of interconnection (meant by radio transmitters; mobile phones were not yet available at that time) fatalities would have been prevented. Later, however, it became clear that the cars had only been traveling for a maximum of five minutes to the crash site, and that the shunters announced the event to the dispatcher with an indefinite delay, perhaps after the collision. Therefore, it is not certain whether the radio link could have averted the tragedy at Krouna. Perhaps, if the interconnection existed on that track, the train driver could have been warned and he might have stopped and made the passengers get out.

2. Application of methods for incident investigation

In the article [3], a simple Kletz's method according to [4] was used to analyze the event. Since the publication of Kletz's ideas, his approach has developed into methods of root cause analysis. In this paper, a method from root cause analysis family is used to analyze the accident. According to the book's [5] terminology, it is a type B method using a predefined decision tree.

First, we reconstruct the sequence of events. We describe the event development timeline using partial events in rectangles. The context of the incident is described by circumstances in the ovals connected to the partial events. After that the causal factors are identified in the diagram, as serious unplanned and unintended contributors to the incident, which, if removed, would either prevent the occurrence or reduce its severity or frequency (modified definition according to [5]). In this way, we gradually create the events and causal factors chart. The result is the diagram in Figure 2.

Construction of the timeline proceeds from the occurrence or suppression of the harmful effects of the incident against the flow of time. It is desirable to include all the partial events that have brought into play all the hazards the realization of which was necessary for the occurrence of the incident. As the examples in [6] show, this often means to include events from the time of creation of the system in which the accident occurred, or to apply original design intentions when assessing whether a partial event is a causal factor or not.

The considerations related to the designer's intentions are precisely the reason why partial events indicated as CF1, CF2 and CF3 were identified as Causal Factors in Figure 2. All three of these events undoubtedly fulfill the second part of the definition of causal factors - if they were removed, they would either prevent the occurrence or reduce its severity or frequency. But an argument could easily arise on whether they meet the first part of the definition, ie whether they represent serious unplanned and unintended contributors to the incident. We consider them causal factors because we believe that they are expanding the use of the Čachnov railyard above the scope originally intended and planned by the designer. The designer was undoubtedly aware of the fact that every railway vehicle left unattended on a track sloping down into other parts of the railway network is always a major hazard. You should always take advantage of the options offered by the local railyard to reduce the risk. First of all, it means that other tracks than the main track should be used to park vehicles.

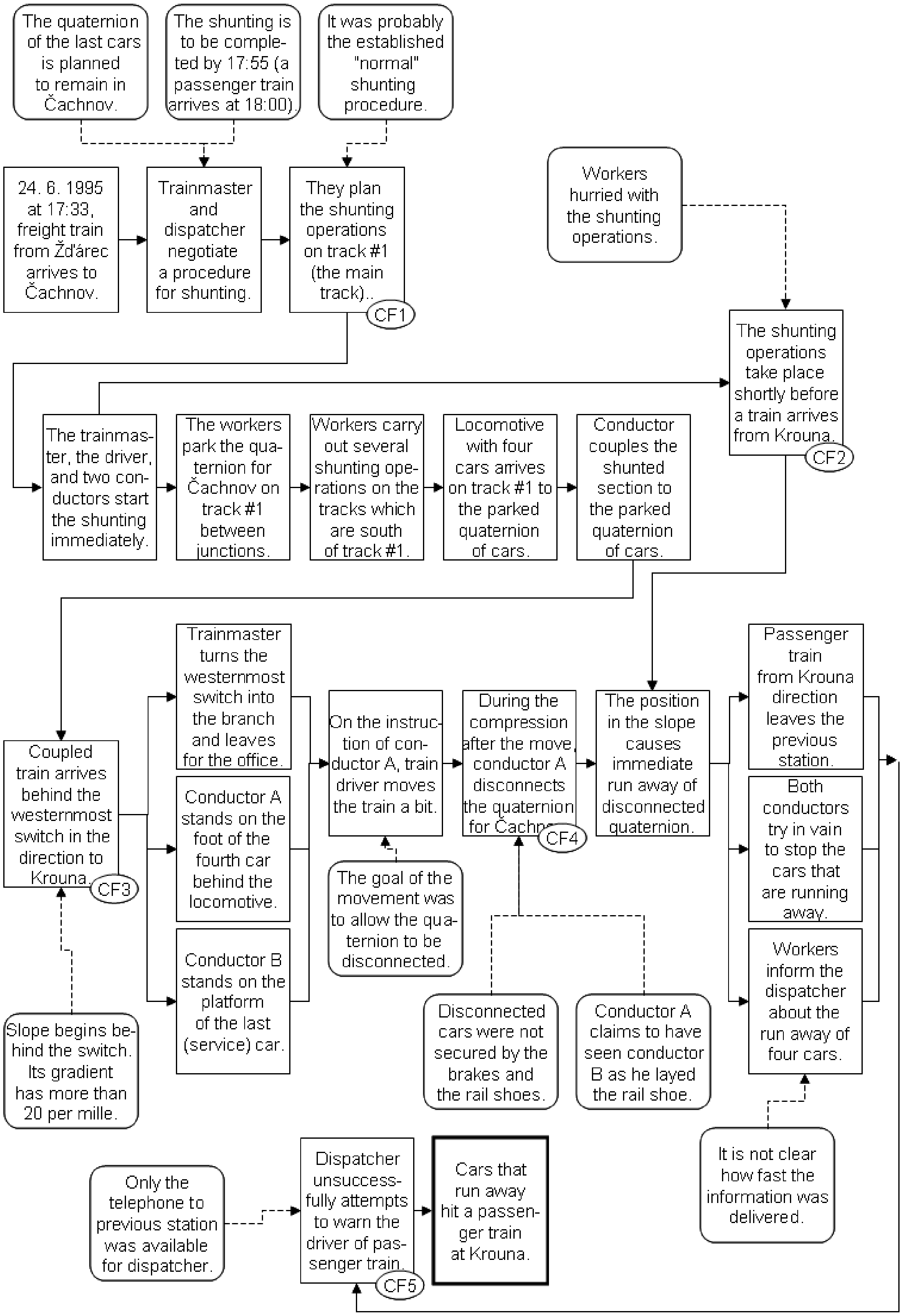

Figure 2. Events and causal factors chart for the incident at Krouna 24. 6. 1995.

Only when the situation is exceptionally such that it is not possible to circumvent the use of the main track for parking of vehicles, it can be allowed but only in the horizontal section between the branches and, if possible, outside the time when another vehicle can enter the slope. The use of a sloping section of the main track for parking unmanned vehicles can practically always be avoided in Čachnov. Hence, it seems unnecessary and therefore inadmissible. The regular repeated use of this track is especially inadmissible. Its regular use is not proved at Čachnov station, but there are indications for it. The fact that the negotiation of the trainmaster with the dispatcher about the shunting operations on the slope was easy and short, hints that it was a normal, established procedure.

It is clear from the use of this procedure that the unmanned vehicle on the sloping track was not perceived by shunters as an unacceptable hazard. At the time of the incident, no identifications of hazards and risk assessments were required. The question of whether this has changed, for example, as a result of the use of more recent legislation [7], will remain open.

In the next step of the analysis, we refer to the identified causal factors. Total of five causal factors was determined as seen in Figure 2. Root causes are assigned to causal factors. For this purpose, we use the description of root causes according to [8] as a predefined decision tree. Recommendations will then be linked to the identification of root causes. All these results are summarized in Table 1 below.

Table I: Summary table of causes and recommendations for incident in Krouna 24. 6. 1995.

Causal factor	Root causes	Lessons learned/ recommendations
CF1: Trainmaster and dispatcher plan the shunting procedure that uses track #1 i.e. the main track. (It was probably the established "normal" shunting procedure.)	Understand Hazards and Risk – Process Knowledge Management – Use Process Knowledge – Ensure awareness, Ensure that process knowledge remains useful. Commit to Process Safety – Process Safety Culture – Develop and Implement a Sound Culture – Maintain a sense of vulnerability. (At the time of the incident, the hazard, represented by the use of a sloped track for vehicle parking, was disregarded. The perception of this practice as a vulnerable point has disappeared from the general consciousness.)	Ensure that everyone involved in the rail vehicle handling at the station knows the slope of the track and is aware of the inappropriateness of the use of the main track and especially the sloping section of the main track for vehicle parking. Reduce the opportunities for vehicle run away. Limit the shunting procedures using the main track. Do not allow shunting procedures that use the sloped section of the main track.
CF2: The shunting operations take place shortly before a train arrives from Krouna. (Workers hurried with the shunting operations.)	Understand Hazards and Risk – Hazard Identification and Risk Analysis – Assess Risks and Make Risk-based Decisions – Select appropriate risk control measures. (The stay of cars without traction vehicles on the main track was not assessed as a so significant hazard, that it should have been prohibited at a time when another train could approach. Nor was it taken into account that the short time until the arrival of a train could lead to an undesirable omission of safety-critical operations that slow-down performing the activity.)	Do not allow the stay of unmanned vehicles and the handling of free cars on the main track in a suitably defined period prior to the arrival of passenger trains. Ensure compliance with this prohibition. Ensure that all workers involved in shunting operations are aware that, unless the measures recommended against CF1 are in place, the constraints of the handling period provents the destructive realization of the present hazard.
CF3: Coupled train arrives behind the westernmost	Understand Hazards and Risk – Hazard Identification and Risk Analysis – Assess Risks and Make Risk-based Decisions – Select appropriate risk control measures.	Ensure that everyone involved in the rail vehicle handling at the station knows the slope of the track and is aware of the

switch in the direction to Krouna. (Slope begins behind the switch. Its gradient has more than 20 per mile.)	Commit to Process Safety – Process Safety Culture – Develop and Implement a Sound Culture – Maintain a sense of vulnerability. (The stay of parked cars on the sloped section of the track was not assessed as a so significant hazard that it should not be used even though its use was not necessary during the shunting. It was not taken into account that the horizontal section of the track could also be used for the parking if only the shunting procedure would have been changed (and made somewhat more complicated). It was not considered that the use of the sloping section should have been compensated by the modification of the rail yard and instructions for its use, which would have limited the realization of the hazard. The perception of this practice as a vulnerable point has disappeared from the general consciousness.)	inappropriateness of the use of the sloping section of the main track for vehicle parking. Do not allow the use of the sloped section of the main track during shunting procedures. If the use of the sloped section has been shown to be inevitable, compensate the increased risk associated with this practice by proper modification of the rail yard and the shunting procedure. See the discussion connected with Figure 3.
CF4: During the compression after the move, conductor A disconnects the quaternion for Čachnov. (Conductor A claims to have seen conductor B as he layed the rail shoe. Disconnected cars were not secured by the brakes and the rail shoes.)	Manage Risk – Conduct of Operations – Maintain a Dependable Practice – Validate program effectiveness. Commit to Process Safety – Process Safety Culture – Maintain a Dependable Practice – Establish and enforce high standards of performance. (Although an operating procedure requiring the combined use of brakes and rail shoes existed, managers did not look after that the requirement was met. The workers did not commit to safety so as to follow the requirement without supervision. Managers and workers apparently preferred other objectives than safety, and were not sufficiently aware of the vulnerability of the process in which they participated, and of how easily the present hazards could realize.)	Ensure that brakes and rail shoes are used. Ensure that all managers and workers involved in the shunting are aware that unless the effective measures recommended against CF1 to CF3 are introduced, no action other than the proper use of brakes and shoes prevents the destructive realization of the present hazard.
CF5: Dispatcher unsuccessfully attempts to warn the driver of passenger train. (Only the telephone to previous station was available for dispatcher.)	Manage Risk – Emergency Management – Prepare for Emergencies – Plan defensive response actions. (The possibility that a vehicle could run from the station against an arriving train was not expected. No procedure has been prepared and trained to warn the driver of the arriving train. No tools existed to make such a warning possible.)	Analyze possible incidents, their consequences and the response to them. Equip the station with a means of emergency communication between dispatcher and trains. Train the use of communication means.

3. Lessons learned

Quaternion of unmanned cars without sufficient protection against a runaway parking on a sloping track represented a hazard. This hazard has gone out of control, and caused an incident. If this hazard was not underestimated and insufficiently limited, it could not be realized. This is the basic aspect to which the incident turns our attention.

The lessons learned and recommendations obtained from the analysis are summarized in previous Table 1. Order of causal factors CF1 to CF5 approximately corresponds with the order how the lessons learned should be prioritized. The most important point is that the use of the main track for shunting operations creates opportunities for the realization of the above-mentioned hazard. This use is in most cases unnecessary. It is advisable to organize the shunting so that the parking of unmanned vehicles on the main track is not used at all. The application of the shunting procedure that uses the main track results from human laziness. This is usually the simplest procedure that requires the smallest number of operations. However, the increased ease and speed of the shunting barely compensates the increased risk.

If it is not possible to completely exclude the use of the main track for parking of vehicles during shunting operation, then it is reasonable to distinguish between two options. Whereas the use of the horizontal section of the main track between the switches for vehicle parking can be considered, the use of the sloping section behind the rail yard in direction to Krouna is to be regarded as completely unnecessary, risky and unacceptable. Routine use of this section for vehicle parking is particularly unacceptable. The following may be objected to the opinion that suitable measures (brakes and rail shoes) can ensure the safety of shunting operations:

If a sloping section is regularly used for car parking, this creates a situation where the non-realization of a serious hazard depends only on the perfect interplay of several persons. The actions of these persons are not redundant. Safety of the whole manipulation depends only on the fact that everyone will carry out their work without an error. It is known that the frequency of human errors in routinely repeated operations is quite high. Hence a situation arises, where due to probability laws, it is practically certain that the connected railway track will be seriously endangered within a foreseeable future. And if deficiencies in safety culture are added to this common human inclination to err, the situation is even more serious. It is difficult to control from the outside the correct execution of all the steps of shunting procedure. The temptation to shortcut the execution of shunting operations and the opinion that some safety measures are unnecessary, are not far away in such situations. And as soon as, for seemingly good reasons, such as making the work easier, an operation (such as multiple use of handbrake) starts to be omitted, easily it becomes to be a habit known as normalization of deviance.

If a general rule was applied in Čachnov, that the main track, and especially its sloped section, would not be used for shunting unnecessarily, this rule would definitely limit the probability of run away. In addition, the adherence to this rule would be visible and controllable. And this is valid even although nothing is changed in the fact that a small group of potentially vulnerable people threatened by a possible collapse of safety culture performs the shunting operations.

Such a rule would shift the emphasis from purely organizational or educational measures to technical measures. This would fulfil the idea of prioritizing technical measures over organizational or educational measures, which is one of the fundamentals of inherently safer design.

A hazard, such as the presence of an unmanned vehicle on a sloped track, deserves to be treated according to all rules for inherently safer solutions. In limiting this hazard, for example, the risk control hierarchy described in [6] can be followed. (The general principles of risk control apply to railway transport as well as to the chemical industry.) The book recommends that six steps be attempted in order to control the risk associated with a certain hazard:

1. Avoid Hazard;
2. Reduce Severity of Hazard;
3. Reduce Likelihood of Hazard Realization;
4. Apply Passive Safeguards;
5. Apply Active Safeguards;
6. Apply Procedural Safeguards.

Step 1 would, in our case, completely eliminate the occurrence of unmanned vehicles on the main track. In the case of rail transport, however, the vehicles on the main track are inevitable. They can be found without the operator for many different reasons. Therefore, the absolute elimination of the hazard is not possible, even if we are limited to the surroundings of Čachnov. The second step is to reduce the severity. The severity of such a hazard is determined by its energy and the value of the targets that can be damaged by this energy. Reduction of the energy of these hazards or the value of the targets is not possible without essential change of the rail transport. Step 3 – reduction of the likelihood of realization of these sources, at least near Čachnov station – thus appears to be the first applicable step in the hierarchy.

Things we suggest in the recommendation column in Table 1 – above all, the prohibition of the shunting where the cars are disconnected on the sloped section of the main track – would contribute to the implementation of step 3. The elimination of the procedures using the main track (proposed against CF1) and the elimination of as many as possible shunting operations during which the unmanned vehicle can get on the main track would reduce the probability of hazard realization even more. The top sketch in Figure 3 illustrates a situation where it is forbidden to use the main track and the disconnection is carried out on track 2 north of the main track. The likelihood that the disconnected train section will get from track 2 to the main track would be further reduced if a dead-end track was connected to the track 2 and the respective switch was turned into the dead-end track during the disconnection as shown in the middle sketch. Building a dead-end track represents an active safeguard.

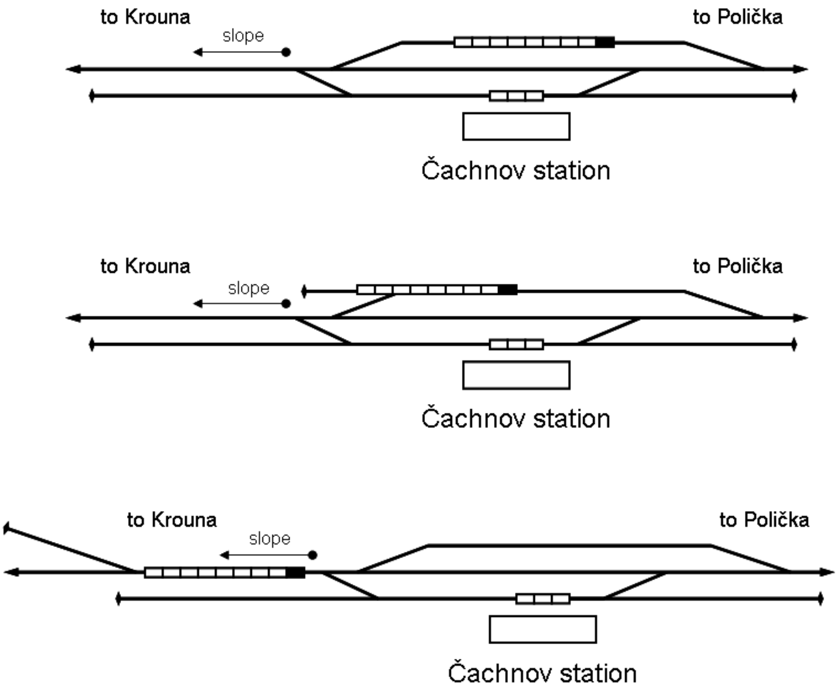

Figure 3. Proposed risk controls in the railyard at Čachnov.

If the use of a sloped section for shunting operations was unavoidable, it would be possible to compensate the increased risk associated with this practice by using a similar active measure – by realizing a dead-end track intended for coupling the trains as seen in the lower sketch in Figure 3. The recommendation against factor CF3 in Table 1 refers to this option.

Construction of a dead-end track serving as a safety measure for shunting represents a change in the rail yard technical solution. It is worthwhile considering whether such a change will at the same time bring other hazards – for example the possibility that the train planned to continue in the direction of Krouna will inadvertently turn to the dead-end track.

Technically, the exclusion of such a possibility is feasible by means of interlocking, which can be mechanical for manually operated switches or electric for remote control. If the switch in front of the dead-end track is not turned into dead-end track, then it is not possible to manipulate other switches and a signal allowing the shunting cannot be displayed.

4. Comparison of lessons learned

Table 1 summarizes lessons learned and recommendations based on authors' analysis. Table 1 should logically be a base for more general lessons learning. Operators of the entire track or the entire network should explore the feasibility of similar recommendations for all of their stations.

It would be very interesting to find out what lessons and recommendations were made by responsible persons after the accident. Unfortunately, our information on these lessons and recommendations is limited. From the available sources, we know only that the imposed measures were threefold:

1. Technical: the introduction of a radio system that ensures warning of the train driver of arriving train in the event of an accident and allows permanent contact between the dispatcher and the train driver.

2. Organizational: Prohibition of shunting when a train approaches.

3. Educational: training of workers, testing of knowledge by examination, increase of control activity.

It is not known whether the investigation drew attention towards other ways of preventing the realization of the fundamental hazard presented in Table 1 in the recommendations against causal factors CF1 and CF3. This means, towards reduction of the use of the main track and in particular its sloped section for shunting operations, or towards compensations for the risk arising from the use of the sloped track. The situation for the implementation of technical and organizational measures, such as the introduction of a retreat (dead-end) track, was relatively favourable at that time: the railway operator and the rail transport operator were one legal entity.

The above three measures have been implemented. The incident has accelerated the introduction of the track radio system on local lines throughout the Czech Republic. The track linking Krouna and Čachnov was equipped with the transmitters in June 1996. In 2012, the track was modernized by a dispatching control system, where the entire track is controlled by one dispatcher from the central workplace. A train without a connection to the dispatcher can no longer be put on the track. The dispatcher knows on which section of the track the train moves and what manipulations are performed with it in the stations.

In all media reports that remind the incident at Krouna, it has become customary to draw attention to the introduction of remote communication with the driver as a measure that should prevent repeating similar incidents. For example, in an interview with a railway expert that was broadcast by Czech Television on the 20th anniversary of the crash on June 28, 2015 (see [9]), the following information was heard:

> Today, such a tragedy could not occur because the track is equipped with technical devices that make such a type of incident impossible. Unlike the situation 20 years ago, the entire track is managed from one dispatch center. The dispatcher who controls the track sees on the computers what's happening on the track. If the wagons were run away during shunting as they were 20 years ago, the dispatcher would see them on the computer and know where they are moving. Depending on where the trains would be on the track, he would have enough time to decide what to do to avert the incident. In the first place, he could immediately contact the train driver at an endangered train and give him instructions on how to behave.

This claim exaggerates. Communication between the dispatcher and the driver only increases the likelihood that they can avert or reduce the loss of life. But the claim that such a tragedy could not have happened again is technically wrong. Complete exclusion of such accidents would only be possible if vehicles running downhill stopped moving spontaneously. However, such vehicles would no longer be suitable for the operation of rail transport. Radio connection only leads to mitigation of the consequences of the incident. It cannot avoid its occurrence.

5. Twenty-three years after

The fact that the repetition of such accidents cannot be completely ruled out is also confirmed by the accident that happened on August 2, 2017 (see [10]).

The electric passenger train (multiple unit, a set of several cars) arrived early in the morning to the final station. The passengers went out, and finally also the driver left the train. Contrary to the instructions, he did not secure the parked train by means of a pressure or locking brake and did not check its securing. As the rails were sloped, the unit began to move. The driver failed to board the train and stop it. Fortunately, the dispatcher intervened and directed the switches to prevent damage. The unit stopped after about nine kilometres at the opposite slope. It spontaneously started to move back down the hill and stopped at the opposite slope again. This was repeated several times before the unit stopped completely and the firemen secured it against further movement by two rail shoes. The unit travelled unattended totally about 15 km, but due to favourable circumstances and mitigation by the dispatcher, there was no damage.

If we analyzed this accident by the same method as the incident in Krouna, we would probably identify quite similar causal factors as those in Figure 2 and Table 1. The classical root cause analysis method is good enough for us to believe that it will help us determine all causal factors, all conditions necessary and sufficient for the incident. The problem does not arise in determining causal factors but in the way how these causal factors are used for lessons learning and recommendations. Any future consideration about the prevention of similar incidents should consider all causal factors, and first of all those that arose first in the incident timeline.

The incident again arose at the track, which had a slope, and at the moment, when a set of unmanned vehicles parked here. It cannot be assumed that all the places where trains stop on a slope can be removed. But it would clearly be worthwhile to consider whether at least in some places in the rail network, where vehicles are regularly unmanned on a slope, would not be able to make adjustments that would increase safety, for example in similar ways as proposed in Figure 3. These considerations would be aimed to the actual prevention of similar accidents as this one at Krouna. It is not professional to rely only on the fact that after repeated training the employees will stop making mistakes in implementing organizational measures.

Because the analysis has shown that it is important to encourage sense of vulnerability in workers' minds, it should be reminded during the trainings how tricky are the places where the track is sloping, how tricky is the reliance on that the vehicle will not get an impulse to start running. This is much better than weakening the sense of vulnerability by reassuring that similar situations can be successfully mitigated with the help of improved means of communication.

Measures that ensure communication after an initial event are also useful. But considerations about improving them should be given only after the measures against run away has been improved. Improvement of communication is a mitigating rather than a preventing measure.

Even when communicating with the public, railway operators should not resort to misleading statements. The public should not be deceived that the measures introduced will completely exclude the possibility of repeating similar accidents. Whoever says something like this, promises that future trains will operate with vehicles that are not moving from the slope.

6. Conclusions

Analysis of a serious incident is an opportunity to rethink the importance of fundamental hazards and defense against them. The presence of an unmanned railway vehicle parked on a sloping track entering the rail network is definitely such a fundamental hazard in rail transport.

The 1995 incident has prompted a great effort to introduce modern communication technology in the railway system. But apparently the discussion and new lessons learning related to the above-mentioned fundamental hazard have not been realized. The quote by the television expert and the incident from August 2, 2017, confirm that the appropriate lesson is still missing, but the hazard has not ceased to be up to date. To date, prevention of the realization of the above-mentioned fundamental hazard is not sufficient at rail transport operators. At the same time, the mere awareness of this hazard and of safety measures leading to its elimination could prevent many undesirable events. Our look into history shows, that the emphasis on prevention has not prevailed yet in learning from a real incident in order to improve safety management. Even the introduction of regulations, such as [7], has not changed enough.

Obviously, an obstacle to lesson learning is not that the existing methods of accident analysis and recommendation making are not sufficient, but rather that they are not sufficiently known and consistently used. In our case, a thorough analysis of root causes, ie causes in organization and management, would leave no doubt that lessons and remedial measures must be devoted not only to the mitigation of scenarios in which long-term efforts have been invested, but also to the prevention of vehicle run away. When designing measures, the use of hierarchical risk control principles, as indicated by above examples, leading to increased inherent safety, could help to systematically exploit the potential for effective prevention.

It is advisable to be equipped by the means of emergency communication for the event of a run away, but it is better to ensure that the brakes and rail shoes are used in the prescribed manner when vehicles are parked and that shunting operations are carried out at a time when there is no danger of collision with arriving trains.

It is advisable to rely on compliance with the rules on the use of brakes and rail shoes and on the appropriate times for shunting, but it is better to compensate for the increased risk of vehicles parking on a sloped track using a retreat track. And it is even better to avoid parking vehicles on the sloping track.

Pravděpodobně nejlepší je minimalizovat příležitosti k ujetí vyloučením všech zbytečných operací posunu na hlavní koleji.

Probably the best thing is to minimize the opportunity to run away by eliminating all the unnecessary shunting operations on the main track.

Do not repeat old mistakes in learning from accidents. It`s better to prevent a run away than be ready for it

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Analysing the depth of railway accident investigation reports on over-speeding incidents, using an innovative method called "SAFRAN"

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Abstract

With the publication of the public enquiry on the Piper Alpha disaster (1990), the concept of a safety management system (SMS) has found its introduction in high-risk industries. This concept went further than being "good practice" and became legally mandatory in some industries, where holding a certificate/licence, issued on the basis of a SMS, is necessary to operate. SMS requires continuous improvement, based on a combination of "knowing the unknown" (risk assessment) and "learning on experience" (occurrence analysis). To do so, accidents/incidents need to be reported and analysed and measures need to be taken to prevent future events. Additionally, national investigating bodies have been given the role of independently investigating serious events, with the same goal. Where a SMS is based on a holistic approach, with operational, supporting and controlling elements functioning together to improve safety, most reporting/investigation methods are not developed in line with a system thinking approach to accident causation. Also, how to link the top-down description of SMS requirements with the operational activities of the organisation that create these risks in the first place, is poorly understood. In result, the current practice in accident and incident investigation does not provide a systematic approach to analyse elements of SMS. As a direct consequence, the opportunity to use these investigations for introducing sustainable system changes is often missed. The paper briefly introduces the SAfety FRactal ANalysis (SAFRAN) method that is developed to guide investigators to identify where interventions might have the greatest impact for improving global system safety, by exploring the composing elements of the concerned SMS and the sociotechnical system surrounding it in a natural and logic way, starting from the findings close to operations that explain the occurrence – being the elements accident investigators are first confronted with. In addition, the proposed methodology provides an innovative visual representation of the investigation process.

The SAFRAN method is then applied to review a selected set of published railway accident investigations, all reporting on occurrences related to over-speeding, possibly resulting in a (lethal) derailment. The depth and focus of the performed investigations are assessed and compared with findings that would result from an analysis that is applying the SAFRAN logic, demonstrating the need to focus accident analysis on an organisation's capability of managing the variability that might put successful process performance at risk.

1. Introduction

In the evening of November 1, 1918, a Brighton Beach Train of the Brooklyn Rapid Transit Company, packed with a rush hour crowd, derailed on a sharp curve approaching the tunnel at Malbone Street, in Brooklyn, and plunged into a concrete partition between the north and south bound tracks. When entering the reverse curve, which had a speed limit of 10 km/h, the train was operating at a speed of 48 km/h or more. At least 93 people died, making it one of the deadliest train crashes in the history of the United States. (NY Times, 1918; Wikipedia, 2018).

Now, 100 years later, the management of safety risks in railways, as in many other high-risk industries, is mainly relying on the holding of a safety management system (SMS). This organisational concept to continuously improve safety of operations, was launched with the recommendations resulting from the public enquiry after the deadly disaster on the oil platform Piper Alpha (Cullen's, 1990) and introduced the transition from an often very prescriptive safety approach towards an approach that is evidence-driven and based on goal-oriented legislation. In different industries, the holding of a SMS to control all risks related to a company's operational activities not only became normative but even legally mandatory, forming the basis for certification and regulation (e.g. Vierendeels et al. 2011; Leveson, 2011; Grote, 2012; Deharvengt, 2013; Fowler, 2013; Lappalainen, 2017). Various standards and regulations exist that describe or prescribe the basic SMS components, but they all share the requirement for procedures to ensure that accidents, incidents, near misses and other dangerous occurrences are reported, investigated and analysed. They also have the requirement in common that this analysis should result in necessary measures to prevent similar, future events. Additionally, in some high-risk industries, national investigating bodies have been given the role of independently investigating significant events, with the same aim of preventing future accidents and improving the overall safety of the system. Despite these requirements, 100 years after the so-called 'Malbone street wreck', over-speeding is still causing some of the most lethal railway accidents; putting in question the capacity of a whole sector to learn lessons from the past.

Johnson's review (2004) of the original BFU accident investigation report of the famous Überlingen mid-air collision concludes that the investigation had insufficiently analysed the SMS. He further highlights the importance of looking extensively at organisational factors and their contribution to an accident. This finding is in line with the findings of other authors (e.g. Antonsen, 2009; Kelly, 2017) that the scope of accident and incident investigations, whether performed internally or externally, is usually limited to investigating the immediate causes and decision making processes related to the accident sequence. Important factors contributing to the accident are hereby often overlooked and the weaknesses in the SMS, or its composing elements, are hardly ever analysed. Since the type of data collected during accident investigation and the method used to analyse this data will highly influence and sometimes even constrain the proposed remedial actions (e.g. Hale, 2000; Hollnagel, 2008; Underwood and Waterson, 2013; Salmon et al., 2016), it should be of no surprise that those investigations don't guide directly towards solutions that can be found within elements of the legally obliged SMS. This, in turn, may result in the perception that the SMS approach does not deliver as much as was hoped for when Cullen published his recommendations. Different authors assign possible underlying causes that could explain these findings. Where a SMS is based on a holistic approach, with operational, supporting and controlling elements functioning together to improve safety, most accident reporting and investigation methods are not developed in line with a system thinking approach to accident causation (Reason, 1997; Hollnagel and Speziali, 2008; Dekker, 2011). More fundamentally, as pointed out by Lin (2011) but also by Deharvengt (2013), the top down description of SMS requirements creates problems of understanding how to link the generic management activities, aiming at identifying and controlling risks in a systematic way, with the operational activities of the organisation that create these risks in the first place. This is in line with the observation of Rasmussen (1997) that, by lack of vertical interaction between the different levels of the socio-technical system, there is a problem in incorporating theoretical management models like SMS as a tool for resolving issues related to human performance or technical failure at the operational level. Also, this could at least partly explain the difficulty industry has, to translate accident and incident findings into effective safety initiatives (Salmon et al., 2016).

In order to address these problems, an investigation analysis method, called SAFRAN, was developed that can guide investigators to explore the composing elements of an SMS in a natural and logic way, starting from the findings close to operations that explain the occurrence – being the elements accident investigators are first confronted with. Furthermore, the method can help to identify those elements of the SMS where interventions might have the greatest impact for improving global system safety, in particular an organisation’s capability of managing the variability that might put successful process performance at risk (e.g. Hollnagel, 2014, Hollnagel 2018). This is illustrated in the next chapter, by applying the SAFRAN method to review a selected set of railway accident investigations reporting on over-speeding incidents.

2. Case study

As long as not all infrastructure and rolling stock is equipped with an automatic train protection system that continuously controls speed requirements, derailments because of over-speeding will remain a major risk of the railway system, as has been demonstrated by several of the most lethal railway accidents over the last decades. As input for this case study, a set of six published investigation reports has been selected to check their depth and focus when investigating accidents or incidents caused by over-speeding. This selection has been made taking into account a geographical spread, the similarity of the accident (i.e. a critical variability in maintaining the appropriate speed of a passenger train), the author of the report in all cases being a national and independent investigating body and the availability of the report in a language that can be read by the author of this paper (that is English, Dutch, French or German). The following Table 1 provides an overview of the selected investigation reports, the allowed and actual train speed and the consequences of the adverse event.

event	critical performance	consequences
Train derailment accident between Tsukaguchi and Amagasaki stations of the Fukuchiyama line of the West Japan Railway Company, April 25, 2005	allowed train speed: 70 km/h actual train speed: 116 km/h	107 people killed 562 people injured
Main-track derailment of a Via Rail Canada passenger train in Aldershot, Ontario, February 26, 2012	allowed train speed: 15 mph (24 km/h) actual train speed: 67 mph (108 km/h)	3 people killed 45 people injured
Derailment of a passenger train near Santiago de Compostela station (ESP), July 24, 2013	allowed train speed: 80 km/h actual train speed: 179 km/h	80 people killed 73 people seriously injured
Derailment of Amtrak passenger train 188 in Philadelphia, Pennsylvania (USA), May 12, 2015	allowed train speed: 50 mph (80 km/h) actual train speed: 106 mph (171 km/h)	8 people killed 185 people injured
Derailment of a SNCB/NMBS passenger train in Buizingen (BEL), September 10, 2015	allowed train speed: 50 km/h actual train speed: 120 km/h	39 people injured
Overspeed at Fletton Junction, Peterborough (GBR), September 11, 2015	allowed train speed: 25 mph (40 km/h) actual train speed: 51 mph (82 km/h)	4 people minor injured

Table 1. Overview of analysed investigation reports and the identified critical performance

These investigation reports have been analysed, using the logic of an innovative method we call "SAFRAN" (SAfety FRactal ANalysis) to set the reference of what to expect of a proper analysis of an over-speeding incident. When applying the SAFRAN method on the specific case of over-speeding incidents, the first step is the identification of the critical variability in the driver's performance of maintaining the appropriate speed, as reflected in Table 1 above. The next step, is to identify the expected performance as prescribed and/or specified. Speed requirements within the railway system, and in particular speed restrictions, are imposed by the assets that are used, in particular through the characteristics of used rolling stock and infrastructure (through design or its actual state). Without an automatic train protection system in use, these constraints are traditionally communicated to the train driver via the lineside signalling equipment. In addition, the trained driver is required to have acquired the necessary route knowledge so that he knows what signalling aspects to expect and where on the line. The third step in the SAFRAN logic then consists of identifying those sources of performance variability (formal and informal) that contributed in shaping the train driver not respecting the applicable speed restriction. The fourth step in the SAFRAN method requires to identify the possibility to identify, analyse and report the critical variability of the specific process that is analysed (i.e. continuously monitoring the match between work as designed and work as actually performed). In this specific case study, this would mean that the investigation has analysed how the concerned organisations are monitoring the actual train speed and its criticality when compared to the allowed speed. With the existing state of technology, train speed is a parameter that is continuously recorded via on board data recorders and could form a basis for managing driver performance (e.g. Balfe and Geoghegan, 2017; EL Rashidy et al., 2017). Monitoring the match between work as designed and work as actually performed, in this context of managing the risk of over-speeding in a sustainable way, would therefore require a railway undertaking to continuously monitor the speed of its trains. Not in order to check driver-compliance, as is traditionally done, but to understand work place reality. Information on these four steps, that together form a first iteration of the SAFRAN method, applied on the driver's activity to "maintain appropriate speed", are expected to be found in the investigation reports. But more is needed if we want to introduce sustainable change. We would also expect to find elements that give indication that the process to "monitor over-speeding" has been analysed in a structured way, in order to assess an organisation's capability to identify critical speed-variability. This represents a second iteration in the SAFRAN method, for which we at least would like to understand the actual and specified performance, as well as eventual factors that can explain the deviation. Finally, we need to understand an organisation's capability to manage those conditions that influenced the driver's performance (i.e. the previously identified sources of performance variability) to better support sustainable and safe performance, which is a next iteration of the SAFRAN method for each identified factor. Here also, we look for actual and specified performance and eventual sources of performance variability. In summary, the reference model that we look for in the selected investigation reports, can be graphically represented as follows, with each iteration represented by a different triangle.

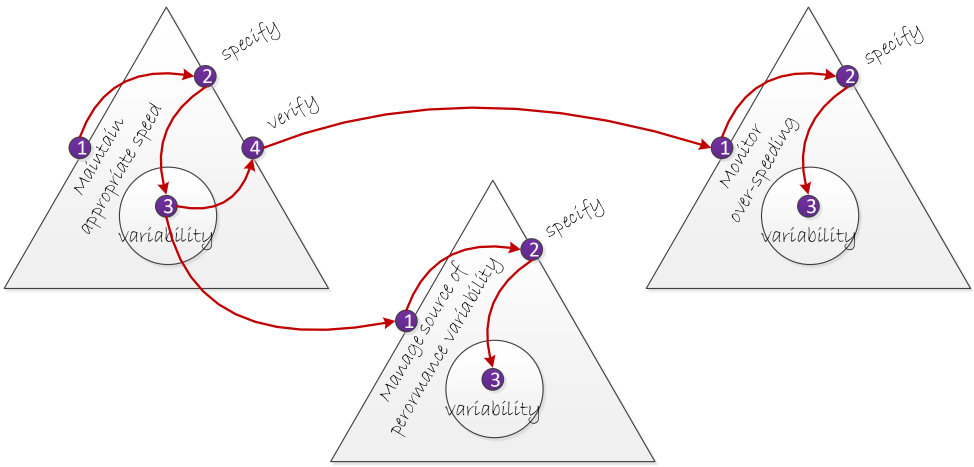

Fig.1: Reference model for investigating over-speeding incidents, based on the SAFRAN logic

When comparing the reviewed investigation reports with the reference model, as illustrated in Figure 1, we found that they all report on the allowed and actual train speed (see also Table 1). Furthermore, all reviewed investigation reports mention the expected performance and the way this is formalised (i.e. the second step in a SAFRAN iteration) in a detailed way. Also, all reports identify the factor(s) that can explain the critical variability in the driver's performance when maintaining the appropriate speed (i.e. step 3 in the first iteration of the SAFRAN method). Table 2 (see annex to this paper) provides an overview of all these sources of variability that were identified. Moving to step 4 of the SAFRAN method, we found that except for the investigation of the derailment in Philadelphia in 2015 (NTSB, 2016), all other investigation reports mention (potential) elements of over-speed monitoring. But only the investigation reports on the derailment on the Fukuchiyama line (ARAIC, 2007) and the over-speeding incident (RAIB, 2016) at Fletton Junction provide a structured analysis (at least identifying the first three steps of a next SAFRAN iteration) on why the (non-) reporting of previous over-speeding incidents did not adequately address the risks related to speed variability on critical parts of the infrastructure. The former report goes even further and actively reflects on the possibility to monitor speed at critical curves, resulting in a recommendation to monitor speed variability by using already existing technology. The reports on the derailments in Buizingen (IBRAI, 2017) and Santiago de Compostela (CIAF, 2014) both witness on the identification of monitoring activities that took place to detect over-speeding incidents and conclude on the inadequateness of these activities. All this, however, without analysing possible factors that influenced this poor monitoring and with the Buizingen-report surprisingly stating "the difficult detection of this type of events" as an explaining argument. The investigation reports on the derailments in Philadelphia (NTSB, 2016) and Aldershot (TSBC, 2012), in turn, do not mention any reflection on the railway companies' activities to detect over-speeding. In particular for the latter report this is curious, since the implementation and maintenance of an SMS, including monitoring and evaluation processes for all aspects of operations, is explicitly mentioned as a legal obligation, in order to integrate safety into day-to-day operations (TSBC, 2012). For the iteration related to the identified sources of performance variability, we found that two of the reviewed investigation reports (i.e. Fukuchiyama line and Aldershot) do not further analyse the capability to manage these. The investigation on Santiago de Compostela identifies a lot of relevant management processes, but systematically only compares the actual performance with the expected and specified performance, turning the investigation into a pure (non-) compliance exercise. A similar remark can be made for most of the processes that are identified to manage sources of performance variability in the Buizingen and Philadelphia investigation reports, with the exception of the analysis of the respective processes that manage train driver competence. The investigation report of the over-speeding incident at Fletton Junction, finally, gives a mixed image. On the one hand there is only mention of the specifications for the processes related to equipping engineering controls and, on the other hand, a detailed and structured analysis is providing for the processes related to the management of driver fitness and the equipment of lineside signs. A complete overview of these findings is provided in Table 2, as an annex to this paper. It has to be noted that all these findings are solely based on the elements that are available in the published reports and cannot take into account analysed elements that are not reported upon.

3. Conclusions

Widely, in all high-risk industries, adverse events are investigated and analysed in order to develop recommendations that, when implemented, help to change the (safety) performance of sociotechnical systems in a sustainable way. To do so, it has been argued by various authors that the treatment of wider system failures, identified through system based analyses, is more appropriate than the treatment of local factors at the sharp end of system operation (e.g. Rasmussen and Svedung, 2000; Reason and Hobbs, 2003; Dekker, 2011). Also analysing the relationship between contributory factors appears to be critical for the development of appropriate countermeasures that will prevent future accidents and incidents (Salmon et al., 2016). Furthermore, for these countermeasures to be sustainable, the performed investigations should enable both single-loop (i.e. correcting errors within the range set by organisational norms for performance) and double-loop (i.e. when correcting errors requires to change the organisational norms for performance) learning (Argyris and Schön, 1996). As stated by Hale (2000), we will be inclined to see the factors we have categories for, prompting those investigating to ask particular questions. It is argued that the application of the SAfety FRactal

ANalysis method can guide investigators to ask questions that help to gain deeper understanding of organisational factors and the capability of organisations to monitor and manage safety critical variability. The essence of using the SAFRAN method for evaluating the performance of the different processes in a socio-technical system, is to approach them in a similar way, regardless of the hierarchical level they are situated at, building on the generic elements that compose an SMS.

The application of the SAFRAN method was demonstrated in this study, by reviewing a selected set of published railway accident investigation reports, all reporting on an occurrence related to over-speeding, possibly resulting in a derailment. A logical focus for the analysis of such an adverse event would be to check a duty-holder's capacity to monitor the speed of its trains, to analyse it and to learn from experience. When issues discovered, it should be obvious that the issued recommendations will no longer be on the driver not respecting a speed limit and the individual corrective actions that need to be taken, but on the objectives of the monitoring process and the related management responsibilities. Also the latter is important, since the introduction of SMS can also be seen as part of a regulatory strategy to place the responsibility for managing safety at the level of the organisation best able to do so (Deharvengt, 2013; Kringen, 2013), challenging them to identify in a structured way what activities are critical for safety and what kind of safety management best fits their particular situation in order to achieve acceptable levels of safety performance, rather than blindly complying with prescriptive rules and regulations (Daniellou et al., 2010; Fowler, 2013; Grote and Weichbrodt, 2013; Kelly 2017). The results of the performed analysis show however a wide variety in depth and focus of investigation when compared with these areas of investigation (i.e. the reference model) that logically would result from an analysis that is applying the SAFRAN method from which one can only conclude that most of the reviewed reports just partly or not address an organisation's capability of managing the variability that might put successful process performance at risk and therefore miss the opportunity to issue recommendations that could really introduce sustainable change.

Based on the idea of nested control loops at operational, organisational regulatory and even political level, that together form a sociotechnical system (e.g. Rasmussen and Svedung, 2000; Leveson, 2016), a similar investigation logic could even be extended beyond an organisation's SMS. In this paper, an innovative method called SAFRAN was employed to investigate how to analyse an organisation's capability of managing the sustainable performance of its processes in the context of an adverse event, detecting possible areas for improvement and safety learning from the factory floor to the Board room, and beyond.

event	sources of performance variability	iteration of the process to "manage source of variability"	elements of monitoring (over-)speed	iteration of the process to "monitor over-speeding"
Fukuchiyama line (JAP) April 25, 2005	driver attention, impacted by: -> stress, due to earlier station overrun -> pressure to contact train conductor -> driver taking notes -> negative reinforcement regime missing engineering control system	no further structured analysis	non-reporting of prior occurrences, although required	non-reporting of prior occurrences, due to: -> negative reinforcement regime active reflection on possibility to monitor speed at critical curves, resulting in a recommendation to monitor speed using already existing technology
Aldershot, Ontario (CAN) February 26, 2012	driver memory driver expectations driver experience quality of rules visibility crew interaction missing engineering control system	no further structured analysis	prior similar occurrences listed	not mentioned in the report curiously enough, the regulatory requirement to implement and maintain an SMS is mentioned, including the obligation to have "monitoring and evaluation processes for all aspects of operations."
Santiago de Compostela (ESP) July 24, 2013	driver attention, impacted by: -> answering an internal telephone call lineside signs system design missing engineering control system task complexity task monotony	for processes to "manage driver competence" and "equip lineside signs" only specifications have been identified - limiting the investigation to a pure compliance check for processes to "equip engineering controls" also the "verification process" has been analysed, but for all only specifications have been identified	performed by railway undertaking: - accompany of train - review of safety recorder content performed by infrastructure manager: - inspection of speed recorders	internal regulations and number of performed monitoring activities are listed no reflection on why these monitoring activities did not enable to identify the critical variability

event	sources of performance variability	iteration of the process to "manage source of variability"	elements of monitoring (over-)speed	iteration of the process to "monitor over-speeding"
Philadelphia (USA) May 12, 2015	driver attention, impacted by: -> emergency situation with other train missing engineering control system driver competence driver fatigue driver fitness to work driver vigilance task complexity	process to "train crewmembers" has been further analysed (steps 1, 2 and 3) for process to "equip engineering controls" only specifications have been identified	not mentioned in the report	not mentioned in the report
Buizingen (BEL) September 10, 2015	driver expectations driver experience decision making skills, impacted by: -> recent leave lineside signs	process to "manage driver competence" has been further analysed (steps 1, 2 and 4), without however identifying what could be the critical variability	sample based analysis of speed recorder data	identification of poor monitoring capability no further structured analysis is elaborated, with the report surprisingly stating "the difficult detection of this type of events" as an argument to explain poor monitoring
Fletton Junction (GBR) September 11, 2015	driver fatigue engineering control system lineside signs driver experience driver expectations time pressure	processes to "manage driver fitness" and "equip lineside signs" have been further analysed for process to "equip engineering controls" only specifications have been identified	(non-)reporting of over-speeding incidents OTDR downloads to monitor compliance with speed restrictions	only the monitoring (and learning) capability based on reported incidents has been further analysed, identifying (monitoring) task instructions and supervisor training as possible sources of performance variability for the process of "monitoring over-speeding".

Table 2. Overview of analysis findings

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On some issues related to the railways events impact on other industries

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Abstract

In some complex industrial systems, as the Nuclear Power Plants (NPP) the evaluation of the potential risks induced both by natural phenomena and man-made, like for instance railways events in their proximity, are of high importance. This trend became even more important for NPP after the latest accident in Fukushima. Therefore, the re-evaluation of the risks induced by external events to the NPP became very important. This trend is supported by implementing new methods for external risk evaluations. One of the new methods defines an external challenge as a hazard, which has an associated risk description. The description of external risks by using hazard risk curves is usual for seismic, airplane crash or other external hazards. Therefore, the use of this method for railway hazards is expected to be useful in improving the risk analyses for NPP. The paper presents a case of preliminary study on the use of hazard curves to evaluate risk on the NPP.

Keywords: Probabilistic safety analysis, Risk, Fragility curve, Hazards curve, railways

1. Introduction

Industrial activities, including the railway traffic and its potential impact, are evaluated as part of the risk analyses for the Nuclear power plants (NPP). Currently, for most of the industrial activities, the evaluations are on a case-by-case basis, depending on the type of challenges.

Potential challenges due to the railways in the proximity of a NPP are related to the type of the damages induced, depending on the transported materials/substances. The evaluations are so far based on the analyses of such cases for potential fire and /or explosion risks and deterministic calculations are used.

However, the evaluation of deterministic type needs to consider the variability of the accidents/incident's statistics, which may indicate that there might be cases when the deterministic analyses are conservative.

The best-known standardized methodology for the NPP is the Probabilistic Safety Analyses (PSA), which is used both for internal and external events. The PSA model for external events starts usually from the evaluation of plant reaction to the internal events is modelled in PSA, by adding on the external events impact.

For the case study a set of real data was used and some probabilistic characteristics used as input are represented in Figure 1.

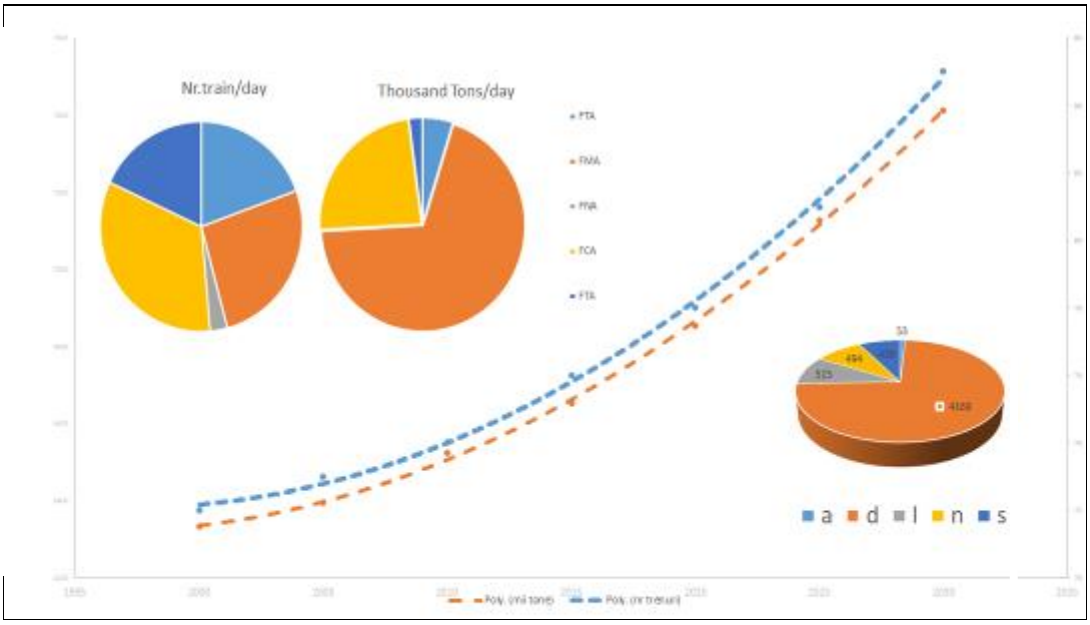

Figure 7. Probabilistic characteristics of railway events considered in the case study [1]

The impact of the railway accidents and / or other events is evaluated using a specific for the evaluation of the risk impact on NPP, called the hazard curve methodology. The results of the case studies are analysed and conclusions are drawn for the future work.

2. Method and case study results

The process of building an integrated PSA model for internal and external events is represented in Figure 2.

The process comprises the development of three modules. It starts from the development of the internal model and of the preparation of the external challenge input in the format suitable for PSA approach and it is followed by their integration for overall risk evaluation.

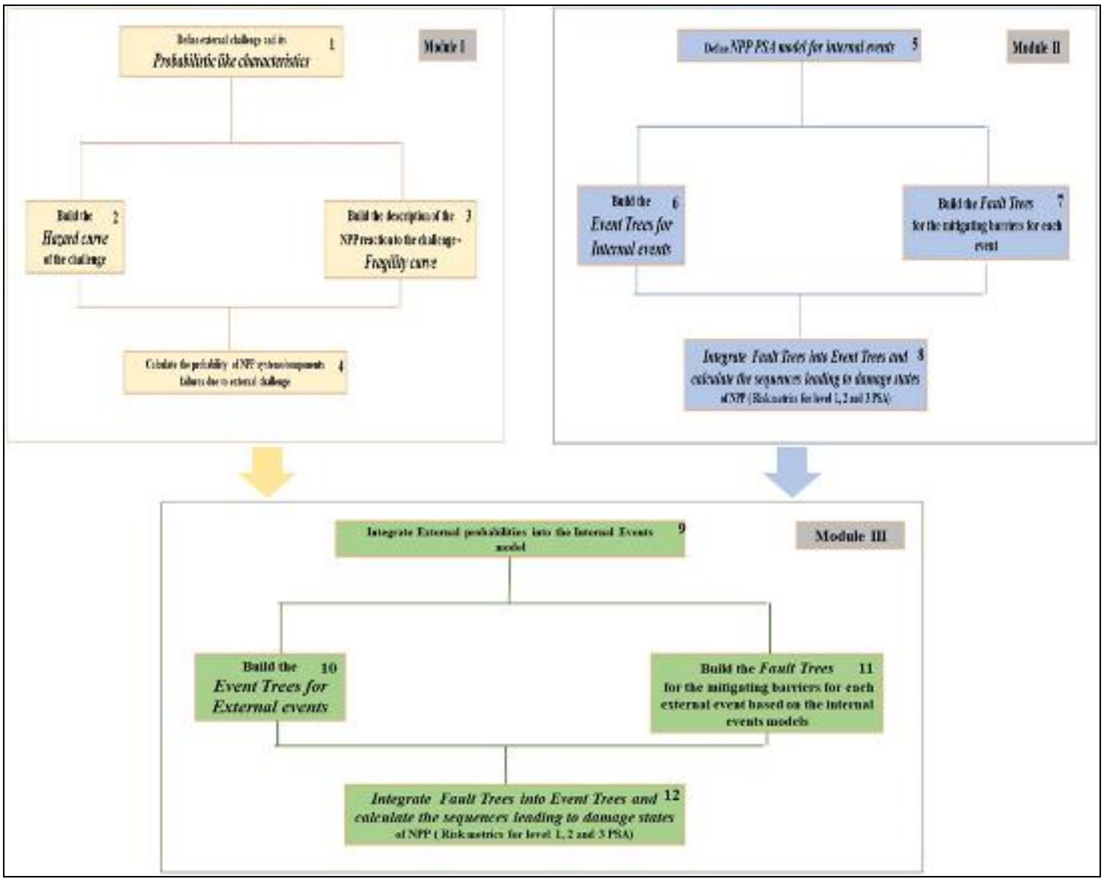

Figure 8. The flow path with the main steps of the Hazard risk methodology applied for railway events

The following main steps are performed in the **Module I:**

1. Step 1 Define external challenge and its ***Probabilistic like characteristics***
2. Step 2 Build the ***Hazard curve*** of the challenge
3. Step 3 Build the description of the NPP reaction to the challenge -***Fragility Curve***
4. Step 4 ***Calculate the probability of NPP systems/components failures*** due to external challenge

Module II is developing the internal events plant model in the following basic steps (the detailed tasks, as described by the standard are extensively presented in the literature [2;3]):

- Step 5 Define NPP ***PSA model for internal events***
- Step 6 Build the ***Event Trees for Internal events***
- Step 7 Build the ***Fault Trees for the mitigating barriers for each event***
- Step 8 ***Integrate Fault Trees into Event Trees*** and calculate the sequences leading to damage states of NPP - Risk metrics for level 1, 2 and 3 PSA due to challenges (Initiating Events) Internal and /or External:
  - ***Level 1*** (Impact on the plant without containment) - ***Core damage frequency (CDF)***
  - ***Level 2*** **(**Impact on the plant considering containment) - ***Large Early release Frequency (LERF)***

– ***Level 3*** (Impact on the personnel, population and environment) - ***Risk calculation on personnel, population and environment (Risk)***

In the **Module III,** the two parts (preparation of the external events impact in a PSA like format and the development of internal events model), are integrated in a single model in the following main steps:

- Step 9 ***Integrate basic events of component failures*** and calculation of railway related initiating events probabilities and their integration in the Internal Events model
- Step 10 Build the ***Event Trees for External events***
- Step 11 Build the ***Fault Trees*** for the mitigating barriers for each external event based on the internal events models
- Step 12 ***Integrate Fault Trees into Event Trees and calculate the sequences leading to damage states*** **of NPP** *(Risk metrics for level 1, 2 and 3 PSA)*

This paper presents only the main **differences and specifics of using the methodology** framework represented in Figure 2, as follows:

1. **The external challenge (probability to have railway events with potential impact on an NPP)** is based, in this case study, on specific data, as it was mentioned before and it is represented in Figure 1.

2. Based on the probabilistic characteristics and evaluation of the potential damages on the nearby NPP **the curve defining the Railway Hazard is defined** (Figure 3). The curve is divided in discrete intervals for which probabilities of exceedance of a certain impact level from the event to the plant are considered (HR_i). The case study if grouping the resultant HR_i into three groups (RH_{I}, RH_{II}, RH_{III}). Those three groups define three Railway related external initiating events.

3. For the plant components, designed to be a barrier for potential challenges from the railway events, a set of **Fragility Curves** are derived (Figure 3). During the step xxx the probabilities of failures of plant structures/systems/components and the evaluation of the railway.

4. For each group of railway related initiating events (groups RH_{I}, RH_{II}, RH_{III}) the plant reaction assumes that a certain set of barrier is designed and a certain failure mode and magnitude may take place for its components (as it will be presented in the paragraphs below on event trees and fault trees). The basic events (**Railway generated plant components failure probabilities"** for NPP components are coded as in formula (1):

$$RH_{i}\_BE_{j}\_k = BE_{ik} \qquad (1)$$

The BE_{ik} are calculated as in formula (2) (and represented in Figure 3)

$$\begin{aligned} &\textit{Probability of failure } PR_i = \\ &= (\textit{Hazard Curve group probability of exceedence}_{I,II,III} \otimes \\ &\quad \otimes (\textit{Fragility of component for a given group}_i\,) \end{aligned} \qquad (2)$$

where the sign ⊗ represents the calculation of the convolution integral, for a certain uncertainty level

The details of the evaluation of the component failure probability due to external challenge are defined in previous applications, as for instance in the seismic PSA models and it is represented largely in the literature (as for instance in [3]).

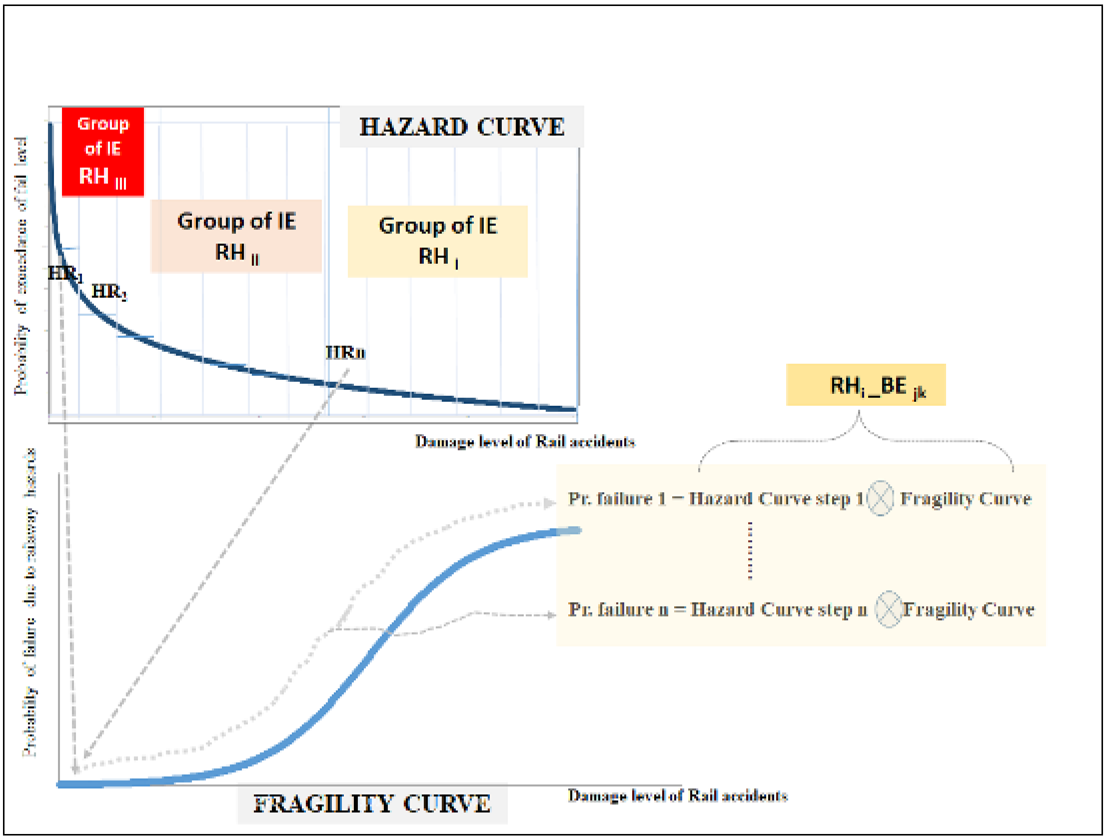

Figure 9. Presentation of the flow path for the risk evaluation by using the hazard curves

5. **Event Trees are built for each group of railway related initiating events** (IE_RH_I, IE_RH_{II}, IE_RH_{III}). In the event trees the **barrier systems** (RH_SYS_1, RH_SYS_2, RH_SYS_3) are considered to be designed to withstand a certain level of the challenge (a certain group of the initiating event) as represented in Figure 4. The function event BAS_MOD is a connector with the internal events part of the model. In the event trees the following end states are defined:
   - **End states designating situation of now impact on plant, but leading to various level of emergency states** declared **in a preventive manner** (on increasing magnitude with their indexes 0,1,2,3).
   - **End states leading to the increase of the risk level** of the plant (the coding is related in this case study to the PSA level 1 risk metrics ΔR_0, ΔR_1, ΔR_2.).

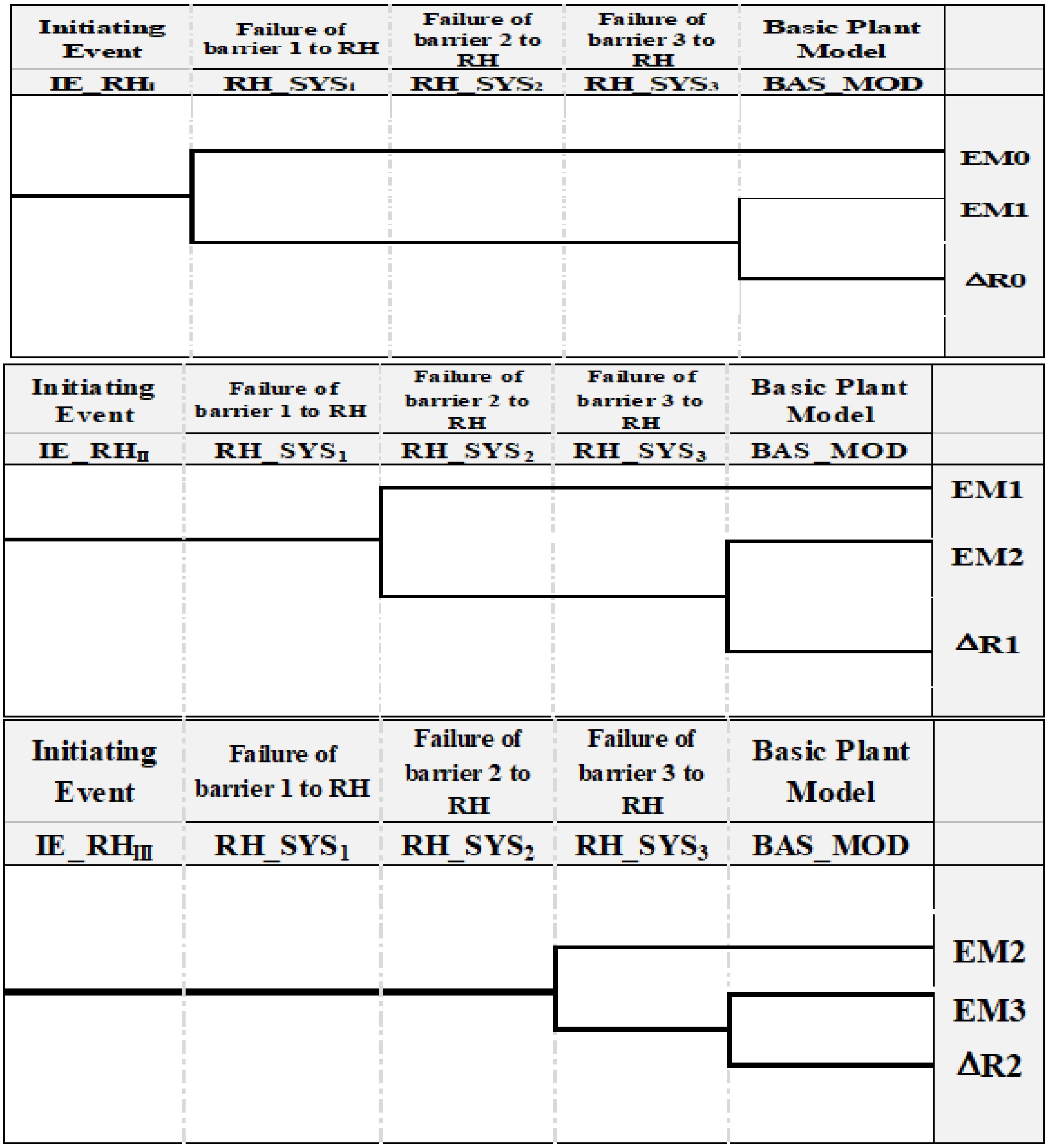

Figure 10. Event Trees for the Railway Initiating events

6. **Fault Trees are built for each group of barrier systems** designed to withstand also an impact of the railway events (RH_SYS_1, RH_SYS_2, RH_SYS_3) as represented in Figure 5. Special techniques existent in previous studies [3] are used to include external events impact on the internal events model (represented in principle in Figure 5).

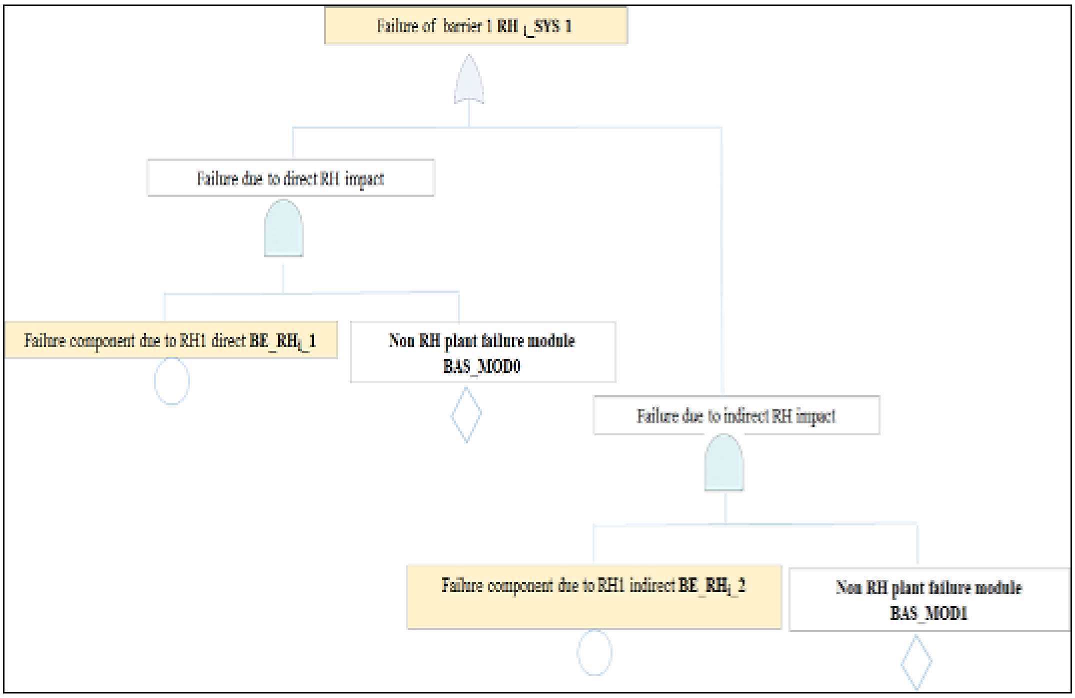

Figure 11. Fault Tree for the barriers designed to withstand railway events, too

The modules coded BAS_MOD represent the fault Tree part available from the model of internal events. This module is coded as per formula (3)

$$BAS\_MOD\_AFFECTTED_m = B_m \text{, where m=1,2} \quad (3a)$$

$$BAS\_MOD\_UNAFFECTED = BAS\_MOD \quad (3b)$$

7. During the last step of the methodology the in***tegration of the Fault Trees into Event Trees is performed and the calculation of the sequences leading to damage states*** **of NPP** (Risk metrics for level 1, 2 and 3 PSA) is performed. The process is presented in summary in formulas (4) – (7).

$$\Delta R_0 = (IE_1 * (B_{11} * B_0 + B_{12} * B_1) + \sum_{m=0}^{1}(B_m)) + BAS\_MOD \quad (4)$$

$$\Delta R_1 = (IE_2 * (B_{21} * B_0 + B_{22} * B_1) + \sum_{m=0}^{1}(B_m)) + BAS\_MOD \quad (5)$$

$$\Delta R_2 = (IE_3 * (B_{31} * B_0 + B_{32} * B_1) + \sum_{m=0}^{1}(B_m)) + BAS\_MOD \quad (6)$$

$$\Delta R_{TOT} = \Delta R_0 + \Delta R_1 + \Delta R_2 \quad (7)$$

The results of the risk impact are represented in Figure 6, which illustrates that:

- **There is an impact** of considering the external challenges generated by events on the railway.

- There are combinations of **non-railway related plant failures** and **railway related plant failures**, which usually are not considered in a pure deterministic analysis. The screening of such combinations gives the confidence that the conservatism of risk metrics is preserved even for such combination cases.

- However, **the values are still under the limits** that require special actions for additional protection of the NPP.

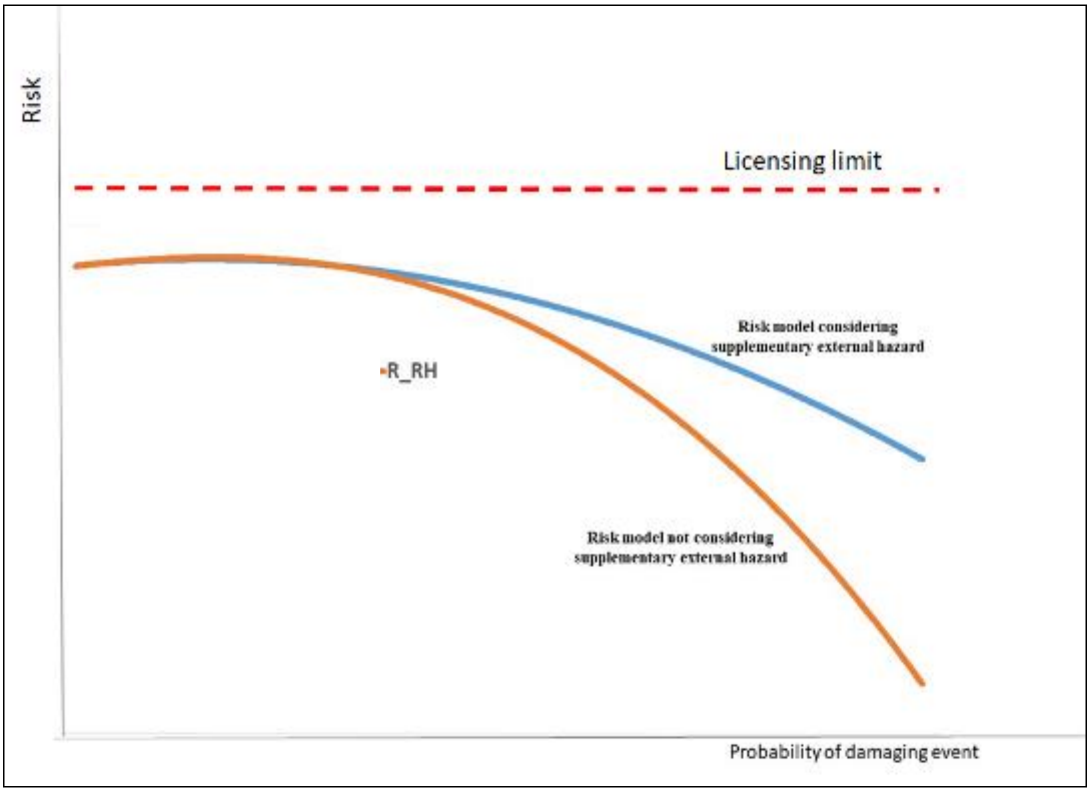

Figure 12. Risk profiles for the basic case and the case study considering railway events

3. Conclusions

The paper presented the results of a case study of using the hazard curve and fragility approach modelling for the railway of the potential risks on an NPP.

The case demonstrated the feasibility of the use of such an approach for external events of railway type and the fact that its use assures a greater confidence that the results are still conservative, even if unexpected external induced events and internal failure combinations take place.

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SESSION 6:

Case studies

Historical contradictions in railway sector work accidents in which workers are run-over by trains: analysis based on the Cultural Historical Activity Theory

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Abstract

The Cultural-Historical Activity Theory (CHAT) enables us better to understand work accidents as the unexpected results of contradictions generated by the historical and dialectical relationships between the different elements that compose an activity system. The objective is to highlight historical contradictions that might contribute to the occurrence of accidents in the railway sector in which workers are run over by trains. Ethnographic data collection was undertaken. In recent years, 9 work accidents and 12 deaths due to this cause occurred in this company which has a highly hierarchical organizational structure, and was created by the merger of three companies 12 years ago and as a result of which there still persist vestiges of the cultures of the original companies. There is a lack of workers in various departments, as well as a lack of materials to carry out maintenance activities. It is a state-owned enterprise in which the procurement of new materials and hiring of new employees is a time-consuming process.

Among the hypotheses of historical contradictions that contribute to the occurrence of accidents there are technological quality changes and an increase in the demand for passenger transport and the flow of trains, which reduce the time available for maintenance and adjustments in the system. In addition, there is a hypothesis relating to difficulties in coordination between different departments, the goals they are submitted to, and the material, technical and professional conditions for carrying out the activities.

Keywords: Accident analysis; Cultural Historical Activity Theory; Contradictions; Organizational Learning, Railway

1. Introduction

Work accidents are complex events that require detailed and deep analysis for their prevention. It is still very common to come across work accident analyses that reduce the event to the consequence of a few causes, and usually all the complexity of the event is understood as due to an unsafe act on the part of the operator or a failure in the related material conditions. There has been a change in the comprehension of the work accident analysis approach from the reductionist ones to a broader, systemic approach (Vilela, Iguti and Almeida, 2004; Llory and Montmayeul, 2014; Dien, Dechy and Guillaume, 2012).

Based on this systemic perspective, the Model of Analysis and Prevention of Work Accidents (MAPA, in Portuguese) was developed during a public policy project between 2007 and 2009 (Almeida et al., 2014; Almeida and Vilela, 2010). MAPA is based on the Ergonomics of Activity (Wisner, 1994; Guérin et al., 2004), cognitive psychology (Clot, 2006) and Organizational Analysis of Events (Llory and Montmayeul, 2014; Dien, Dechy and Guillaume, 2012), and proposes some categories of analysis that help to understand the event: Habitual Work Analysis, Change Analysis, Barrier Analysis, and Conceptual Expansion (Almeida and Vilela, 2010).

Using the Organizational Analysis of Events, the investigator tries to understand in depth the systemic and historical origins of the accident in relation to production, procurement and maintenance processes and the conditions of the materials which determine the operational modes. For this, it is important to understand the Pathogenic Organizational Factors (POF) which correspond to an organizational degradation that leads to the occurrence of phenomena which diminish safety. Some POFs are commonly found in accident analyses and include time pressure; insufficiency or lack of a safety culture; complexity, obscurity or maladjustment of the organization; the fragility of control bodies, and the lack or inefficiency of the feedback from operational experience (Llory and Montmayeul, 2014; Dien, Dechy and Guillaume, 2012).

After this expanded analysis, the investigator proposes some recommendations for implementation, but the organizational recommendations are not usually implemented by the company concerned. Cedergren (2013) points out two factors involved in the challenge presented by the process of the implementation of recommendations: first, the trade-off between the internal and external actors of the company, and second, that between the micro and macro levels. Both these trade-offs are usually made by individual actors, and the author observes that the co-ordination between the different actors involved in the implementation process is important.

Besides that, the accident analyses are usually undertaken by experts and do not involve any other of the company's actors (Osório, Machado and Minayo-Gomez, 2005; Vilela et al., 2018), especially that ones who will implement the actions, and when it involves them, they participate mainly as informants during the accident analysis process. Moreover, the accident analysis is not based on a learning theory - which hinders the organizational learning and the implementation process.

Despite the relevance of historical prospection to the understanding of the incubation period of the POFs (Dien, Dechy and Guillaume, 2012), it is not clear in the Organizational Analysis of Events approach, how to conduct this historical analysis and, when following this path, how to identify and grasp the contradictions that underlie the accidents and how they arose historically within the system.

To conduct this narrative some research questions, emerge:

- What is the activity system under analysis? What are its elements today and how and when were they modified in the past?
- What historical events favored the changes made in the activity?
- What contradictions led to the development of the activity and in what direction?
- What contradictions underlie the disturbances observed now and in the past?

Within this perspective, the Cultural-Historical Activity Theory (CHAT) presents some answers and helps one to understand work accidents and other organizational anomalies as the unexpected results of contradictions generated by the historical and dialectical relationship between the different elements that constitute an activity system.

The CHAT can be summarized in terms of five principles: the Theory of Cultural mediation by human actions; multivocality, historicity, contradictions as sources of changes and development, and the possibility of expansive transformations in activity systems (Engeström, 2001). Many accident analyses do not present any well-defined unit of analysis and CHAT can contribute in this way by the use of an activity system.

The activity system (Figure 1) is considered the unit of analysis and is composed of a subject whose perspective of analysis is driven by an object (the motive of a collective activity). Here, subjects' actions are mediated by instruments. The activity system has rules that need to be followed within the context of the division of labor and with a community which also intervenes in the object. All these elements interact dialectically among themselves over time and are dynamic. Some contradictions can occur within one element or between elements, thus giving rise to unexpected results (Engeström and Sannino, 2011) such as work accidents in the health and safety area.

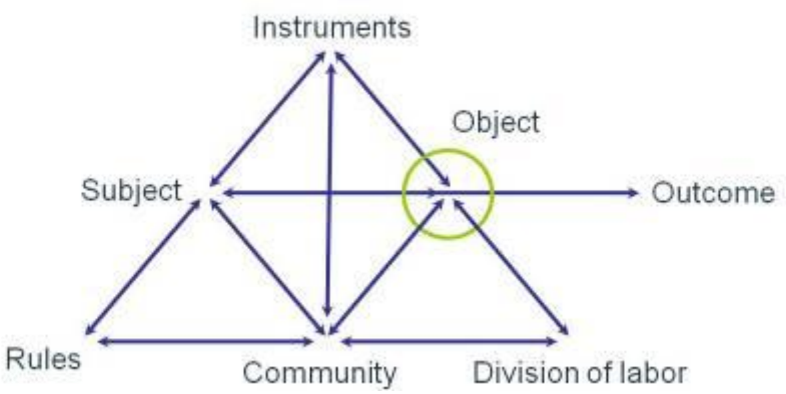

Figure 01: Activity System Model
Source: Engeström (1987; 2016).

There are but few studies that use CHAT in accident analyses (Nuutinen, M, and Norros, 2009; Yoon, Ham, and Yoon, 2016; Lopes, Vilela and Querol, 2018) and this paper presents this innovation, important to this discussion. For this, an empirical case within the Brazilian railway context - which is a complex system and can help to understand the potential of the tool – will be used.

In recent years, nine work accidents and 12 deaths caused by trains' running over workers occurred at this company. Thereafter, the Labor Prosecution Service sought a researcher from the São Paulo University - School of Public Health to help with the accident analyses. It was then proposed that the MAPA (Antunes, Vilela and Almeida, 2018) be applied and a formative intervention undertaken using Change Laboratory concepts and tools (Engeström, 1996; Virkkunen and Newham, 2015) to help understand the accidents and implement any changes considered necessary to prevent new events.

The objective of this paper is to highlight the historical contradictions that may contribute to work accidents in which workers in the railway sector are run over.

2. Method

This research adopts a qualitative approach. It can be divided into two phases: the ethnographic phase and the formative intervention phase which consists of sessions based on MAPA along with the CHAT and the Change Laboratory (CL) method (Engeström, 1996). The formative intervention seeks to create a new activity concept and present solutions with a view to overcoming contradictions by developing the agency of the actors involved (Virkkunen and Newnham, 2013; Engeström, 2011).

For the ethnographic phase, 46 individual and collective interviews and two sessions of Collective Work Analysis (ACT, in Portuguese - Ferreira, 1993) were conducted and the observation of activities related directly or indirectly to work accidents in which workers were run over and the related documentary analysis were undertaken. ACT is a method that helps to understand the real work done, and is applied by posing one leading question "What do you do at your work and how do you do it?" which will be exhaustively detailed by a homogeneous group of workers. The interviews, to a total of 29 hours, with workers from different positions and departments were recorded, and the ACTs lasted 5 hours.

Four workshops, to a total of 40 hours, were conducted with 49 workers, on the methods to be used. These workshops were planned according to the double stimulation method (Engeström, 2007), and they were applied in such a way as to help the participants to understand and apply the MAPA and CL methods and their principles.

The interviews and workshops were recorded and transcribed. These ethnographic data were analyzed based on CHAT, and helped to build the hypothesis from the main historical contradictions within the activity system which will be presented in this paper. They will also be used as mirror data on the formative intervention phase. The mirror data reflect the reality and will stimulate the participants during the debate of the next phase (Virkkunen and Newnham, 2015; Engeström, 2011).

The results are preliminary and after this phase the Model of Analysis and Prevention of Work Accidents – MAPA in Portuguese (Almeida and Vilela, 2010) will be applied together with the CHAT and the Change Laboratory to implement changes, which is also an innovation that enables collaborative analysis with workers from the company to be made and organizational learning to occur.

The CL method creates a favorable environment for the construction of theories, models and concepts about the learning process and management organizational development which contribute to an expansion of concepts and ideas for the understanding of the activity system (Querol, Cassandre and Bulgacov, 2014; Querol, Jackson Filho and Cassandre, 2011; Virkkunen and Newnham, 2015; Engeström, 2007).

For this, 8 sessions will be applied based on the double stimulation method and on the expansive learning cycle to provoke the actors' agency and their protagonism. The participants will debate the main problems of current practice, making an analysis of their historical contradictions and then creating new solutions based on this analysis. In this empirical case, they will together analyze the work accidents in which workers are run over and create collaborative solutions. It will be important to listen to different voices during these sessions (Virkkunen and Newnham, 2015). They will be recorded and filmed for future analysis.

This research is part of a Thematic Project "Work Accidents: From socio technical analyze to the social construction of changes" (FAPESP process nº 2012/04721-1) which has been approved by the Ethics Committee of the School of Public Health of the University of São Paulo nº CAAE 11886113.5.0000.5421.

3. The railway activity system

CHAT helps to understand accidents within a dialectical, systemic, historical, and dynamic perspective. For this, it uses the activity system as a unit of analysis, which helps systematize, understand and analyze complex systems. As has been said above, tensions can arise over the years between elements of the activity system that lead to unexpected results, such as accidents, rework, occupational diseases, etc.

In the empirical case of this railway system (Figure 2), the subject was the railway company X (subject) taken as the perspective of the analysis whose object is the safe transport of passengers.

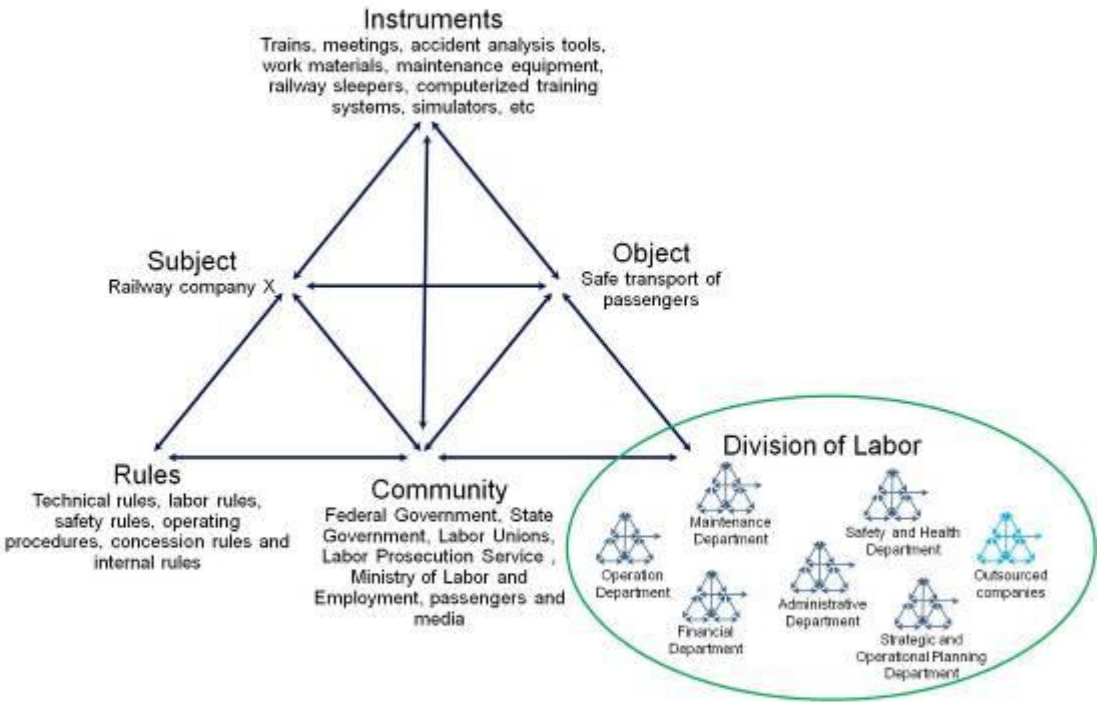

Figure 2: Railway Company's Activity System

The activity of passenger transport is mediated by the use of instruments such as trains, meetings, accident analysis tools, work materials, maintenance equipment, railway sleepers, computerized training systems, simulators, etc, and must follow rules such as technical rules, labor rules, safety rules, operating procedures, concession rules and internal rules. It is a state-owned company that follows the rules of the state government, like norms for the procurement of human resources, as well as of materials and equipment.

Some of these rules are developed by public institutions, such as the federal government, state government, the Labor Prosecution Service, and the Ministry of Labor and Employment. These institutions, besides producing rules for this activity system, also act as part of the community, intervening to ensure safe passenger transport (object) by means of the interdiction and inspection of the activity and the production of rules as well. Other important elements of the community are the passengers and the media, which are always demanding better conditions of transport and the punctuality of the service, thus interfering in the object of the transport activity.

Finally, to deal with this complex object, this activity system presents a division of labor which consists of various departments and outsourced companies, such as those relating to health and safety, maintenance, operation, strategic and operational planning, administration, finances, etc.

3.1 A dialectical, systemic and historical perspective for the understanding of work accidents

The ethnographic phase permitted the elaboration of the historical hypotheses regarding the contradictions (Figure 03) that contributed to the occurrence of work accidents and other organizational anomalies, which will be detailed throughout this section.

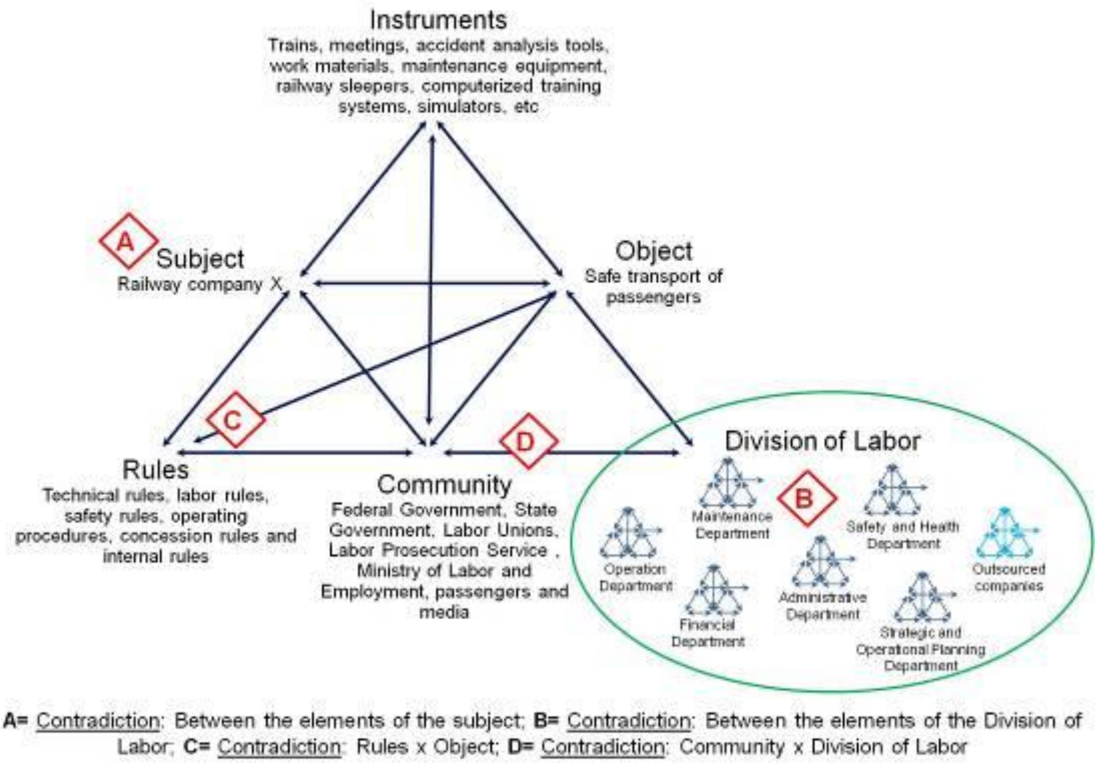

Figure 3: Main contradictions in the railway sector and the work accidents

Historically, this company X was formed 12 years ago by the merger of three previously separate companies (1, 2 and 3). However, according to workers' reports, the distinct cultures of those original companies still persist. On the occasion of the merger, all workers, regardless of the conditions of their initial contracts, became employees of company X, though they are still classified according to their company of origin as coming from company 1, company 2 or company 3, or they are classified as "pure" when they have been hired, more recently, by company X.

The creation of an organizational identity and culture requires some time for its consolidation in a new organization (Daniellou, Simard, and Boissières, 2010). According to the origin of the individual companies concerned, there are differences in labor rights acquired as also in the work process itself and the method used to fill in documents. Further, in the history of the individual railway lines, different procedures were also observed according to their origin. At the time of the merger described above, there were technological, procedural and financial differences between companies 1, 2 and 3. In consequence, there continue to exist contradictions within the subject itself between the definition of identity as company X and the plurality of cultures present within it (Figure 03-A).

> *"And they [those hired from Company 1] still work today with the kilometer. And we [those hired from Company 2] there used to work with intervention between signals. And that still happens…There in the strategy department, when you receive a Request for Access from one line to another, if the person who made it comes from line B or C, you write "between signals". But if you get it from line A, D or E it is expressed in kilometers. And now as the Access request system was drawn up on the basis of a kilometer/post parameter, they put "kilometer/post"*

> *but in "Observations" we put "between signals" [...] That's a concept which I think is taking a long time to change [...] At the beginning it can cause some kind of problem. Afterwards you get used to it. But initially you feel a rejection, a desire to change it. But what is written there is the same thing as the other has written, just expressed differently."*

As a reflection of its history, this railway company presents a hierarchical organizational structure in its division of labor, which delays and reduces feedback between the different levels and also the access of the workers from the lower to the higher hierarchical levels (Daniellou, Simard, and Boissières, 2010). It is a company with many departments between which there are difficulties of coordination. In addition, safety is not integrated into company management, so in practice the safety department usually works separately from other departments. There is thus a hypothesis of contradiction due to the difficulty of coordination between the elements of the division of labor (Figure 03-B).

Over the years there has also been an increase in the demand for passenger transport and in the circulation of trains (object) and, as a consequence, a reduction in the time available for railway maintenance activities. Also reported during the ethnographic phase was that the same financial resources had been available over the last few years both to hire new workers and to buy new equipment to carry out the company's various activities (rules), including maintenance. In addition, in recent years changes have been made to some railways tracks that used to be shared with freight trains, which has increased the deterioration of the tracks and led to a correspondingly greater need for maintenance. There is thus a contradiction between a more complex object and the established rules not yet adapted to the new reality of increased demand (Figure 03-C).

It is noteworthy that many of these rules used by company X, such as those related to the hiring of new workers and the purchase of new equipment made by the state government by auction, have been made by the community. As it is a state-owned company, the auction process usually takes a long time and undergoes delays. When there are disputes in the judicial sphere, the process is delayed in court and new employees and equipment cannot be hired.

Also related to the community, it was pointed out that the railway sector is a very specific sector, calling for the specialization of workers which in its turn requires longer preparation; further, such persons are not easily available in the community. In addition, historically, many of these workers came from families with a tradition of working on the railway and had a passion for and an identity with the railway sector. Currently, due to the present tendering process, many workers begin with no experience in the area and without this "passion" for and identity with it. There is a contradiction between the lack of engaged, committed and qualified professionals in the community to be hired to work in the rail sector and the expertise demanded by the division of labor and hiring rules (Figure 03-D).

> *"In fact I came here young. I am proud to be a railway worker, so that every novelty that appears related to railways I read about [...] So being a railway worker to me is a matter of pride, I am the son of a railway worker, grandson of a railway worker. I have grandparents who were railway workers, an uncle who was a railway worker, I am also the last generation here. It is because my son is studying production engineering and I don't know if he will want to come to work here."*

Another point raised during the ethnographic phase was related to the creation of operating rules and procedures inside company X. After some serious accidents and fines applied by the Labor Prosecution Service (community), company X began to encourage the creation of operational procedures. Nowadays, there is a large number of such procedures. There is a hypothesis that because of the heavy workload required due to understaffing, it is not always possible to go to the field to verify the real needs and talk with the workers in the field. There were discrepancies between the activities prescribed in the procedures and their implementation in practice (prescribed work versus real work).

> *"The rule states you have to maintain a distance of 1.80m from the tracks while you inspect them with trains circulating. But how can you make a good inspection and check on any problems from that distance? It is impossible!! You have to be right on the tracks to do the job well. And at night there is just not enough light to enable you to make a good inspection. You have to do it during the day while the trains are in movement."*

With regard to the activities carried out on a permanent railway track, it was mentioned that workers from outsourced companies earn according to their production for activities such as the changing of railway sleepers, and there is a resulting intensification of work which means the workers put their own safety at risk to produce as much as is possible.

The main contradiction may be summed up in terms of the conflict between, on the one hand, good-quality work and the rapidity necessary to avoid stopping trains and not diminish the passenger flow and, on the other, compliance with the safety procedures which state trains must be stopped for the maintenance job to be done, which reduces the passenger flow. The rules cannot be followed because it is necessary to see the rails and components from close up. On the other hand, failure to follow the rules exposes workers to the risk of undertaking operations on the track and thereby increasing the risk of accidents in which workers are run over.

The increase in passenger demand and the demand for good quality services (object), pressure on the part of the passengers and the media (community), all lead to the briefest possible interruptions for maintenance (rule), which also reduces the time for the maintenance carried out on the rails. The maintenance activity (division of labor) is therefore preferably performed at night when there is no movement of passenger trains, however, depending on the line, it may be shared with freight trains which also reduces the time available for maintenance.

This results in time pressure for the execution of maintenance activities, aggravated by the reduced staffing (division of labor), with insufficient materials (instruments) available for the job. This creates a situation which facilitates the occurrence of fatal work accidents in which workers on the tracks are run over (an undesirable outcome). Many workers try to remedy these difficulties by acquiring the necessary materials for their activities themselves and also by leaving aside some procedures, in which they adopt, for example, new methods of carrying out their inspections different from the prescribed methods which are of better quality and safer.

4. Final Considerations

It has been shown that historical analysis deals with activity system created from the juxtaposition of companies fusions, that is to say, fusions which result in previously inexistent interactions, cultures, technologies, types of equipment, teams, activities and practices. The resulting, new system continues to maintain different, parallel procedures that have historically operated on some lines, creating situations in which it would essentially fall to the operators to ascertain in what type of situation they find themselves. Maintenance personnel, with no experience of acting in this type of situation, are selected to participate in such interventions in these segments.

Further, initiatives are taken for the application of technological innovations, such as the creation of new computerized centers for traffic control, without the necessary related modernization of the trains, methods of communication and other related services and equipment. This process has already been described as an asynchronous evolution of the system and has been seen as creating new types of hazard and risk, especially in the interfaces between the new activity system and the old.

Unfortunately, the new challenges that this process presents to safety were not previously recognized as requiring the adoption of related prevention strategies. In addition to this time lag, the non-detection of and failures in the correct interpretation of the warnings provided by the accidents which occurred in the system, in particular those involving collisions of trains with workers discussed in this study, were not perceived. Superficial, hasty investigations attribute such occurrences to human error, namely to the unsafe acts practised by the operators involved; and the system was thus deprived of the opportunity for learning.

One of the main contributions of this study is the way it highlights the need for an integrated new safety system, closely related to the notion of activity system. Safety in permanent monitoring should involve the anticipation of changes, of necessary adjustments, the recognition of emergent risks and hazards as well as the capacity for system adaptation. A safety that is not restricted to the management of equipment for personal protection and that includes in its agenda the notion that total safety requires the combination of normative practices with those of safety in action, understood as that which is carried out to deal with variability, uncertainties and challenges for which there are no rules that would indicate *a priori* what needs to be done.

From this point of view, CHAT contributes to safety by using the activity system as a unit of analysis which contributed to the visualization and understanding, systemically and historically, of the development of the railway activity system on both the micro and macro levels and the contradictions within it which led to collisions involving trains and workers in work accidents. Based on this analysis it is possible to create systemic solutions to prevent similar events.

In addition, as a continuation of this research, it is necessary that these hypotheses of contradictions should be confronted and debated in the next phase of the MAPA and Change Laboratory sessions so that the participants are able to assume responsibility for the work accident analysis process and become protagonists in the process of change in the health and safety areas, thus avoiding undesirable events such as work accidents and other organizational anomalies.

Acknowledgements

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An historical and organisational point of view on Bretigny 2013 railway accident

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Abstract

The railway accident that occurred 12 July 2013 in Brétigny-sur-Orge has deeply impacted the French railway sector. It is one of the deadliest disasters to have occurred on the French network in recent decades. But it is also and above all an accident that has seriously challenged the national railway network maintenance policy as it has been conducted for more than thirty years.

The analysis of this railway disaster takes us right to the heart of the organisation of a large scale socio-technical system that has undergone far-reaching changes in a context focused on productivity gains. It reveals many examples of dynamics that, at different levels of the organisation, can contribute to the degradation of the security of the system.

We show in particular how regulatory changes and productivity pressures have led the network manager to undertake various reforms that will result in radical changes in maintenance. This transformation was affected by a succession of adaptations and deeply impacted the fundamental equilibrium of track safety without any real consequence assessment. These weaknesses proved to be critical in a local sector that is subject to extreme traffic conditions in a highly unfavourable technical and organisational environment.

Most of the factors and mechanisms brought to light in the analysis of the Brétigny accident (productivity pressures, insidious impact of reorganisations, getting used to deviations, loss of skills…) can be approached in a generic way. As such, they constitute a useful source of feedback for industrial risks management.

Keywords: Industrial risks management, railway safety, feedback.

Warning

The analysis presented in this document is based on public sources. It does not claim in any way to identify individual or collective responsibilities for the Brétigny accident.

It aims to learn from the accident, on the basis of **feedback,** for the management of industrial risks. The objective is to **understand** the factors (technical and organisational) that may have contributed to the likely occurrence of the accident, in order to identify items that could be worked on to help **prevent** an industrial disaster. With this in mind, we are paying particular attention to generic aspects that could potentially be transferred to other socio-technical systems. This is therefore not an exhaustive analysis of the accident.

Introduction

On 12 July 2013 at 4:53pm, train n°3657 that ensures the national connection between Paris and Limoges, leaves the Paris-Austerlitz train station with 385 passengers on board. It consists of a motor and seven passenger cars. Its maximum authorised speed is 200 km/h.

When it approaches the Brétigny-sur-Orge train station (about thirty kilometres south of Paris), the train is travelling at 137km/h and accelerating to reach its cruising speed. At 5:11pm, the four last train cars derail over the switches and crossings area located 200 metres upstream from the train station, before toppling over and ram into the station platform. The accident killed seven people (3 train passengers and four people on the platform) and injured another 32.

According to the official reports of BEA-TT[68] [1] and SNCF[69] [2] [3] on the accident, the derailment was caused by a track failure. Both forensic experts [10], BEA-TT and SNCF CHSCT (health and safety committee) [4] point severe maintenance failures on the set of switches involved in the accident, questioning the maintenance policy of both SNCF and RFF[69].

Moreover, the maintenance policy for French rail infrastructure had been questioned for several years before the accident, notably through international audits (Rivier'2005 [6] and 2012 [7] audits) and through national public reports from the Court of Accounts [8] [9]. These reports describe a structural crisis in the maintenance of the railway infrastructures associated with decades of underinvestment by the public authorities.

On the basis of this abundant documentation, we will analyse how these productivity pressures have over time impacted the fundamental equilibrium of track maintenance and resulted in the end to a setting in the Brétigny-sur-Orge area that was conducive to the occurrence of an accident.

We will proceed with our analysis in four parts: first, we will present the track maintenance model as it is specified in the reference guides. We will focus in particular on the principles

[68] BEA-TT is the French public body responsible for investigating accidents in the land transportation sector (rail and road).

[69] **SNCF** is the historical French national railway company. Its maintenance department *SNCF Infra* was responsible for the implementation of the RFF maintenance policy for railway infrastructure. **RFF** (Réseau Ferré de France) was the public institution that owned the French railway infrastructure. It was responsible for defining and funding its maintenance policy (cf. Figure 13)

that can be used to ensure track safety. We will then use these items as a basis to understand and analyse factors likely to negatively affect this safety model. In the second part, we will then describe the structural crisis in the funding of the maintenance of railway infrastructures, which results in the aging and significant deterioration of the national railway network. Then, in the third part, we will study how this crisis has impacted over time the organisation of the maintenance and resulted in the significant deterioration of the safety management in Brétigny. Last we will mention in the conclusion (fourth part) the findings of this analysis for understanding industrial accidents and risk management.

Bodies involved with the maintenance of the French railway network

The French government has always played a leading role, as the architect and financier of the national railway system. It decides of the strategic orientations and controls the various public entities to which it has entrusted the management of the network.

From 1937 to 1997, the railway infrastructures belonged to the ***SNCF*** (*Société Nationale des Chemins de Fer français*), which was responsible for the development, maintenance and operation.

In 1997, as part of the European policy to open national railway networks up to competition, French lawmakers created a new public body, ***RFF*** (*Réseau Ferré de France*) to whom they transferred the ownership of all national railway infrastructures. RFF became the new network manager, responsible for its maintenance and operation. The operational maintenance of the network however remains the responsibility of the SNCF, via its subsidiary ***SNCF Infra.*** The maintenance policy results then in a contractual agreement between RFF, which specifies and finances the maintenance policy, and SNCF Infra, which applies this policy in the field and ensures the monitoring and maintenance operations on the equipment.

In 2014, the lawmakers brought together all RFF and SNCF Infra personnel and activities into one public entity called ***SNCF Réseau***.

Figure 13: Organisation of maintenance for the French railway network[70]

1. Track maintenance and safety model in France

Before going into the analysis itself of the accident, it seems necessary to present the main principles of track maintenance in France, and in particular those that are used to ensure its safety. This is what we will refer to as the *track maintenance and safety model*.

According to the SNCF reference guides, the purpose of track maintenance is to "*ensure the safe flow of people and performance of the network for the best maintenance cost*"[71]. This statement is widely reported by the management and highlights the three conventional

[70] Source [4]
[71] [5] page 1

objectives of an industrial system: safety, technical or functional performance (train traffic in this instance) and economic performance.

We will focus here on **three basic principles of track safety**: the preventive maintenance of the network in good working order to help prevent the occurrence of physical failures, the provisions to help manage systems that are periodically deteriorated, and the territorial organisation of operational maintenance around the brigade route.

1.1. Preventive maintenance of tracks to keep them from deterioration

The maintenance policy for French railways[72] is based on the **preventive renewal of the network** to help **keep the tracks from getting deteriorated**. This policy is all at once a performance objective in terms of operation, safety and economic optimisation of the maintenance.

Keeping **a network in good working order is the basis for track safety**. Preventive maintenance helps anticipate network deterioration and makes it possible to intervene (thanks in particular to the renewal of equipment) before physical failures occur. It helps reduce physical failures that could cause accidents.

It should be noted that a network in good working order is also a source of operational performance: it can help prevent traffic disturbances associated with equipment deterioration and corrective maintenance interventions.

Last the economic efficiency of the preventive track restoration is linked to the fact that an aging network generates an exponential increase of the corrective maintenance volume whose cost rapidly exceeds that of the preventive renewal of tracks. Examples in Germany, Spain or Switzerland prove that policies based on strong restoration investments achieve good technical and economic results [6] [9].

1.2. Precautionary measures to manage occasional deteriorations

In addition to the preventive renewal of tracks, a continuous monitoring of the equipment helps detect the deterioration of components (rails, switching and crossings…) in order to anticipate and prevent their failure. With this in mind, the reference guides provide a classification of the condition of the components split into four levels, and specify the precautionary measures to undertake in case of deterioration (see Table 1). The prescribed provisions may go as far as slowing down or stopping traffic when the deterioration level endangers train safety.

[72] Reference guides SNCF IN 00312, IN 0022, IN 0114.

Table 6: Qualification standard for the condition of track components

Qualification of the condition of the component	***Definition and precautionary measures required***[73]
Objective value:	Condition of a new or renovated system
Warning value:	Condition that is still acceptable but **observation** is needed for the purpose of increased monitoring.
Intervention value:	Poor condition that requires **correction in the short term** (response times are specified in the reference guides)
Slowdown value:	Highly deteriorated condition that requires, for **safety** reasons, for the traffic to be **slowed down or stopped**.

This system is designed to manage the occasional deterioration of a few isolated pieces of equipment, pending their renewal. As such the prescribed precautionary measures significantly impact maintenance activities: they impose complicated interventions with highly costly resources and tight deadlines that disrupt planning. The system is therefore not adapted to the sustainable management of an overall deteriorated network.

Finally, we emphasise **the crucial importance of equipment monitoring**, on which the whole system is based.

1.3. The assignment of a track sector to a dedicated team that is responsible for its maintenance.

Practically the operational maintenance of tracks is historically based on the *brigade route*, which is a 3-5 km track section, dedicated to a team that ensures both its monitoring and maintenance. The *team leader*, a foreman, is responsible for the condition and safety of his brigade route.

The brigade route constitutes a powerful tool to manage equipment: it defines responsibilities clearly, based on a detailed network grid and consistent with the activities of a team. Moreover, the fact that the team agents carry out all of the maintenance activities on their route allows them to gain an accurate knowledge of the equipment and maintenance history.

2. An aging network that is deteriorating due to a lack of investment

The Brétigny accident is part of a broader context of structural crisis in the maintenance of French railway infrastructures, in association with several decades of underinvestment.

We will first present some items that will help appreciate the level of underinvestment in the maintenance of French railways and its impact on the network. We will then present the

[73] These definitions are taken from the report by Cabinet Aptéis [4] page 61.

situation specific to the Brétigny sector that is subject to local factors that add significantly to the deterioration of the tracks.

2.1. A structurally unprofitable system that is inadequate to maintain the substance of the network.

From the 1980s onward, the French railway network has been suffering from a significant reduction in the government's financial commitment, thus resulting in a 20% budget decrease for network development and maintenance. This financial reduction was not accompanied however by an adjustment of the perimeter, in particular with the closing of less travelled secondary lines[74]. On the contrary, the government required SNCF, then RFF, to develop a significant network of very high-speed lines. Due to a lack of public funding, these works were paid with an unchanged budget to the detriment of the maintenance of the existing network.[75]

In comparison with other European countries, in 2005, the maintenance budget for the French network was more than 30% less than that of neighbouring countries (Italy, Spain and Switzerland - see Figure 14).

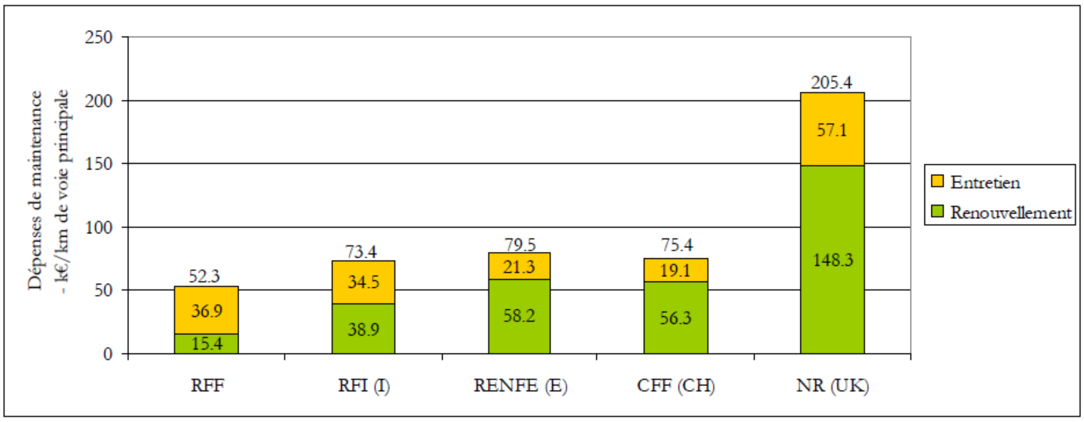

Figure 14: Comparison of track maintenance expenses between European countries [6]

What is striking beyond the overall amounts is above all the very low level of expenses for track renewal: in France, the investment level (per km of track) is 60% lower than that of Italy, 70% lower than that of Spain or Switzerland, and 90% lower than that of the United Kingdom. This means that the French network is hardly renovated thus leading to the aging of infrastructures.

Over time, the low investments in the renewal of tracks leads to a cumulated delay that is difficult to make up: **in 2011, it is more than 40% of the French network that has exceeded its normal renewal age.** Moreover, the aging of the tracks leads in the long term to an explosion in corrective maintenance costs, which, in a constant (or decreasing) overall

[74] While most of the other European countries have massively closed secondary lines in order to focus their resources on the maintenance of main lines, France has maintained an important secondary network (more than a third of the French network consists of lines that are used by less than 20 trains per day).
[75] SNCF, then RFF have had to heavily rely on loans to compensate for their insufficient maintenance and network development budget. RFF's debt amounted to 20Md€ in 1997, and 34Md€ in 2011.

maintenance budget means an ever-increasing reduction in resources dedicated to renewal. This spiralling situation resulted in the renewal rate of French tracks to be halved over 20 years.

In 2005, within the scope of an independent audit of the maintenance policy for the French railway network[76], international experts warn about the **risk of system failure** if nothing is done to stop the aging of the network, by boosting in particular massive investments for the regeneration of infrastructures:

"It is worth reducing the maintenance costs by regularly investing in renewal, a policy that is implemented by several European railway networks. Therefore, an inadequate maintenance policy incurs, in the medium and long term, a serious drift in infrastructure costs and/or performance, which can seriously affect the technical and economic efficiency of the railway industry. Such a drift is part of an exponential process. If it is detected too late, it ***can lead to the ruin of the railway network and deterioration of traffic safety and reliability****. Over time it incurs massive financial rehabilitation requirements, which must be raised very quickly. Great-Britain has acutely experienced this. Keeping working components to the very end reveals a lack of resources and/or lack of long-term vision for the system or "infrastructure" as a whole. Savings are made in the short term but to the detriment of the substance."*[77]

Experts outline an important consequence of network aging: the exponential increase in maintenance volume. Indeed, deteriorated pieces of equipment require corrective maintenance that proves to be more complicated and expensive than preventive maintenance. When a significant part of the network is in a deteriorated condition, the increase in maintenance volume quickly puts pressure on the maintenance organisations whose resources are otherwise constrained. The maintenance teams are then unable to keep the network in a state that complies with the reference guides:

"The maintenance managers responsible for the implementation of the policies specified by the reference guides are then facing a dilemma: allocate restricted budgets to actions that are vital and not to necessary and sufficient. They allocate resources on the basis of emergencies [..]. ***This situation makes the application of maintenance reference guides increasingly difficult in practice"***[78].

This situation is formalised by RFF with the introduction of "forfeitures". The network manager thus accepts the non-upgrade of certain track sectors due to a lack of resources. The sectors in question are then subject to precautionary measures to limit traffic, in order to guarantee traffic safety. This was explained by the Court of Audit in its 2012 report [9]:

"The adjustment that could not be made on prices occurred on volume, with SNCF adjusting its performance downwards from 2009 and 2010 onwards, that is a 30M€ decrease per year over those two financial years, when the maintenance need was simultaneously increasing with the continuing aging of the network. These planned production reductions, these

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[76] In 2005, as a result from the difficulties encountered by RFF and SNCF Infra in the contractualisation of agreements for network maintenance, both entities jointly commission an audit by international experts from the École Polytechnique Fédérale de Lausanne (EPFL, or Swiss Federal Institute of Technology in Lausanne). A second audit will be commissioned from EPFL in 2012 to assess how the situation changed when compared to the first audit.

[77] Rivier audit 2005 [7] page 14.

[78] Rivier audit 2005 [7] page 10.

"forfeitures" result in an agreed decline in network performance, mainly by way of traffic restrictions and slowdowns."

In 2011, some 3,200 km of tracks are subject to slowdown measures imposed by the forfeitures, thus representing 10% of the national network.

2.2. A specific local context that heavily penalises the Brétigny sector

We have noted that track aging impacted a significant portion of the national network. But the condition of the infrastructures varies greatly per location. Indeed, the speed of deterioration strongly depends on the level of mechanical stress to which it is subject and as such on the traffic conditions.

We will see that the Brétigny track sector is subject to highly penalising traffic conditions, both in terms of equipment configuration and traffic density. The combination of these factors leads to a critical level of stress on the equipment.

2.2.1. The intense traffic on the Brétigny sector accelerates track aging

The Île-de-France network is the heaviest in the country: it counts 30% of the national traffic in number of trains, and 70% in number of passengers, with an ever increasing traffic[79]. Moreover because of the density of its grid, the Île-de-France network counts a significant number of track equipment (in particular switching systems) that are fragile and difficult to maintain.

The Brétigny-sur-Orge track sector constitutes an important junction in the Île-de-France regional network, crossed by very dense suburban passenger transportation (in particular the C Line of the RER). Moreover, it is usually crossed by national lines for passenger transportation and freight, each generating significant traffic, with a total of 400 trains per day.[80]

This **convergence of three types of traffic with such density levels constitutes an exceptional configuration on the French network**. Its outcome is the **combination of mechanical stresses** associated with high passage speed (passenger trains of national lines pass at speeds ranging from 130 to 150km/h), significant volume of tonnage and frequent passages, **thus increasing the speed of aging and deterioration of the tracks**.

2.2.2. An inadequate track design that exacerbates equipment fatigue

In addition to highly penalising traffic constraints, the Brétigny-sur-Orge train station is also plagued by track design problem that further exacerbates track deterioration.

The presence of a railway junction results in a rather complicated railway tracks layout around the Brétigny train station. It is characterised in particular by a row of four double slip switch on a narrow plateau to enable the connection between the different lines (see Figure 15).

[79] Between 2000 and 2010, regional transport increased by 33% in Ile de France. The figures mentioned in this paragraph come from the 2010 report of the Court of Audit on rail transport in Ile de France [8].

[80] This traffic density puts the Brétigny track sector in the UIC 2 group. (UIC groups correspond to the classification of lines as defined by the International Union of Railways, depending on the density and type of traffic they support. It consists of 9 groups: UIC 1 group corresponds to heavily used lines whereas the UIC 9 group corresponds to lines with very little traffic.)

Figure 15: row of track equipment around the Brétigny train station

This equipment set has been experiencing recurrent problems related to the geometry of the tracks and repeated switching equipment failures since its installation in 1991. Defects and significant damages were discovered during each inspection visit carried out between 2001 and 2011. Considering only double slip switch 6-9 (the one implied in the 2013 accident), the maintenance teams detected between 2001 and 2013 36 serious flaws with a slowdown or intervention value (see Table 6 p. 249), and changed 8 crossing centres impacted by mechanical breakdowns or cracks.[81]

The national engineering department of SNCF Infra, concerned by the recurrence of the problems carried out in 2009 technical appraisals that concluded to design errors in the plateau: the switches and crossings are set in a curve, on a slope, in a place that is too narrow and that requires their interweaving. As a result, vibrations propagate from one piece of equipment to the next each time a train comes through. Moreover, the rails are too long for such a configuration: it magnifies constraints and dance phenomena (vertical oscillation), in particular for trains travelling at high speed.

Such a configuration proves to be ill-adapted to the traffic conditions (density, and most of all speed). It magnifies greatly the mechanical stress on the tracks and as such the speed of deterioration of the equipment[82].

2.2.3. The combination of these mechanical stresses leads to accelerated track deterioration

The combination of the stresses to which the Brétigny tracks are subjected result in an extraordinary situation for the area. The level of equipment fatigue is such that checking annually as is recommended by the reference guides is not enough to guarantee the condition of the switches on the plateau of the Brétigny train station.

[81] A double slip switch has four crossing centres. The break of one of those centres, due to a crack, is the reason behind the derailment. The centre in question had been replaced in 2003 and 2006.

[82] As a result from these appraisals, RFF and SNCF had planned a complete overhaul of the Brétigny railway junction for completion between 2018 and 2024.

The multiple corrective interventions carried out on the double slip switches show indeed that the fastenings and bolts did not hold from one inspection to the next. The Aptéis report [4] mentions the example of an incident that occurred in November 2002 on the very equipment involved in the 2013 accident and which showed that the bolts could come completely undone (with loss of nuts and washers) a few weeks only after a thorough inspection. In his intervention report, the District Manager wrote that it was "*surprising to note that the bolts had loosened over such a short period of time (4 weeks)"*.[83]

2.3. Budgetary pressure blocks the implementation of measures adapted to the excessive track solicitation in Brétigny

The speed of equipment deterioration in Brétigny thus justified a fast track renewal. We note however that budgetary pressures have led to the delayed replacement of the equipment.

Indeed, agreements with RFF state that the replacement period for switches is *"about 25 years"*[84]. This approximate duration that is solely governed by budgetary considerations [4], is included in the maintenance programmes of SNCF Infra **regardless of the level of stress on the tracks.** This life duration however is totally unsuitable for the aging of the switches and crossings located on UIC 2 group tracks, such as Brétigny. By way of comparison, the other European countries completely replace all of the UIC 2 group tracks every 15 to 20 years.[85].

Moreover, under pressure from the budgetary constraints, **the interpretation of this reference guide tends to drift**: the maximum 25 years tends to become a minimum age to start planning for replacement. This is used to justify the postponement of replacements that cannot be carried out for lack of budget. This is how in 2009 more than half the double slip switches under the regional maintenance body responsible for Brétigny had exceeded their theoretical 25 years lifespan [4].

This drift will then impact the replacement process for double slip switch 6/9 involved in the accident (see Figure 16). It took five years of legal investigations and two appraisals for the replacement request made by the local manager to be approved by the national engineering department. To add to this, there was also a minimum additional period of four years for planning, as required by the regulatory constraints set out in the contracts between SNCF Infra and RFF.

The replacement of the double slip switch was requested in 2007 and was actually planned 9 years later in 2016. The fact that the double slip switch, installed in 1991, was only 16 years old at the time of the initial request is probably the reason behind the reticence of the decision centres to validate an early replacement, even though its need was acknowledged by all.

[83] [4] p. 212.
[84] Appendix 1 of Item 2 of the RFF/SNCF Programme Agreement, stated in the SNCF Infra report [3].
[85] The fact that the replacement periods are much more restrictive than with our European neighbours was known to SNCF Management, as is evident in a 2011 internal note: "*if certain components can have up to 50 years of service life for class 4 lines, for the equivalent of Group 2 lines, the Dutch consider that both the track and the ballast must be completely replaced every 15 to 20 years. The Swiss have a similar view of the matter"* (SNCF Infra, *Productivity at Infra (2)*, 2011, p. 2/16, stated by the Aptéis agency [4] page 209).

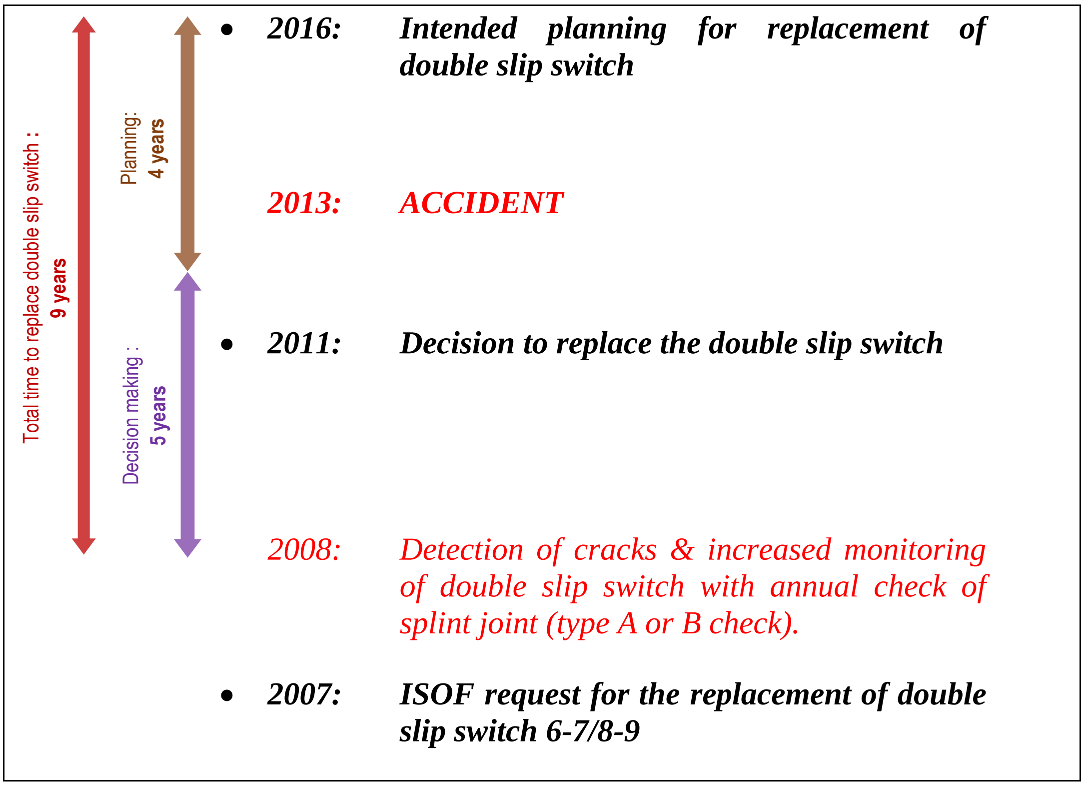

Figure 16: Time to order the replacement of double slip switch 6/9

2.4. Due to a lack of adjustment, the network's deterioration level becomes critical and impacts safety

In the absence of a replacement policy adapted to the extreme level of stress on the Brétigny tracks, the equipment fatigue level becomes critical as from 2009, with an increasing number of incidents and failures. An expert from the SNCF Infra national engineering department talks at that time of "***a critical situation where nothing much is controlled anymore***"[86]

This situation lasted until the 2013 accident and **is not without impact on the track safety model**:

- It is indeed reflected in the **discontinuation of the fundamental track safety principle. Namely the preventive maintenance applied to keep them in good working order**. The Brétigny sector is then thrust into a deteriorated configuration for several years **where traffic safety relies solely on the precautionary measures that were first introduced as recovery loops.**

- Moreover, maintaining a deteriorated network becomes highly penalising for maintenance operations: it causes an inflation of the maintenance volume and increases the number of intervention constraints. The teams are forced to react to detected failures or incidents, often within a specified timeframe (as such they lose the opportunity to plan for their activities). In the absence of sufficient resources, this **overload can divert the teams from their fundamental monitoring mission**, which constitutes the basis

[86] Delaunay report dated 15 September 2009 mentioned on http://www.leparisien.fr/faits-divers/bretigny-revelations-sur-une-catastrophe-annoncee-09-05-2016-5779129.php.

for all precautionary measures.

- Last constantly facing a deteriorated network has an impact on safety representations. Indeed, the maintenance personnel become used to the deteriorated condition that eventually becomes the new normal in the end. As such they gradually lose sight of what should a safe network be, as it has become an unachievable goal with their lot of constraints and as they try to maintain a network in the least deteriorated condition as possible. In the long term, with the proliferation of incidents, precautionary measures tend to become commonplace and cease to be ultimate safety measures.

3. A structural crisis that puts the pressure on maintenance organisations and impacts safety management

The stress overload on infrastructures in the Brétigny sector and its ensuing accelerated aging cause maintenance requirements that are much greater than anywhere else. One could therefore expect that RFF and SNCF Infra mobilise special means to maintain this extraordinary sector.

The unit responsible for the maintenance at Brétigny (ISOF) did not benefit from any special provisions however. On the contrary, it was penalised through a drastic reduction in personnel and skills.

This situation results from the significant productivity pressure that requires maintenance organisations to significantly reduce personnel and undergo radical reorganisations.

3.1. Reorganisations with insidious consequences

Burdened by regulatory changes and increasing financial pressure, SNCF Infra initiates a number of changes to adapt and improve productivity. Many reforms developed since the 2000s, in a difficult context, lead to significant gains in productivity. However, the **cumulated impact of these multiple changes eventually end up modifying the fundamental equilibrium of the safety and track maintenance model**. This change occurred insidiously, through successive adaptations without any real perception of the consequences.

3.1.1. <u>A process of progressive adaptations with budgetary imperatives</u>

Since the inception of RFF in 1997, the SNCF Infra branch has undergone many reorganisations that have significantly impacted its structures. **The main objective** of the consecutive reforms is **to increase productivity, focus** on **specialised** resources to enable economies of scale.

The move towards **focus** goes hand in hand with the decrease in personnel (see paragraph 3.2 below) by merging territorial operational units. This means pooling resources in bigger entities that cover territories that are larger and larger. The operational units were reorganised in-depth and quickly, and went from 81 entities in 2002 to about thirty in 2010.

The reorganisations also concern the internal management of the entities. In the 2000s, SNCF initiated a general reform to improve its management line, by removing the hierarchical role of foremen (team leaders) and by placing several teams directly under the responsibility of an executive, formerly a second level manager. For track maintenance, this means gathering several brigade routes under the responsibility of a sole manager (the *local manager*).

Moreover, SNCF Infra is adapting to the new regulatory context[87] that requires its organisational and functional autonomy from SNCF. It aligns its territorial organisation with that of RFF. SNCF Infra introduces a *Industrial Production Directorate* (DPI) with three *Production Territories* (TP – see Figure 17) that are in direct contact with RFF's territorial levels. The TP oversee the work of the territorial operational units and support teams, and **become real decision-making centres for network maintenance**.

Figure 17: Production Territories

The move towards the **specialisation** of units implies the creation of logistic entities at national and regional level, which are specialised in the development and implementation of heavy interventions. It means the creation of dedicated units with heavy maintenance means (such as work trains) and associated expertise that were until then scattered across various territorial operational units. These specialised units can help significantly increase the usage rate of expensive equipment and thus increase their productivity. It should be noted that **these specialised units are rigged by the transfer of personnel and equipment from territorial operational units**.

3.1.2. Reorganisations with an insidious and in-depth impact on the equilibrium of the maintenance and safety model

These consecutive reorganisations are consistent within the scope of strong pressure of costs and personnel but **have impacted the fundamental equilibrium of track maintenance function** in its application until then.

The first major change is the **gradual discontinuation of the *brigade route***, which was the historical basis for the track maintenance. The teams who were until then committed to a

[87] "ORTF" law (organisation and regulation of rail transport) dated December 2009 that adapts the European regulatory changes for the opening of the railway network to the competition.

dedicated portion of track have been gradually removed from that territory. First with the local management reform that deprived the teams from their duty of responsibility for the brigade route. By combining several brigades, the local managers then became responsible for territory that was much larger and therefore much more difficult to manage. Subsequently, to counter the decrease in personnel and increase in problems, the teams became progressively non-territorial and started operating without distinction on any tracks in the sector, as and when required, and no longer on a dedicated route. This change may foster team polyvalence and responsiveness but it progressively deprives the entity from developing a specific knowledge of the each track sector and as such leads to the significant weakening of the monitoring function.

It is interesting to note that this change occurred in an insidious manner, by way of successive adaptations, without any real management decision to relinquish the brigade route. As a result, its potential impacts on the track maintenance model, and in particular on the safety aspect, have not been assessed.

This same reasoning is reflected in a second fundamental change that concerns the territorial organisation of maintenance units through the creation of regional support units specialised in heavy maintenance. **In a decade, the organisation of track maintenance has thus gone from a preventive maintenance model, based on generalist units committed to a dedicated territory, to a <u>reactive maintenance model</u>, structured into specialised mobile units.** This transformation however occurred through the transfer of resources that were originally affected to maintenance territorial units. It has therefore greatly drained the latter's own expertise and resources. This change helps **remove on-site expertise** and as such **weaken specific knowledge and the continuous monitoring of infrastructures**. It should be noted that this change was once again insidious: territorial operational units are formally retaining their track monitoring and maintenance mission, even if in fact, they do not have any substance any longer as a result from the transfer of their most skilled personnel.

The third change concerns the structural modification of the arbitration processes with **the decision centres being now further away from the operational teams**. This change started when the entities merged and was exacerbated after 2009 with the creation of production territories.

For example, the Production Territories are responsible for managing the personnel of the entities as well as for planning major works and renewal projects. The three Production Territories that cover the national territory are removed from the operational reality of track maintenance and associated constraints while they are directly subject to the RFF's productivity and budgetary pressures. In a general cost reduction environment, this change tends to **favour the primacy of budgetary aspects over technical or safety aspects**.

We would like to see how these organisational changes have occurred in the Brétigny sector by taking as an example the management of personnel and skills.

3.2. Arbitrary cuts in personnel that heavily penalise the Brétigny sector

The decrease in maintenance personnel numbers has been continuous since the 1980s and accelerated with the 1997 reform. The Track activity lost 4400 agents between 2000 and 2010, that is 20% of its personnel. This decline does not follow a diminution in maintenance needs, which increase with the aging of the network, but **budgetary <u>imperatives</u>** that are imposed on the payroll. Disconnected from the operational needs, the management of the decrease in personnel in recent decades seems to be limited to the non-renewal of a certain percentage of departures, without taking into account the need to retain or renew key skills (see Figure 18). This policy reaches its peak when the Management of SNCF Infra blocked all recruitment during the second half of 2009 within the scope of a saving plan. Such measures deprive units from any room for manoeuvre when managing their personnel and skills.

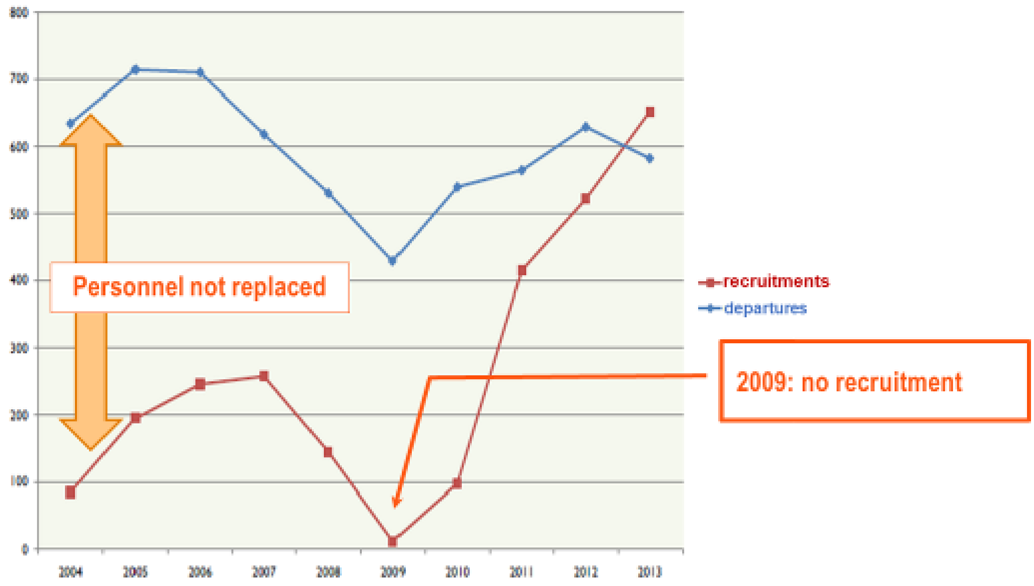

Figure 18: national departure and recruitments curves for track maintenance agents

Since the number of departures varies greatly from one unit to the next, the accounting application of a replacement rate can impact the units in uneven fashion. The Ile de France units are penalised twice because their age pyramid and significant turn-over[88].

Moreover, during this period, the maintenance units underwent significant personnel turn-over with the creation of specialised regional units. For the maintenance operational territorial units, this decrease in personnel is compounding the loss of personnel members who were transferred to specialised regional units. The cumulative impact on personnel and skills of these two concomitant measures can therefore be critical.

The management of the maintenance units' personnel was transferred to the Production Territories however. The Atlantic Production Territory (TPA) is therefore responsible for managing the personnel and skills for Brétigny. Based in Tours, the TPA manages all units located in the centre, west and south-west or France, and cannot know the detailed situation of each track sector. In any case, the TPA did not provide the Brétigny sector with resources adapted to the critical situation it was facing.

Between 1985 and 2013, the personnel responsible for the Brétigny sector **went from 78 to 15 agents**. **The impact is even more critical** taking **the skills** into consideration**.**

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[88] The high turn-over in Ile de France is associated with the fact that track jobs in the region are not attractive due to high cost of living and difficult working conditions (obsolescence of infrastructures and traffic constraints). The Brétigny sector was short of staff by 20% in 2013 as a result from recruitment difficulties.

The three key positions for the local technical and managerial supervision are filled in by inexperienced agents: in July 2013, the local sector manager is a young recruit of 24, who has been in the job for 5 months only. His two technical supports were recruited in 2012 and have hardly more experience. Within the Essonne–Val-d'Orge track Production Unit (that includes Brétigny and three other neighbouring sectors), 8 of the 9 main executives are also "young executives". Moreover the Unit Manager had taken office in April 2013 and his predecessor had stayed in the job for less than a year.

By July 2013, there are therefore no members in the Unit management with enough seniority and hindsight to control the maintenance function for the tracks of the Brétigny sector. This constitutes a major organisational flaw for a sector that is as exposed in terms of traffic, volume and complexity of maintenance.

As far the track teams are concerned, the situation is hardly any better as stated by a former executive: "*For Brétigny, we have sixteen agents including two who delegated periodically. Out of the remaining fourteen, there were maybe two agents with proper technical skills and they are currently retired."* [89]

Moreover, the remaining experienced agents are monopolised by emergency interventions that are more and more complicated that only they are able to address. As such they no longer have the time to train less experienced agents. This is how **once the skilled personnel gets below a critical threshold, the loss of team competence becomes barely reversible**, even if new agents are hired.

Finally, we can note the **de facto disappearance of the brigade route principle:** the sector used to have five brigade routes and by 2013 it had only two teams left that were not even territorial. The responsibility of the entire sector used to spread over five experienced team leaders and by 2013 it had become that of one only novice local manager.

3.3. The collapse of the track safety management system in Brétigny

The convergence on the Brétigny sector of the track deterioration and considerable weakening of the maintenance operational teams leads to a **spiralling loss of control of the maintenance function**.

Indeed, the Brétigny track sector is subject to extreme stress levels due to a very high traffic density in terms of frequency, speed and tonnage, on unsuitable pieces of equipment. The constraints cause an accelerated aging of the equipment that in the absence of anticipated regeneration lead to an ever increasing deterioration of the tracks.

As such **safety is not longer guaranteed by the appropriate condition of the** physical **pieces of equipment**. It refers then to **organisational barriers** that rely in fact on all of the sectors' maintenance operational teams.

A deteriorated network however does generate a higher maintenance load with prescribed monitoring and corrective maintenance that are forced upon the teams and reducing their room for manoeuvre. Last the proliferation of problems interferes with scheduling, generalises

[89] Extract from judicial statements mentioned by *Le Parisien* (Mai 9th 2016), http://www.leparisien.fr/espace-premium/actu/bretigny-ou-la-chronique-d-une-catastrophe-annoncee-09-05-2016-5778305.php

working in a state of emergency and disrupts maintenance. Forced to focus on emergencies and corrective maintenance for the most deteriorated systems, the maintenance agents lose sight of the global concept (already weakened by the discontinuation of track routes) for their sector and are no longer able to ensure an efficient monitoring.

For the Brétigny sector, the reduction in competent personnel magnifies the saturation and disorganisation of the teams and reduces even further their flexibility. Lacking hindsight and sufficient room for manoeuvre, the weakened and inexperienced operational management is not able to stop this dynamic. In this increasingly restricted framework, the work practices move even further away from the reference guides that have become inapplicable in such a deteriorated environment.

The Local Manager is the one who is ultimately responsible for managing track safety in his sector. But he is also responsible for track maintenance and to ensure the tracks are returned to traffic as quickly as possible. This concentration of responsibilities causes him to make operational arbitrages between the requirements in maintenance or safety, the resources available and the traffic imperatives. In the Brétigny sector, such arbitrages are subject to heavy pressure: the level of deterioration of the tracks requires a maintenance volume that the track teams cannot address. The Local Manager must manage the work by addressing what is most urgent. Moreover, the density of the passenger traffic generates some strong pressure from the driving and traffic operators who seek to reduce the number and duration of traffic stoppages, in particular at peak times.

However, as we have seen, the Local Manager function is entrusted in Brétigny (and for the whole Production Unit for EVO track) to young inexperienced executives who must make multiple at-risk arbitrages for a deteriorated facility whose control they no longer have. Overworked, far from the decision centres and deprived from room for manoeuvre, they are hardly in a position to effectively fulfil their role of ultimate defence.

Thus, the deterioration of the network together with the exponential increase in workload leads both to the saturation of the operational teams and to the collapse of the safety management system in Brétigny.

4. Conclusions and perspectives

We have demonstrated that the Brétigny accident occurred in a context of structural crisis of the maintenance of French railway infrastructures, associated with several decades of under-investment. In the absence of an adequate renewal rate, the tracks do age and end up deteriorating over an increase part of the network. Under increasing financial pressures, the network manager has initiated multiple reforms to improve productivity. The adjustments however have led over time to deep changes in the maintenance entities, which have impacted the fundamental safety equilibrium. These weaknesses have proved to be critical in the Brétigny sector that is subject to extreme traffic conditions in a highly adverse technical and organisational environment. Whereas this sector was going through an accelerated deterioration of its equipment, decision-making authorities, removed from operational reality and under budgetary pressure, failed to initiate the renewal of the equipment within an appropriate timeframe. The local teams, heavily affected by the reorganisations and drastic cuts in personnel, were overwhelmed by the proliferation of equipment failures and by the explosion of the corrective maintenance volume required by pieces of equipment on their last leg. Saturated and disorganised, without any real room for manoeuvre, the local maintenance entity has lost its coherence and ability to keep the Brétigny track sector in a safe state.

The Brétigny accident highlights several industrial safety concepts that have already been noted in other major accidents:

- It confirms that a major accident results from the conjunction of multiple Factors that do not always constitute individually sufficient cause for the event to occur but which can overlap and get stronger together in an enabling environment and lead to an accident (Y. Dien [11]). We also note the determining influence of *productivity pressures* studied by C. Perrow [12], which tend to generate bureaucratic decision-making systems that are disconnected from operational realities.

- The fact that the deterioration of the network in Brétigny is part of long-term dynamics whose impact can appear only years, or even decades later (such as the under-investment in the renewal of the infrastructures) is a good example of the *incubation* phenomenon of accident as theorised by Turner [13].

- The deep changes in the maintenance system that insidiously modify the fundamental equilibrium of organisations and representations of the stakeholders are reminiscent of the dynamics of *normalization of deviance* as theorised by the sociologist D. Vaughan in her analyses of the accidents of the Challenger [14] and Columbia [15] space shuttles.

The Brétigny accident confirms the generic nature of these concepts that apply to different socio-technical systems. Moreover the multitude of sources available for Brétigny makes it possible to appreciate the variations and interactions at different levels of an organisation and over long periods of time.

As far as the *accident investigation and learning* methodology is concerned, the Brétigny case outlines the interest in **going beyond the paradigms of *human error* and *direct causality*, which prove ineffective in the understanding of the complexity of such an accident**. It seems necessary to dig into the history and depth of the organisations **to understand their systemic dynamics and weaknesses because it is where the future accidents are growing.**

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A freight train derailment analyses using Accident Investigation Board Norway method and Safety Management System wheel tool

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Abstract

The derailments of trains could have serious consequences related to service interruptions, property damage, including environment and possible victims, so the study of this occurrences through methods and models borrowed from other sectors of economy, may be beneficial for the railway sector.

The paper has analysed a railway accident occurred through a freight train derailment on the Romanian railway network (the derailment of the freight train no.51720 occurred in the railway station Ditrău, on 17th of November 2016) using two working instruments: the investigation method developed by the Accident Investigation Board Norway and Safety Management System developed by European Union Agency for Railway.

In the first part of the paper it is presented a short description of these two working instruments and goes on by identifying safety problems for this accident, comparing the results and usefulness of those two methods.

By applying these two methods it is shown their ability to a thorough investigation of the occurrence by analysing organizational and working environment as well as by identifying the key factors that contributed to the accident. It also highlights the action directions for improving the safety level on which the safety recommendations were designed.

Although at first sight the accident could be categorized in a series of accidents generated by a simple human error, by analysing the factors that have influenced the behaviour of those involved, some aspects represent safety issues. These issues could affect in the future the activity of other economic operators on the railway market and can represent lessons to learn for the entire sector.

Keywords: railway transport, accident, safety, investigation methods

1. Railway safety (Safety Management) and learning from experience

The safety management system (called further SMS) can be defined like the totality of procedures of an organization to ensure and optimize safety. In other words, SMS is the basic element that ensures the safe functioning of the railway system.

The concept of safety management through processes and management systems was inspired by the standards used in the production processes. The initial standards were asking the producers to document their working procedures, that were then inspected to confirm that the activity was completed accordingly. These early approaches aimed at compliance rather than improvement. Then another approach was applied, generated by the experience of the Japanese companies that looked to involve the whole organization and its workers in these processes, continuously, in the whole production cycle, the approach being known in the literature as Total Quality Management (TQM)[1]

Until 15-20 years ago, in the railway system, traditionally, when rail safety was discussed, the main principal was to ensure a conformity with the standards and regulation. Currently, through updating the regulation at national and European level, the safety management achieved a greater importance in the industry. An efficient safety management needs to ensure a balance between the conformity achievement operationally and understanding the way the processes and procedures are implemented across the organization.

Learning from experience is one of the key pillars of safety management and safety investigation of accidents and through a deep analysis of the way technical and organizational systems interact efficiently could help ensuring that in the future similar accidents would be avoided.

Generally, an accident occurs [Turner 1978] [2] as a result of an incubation period, in which events and signals are produced and after which no measures are taken either because those signals were not received by the ones accountable or the events did not receive the required attention proportional to its degree of threat to the safety.

The decision to launch an investigation can be taken only in the case of a serious accident with material damage and human victims. The organizations and systems with high defence capability launch investigations for the near miss situations that could easily lead to disasters, those being occasions to intervene in the events chain by taking the necessary safety measures to avoid more serious accidents that could have the same determining factors.

An accident investigation involves three main elements: what happened, why it happened and reaching conclusions and recommendations to establish the actions to be taken in order to prevent a similar accident.

In such cases, near miss, an inductive analysis of the accident is being done, in which starting with a single event, similarities with other accidents can be found and learnt from, identifying safety recommendations that could be valid for a larger range of accidents. One of this type of accidents is analysed here, out of which the infrastructure management can draw some key learnings, referring to the way of controlling the associated risks of a third-party work and the way of considering the risks coming from the collaboration with other organizations.

2. General terms about investigation methods, the method of the Investigation Body of Norway AIBN and " SMS wheel" tool of the European Union Agency for Railways

An accident model is a referential format or a pattern way of thinking over an accident used in order to understand how the accident occurred. The advantage of using a pattern is given by the fact that sequencing the events is easier to present and understand [3]. Validated accident models are:

1. Sequential models – based on a events sequence.

This one is a simple, linear model type cause-effect, the accidents being considered the highlight point of some events, circumstances, actions that happen in a specific order. This model can be represented through a chain that contains a weak link or a domino series. The consecutive events that lead to an accident starts from an environment factor, an individual one, an action that puts in danger the safety, the mechanical or physical dangers, etc.

Preventing accidents in this idealized way could be done by replacing the weak link or through the elimination of a piece that could interrupt the domino effect. [4].

In this model, an unexpected event initiates a sequence of other events that culminates with an unwanted occurrence. The unexpected even is usually a human error or an action that endangers the safety.

This model has some limits, because it implies the existence of a strong link between cause and effect, a link more visible in the technical aspects case but less visible in the human factor or organizational one.

2. Complex linear models.

The most well-known model of this type is borrowed from the medical industry, the accidents being seen as a combination of actions that jeopardises the safety and latent conditions with influence on the safety. The latent conditions are as the pathogenic factors from the human body that produce effects only when a trigger appears. In the case of this model, the trigger is an action that puts in danger the safety and that leads to the accident occurrence. Inside this model, the accidents are prevented by enforcing the barriers and defence systems. One of the best illustrations and development of this model is by James Reason [5]

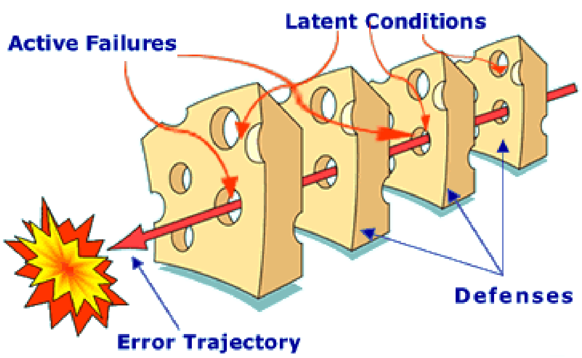


Figure 1 "Swiss Cheese" model developed by James Reason Courtesy and Copyright DOE HANDBOOK Accident and Operational Safety Analysis

In the case of this model, the occurrence of an accident is the result of older deficiencies that under certain conditions generated by the initiators result in an unwanted event. In this situation, attention is focused on organizational contribution to the occurrence of accidents and allows investigators to learn in a way other than that of a causal series. However, a sequential character is retained, projecting the event along a line passing through all the barriers. Because it is a linear system, it tends to simplify the complex interactions between latent conditions and safety-critical actions.

Its limitations are due to the fact that an analysis of the deficiencies is made at all hierarchical levels, but no attempt is made to explain why these conditions and decisions seemed logical to those involved before the accident.

Another model is the nonlinear, systemic model [6], [7] where the accident is seen as an unexpected combination of variables. In this case, both variants (the accident and the success of the operation) are viewed as developing from an unexpected combination of variables in the system. Accidents are triggered according to this view of unexpected combinations of ordinary actions rather than failed actions, which combined or in resonance with other actions lead to conditions whose common result determines the accident. Accidents can be prevented by understanding the factors that interact.

Erik Hollnagel's resonant functional model uses a metadata signal to visualize this model with the undetectable variables that resonate unexpectedly to result in a detectable result.

Often a worker makes a mistake or undertakes certain actions that appear to be appropriate but combined with other variables can produce the accident. The first impulse is to blame the worker whose actions triggered the chain of events, but it should be kept in mind that the action would not have the same result, if there would have been other elements whose combination had determined the event.

An advantage of the systemic model is that it provides a comprehensive understanding of the interactions that led to the accident. In fact, this model seeks to understand how certain variables - common inter-vals, latent conditions and weaknesses of the organization-in a particular combination may have an unwanted outcome.

The AIBN [8] method, is a framework for process analysis and systemic investigation, taking into account collecting, organizing, analysing and interpreting information and data in a verifiable manner that enables those who use it to understand why accident and how the level of safety can be improved to prevent such accidents from occurring.

It starts from the data collected at the site that forms the basis for process analysis in all investigations, so that the quality and confidence in the accuracy of the information is decisive for the validity of the analyses and conclusions.

The AIBN method combines elements from the STEP sequential method (sequential graphic representation over time) developed by Hendrik and Benner in 1987, elements of barrier functions Hollnagel, E. and other concepts developed by Sidney Dekker.

Starting from a graphical representation of the events in time, pursue further with identifying the safety issues -figured in Figure 3 with triangles, problems that are further analysed in depth to identify safety factors at all levels.

To identify safety issues, that is, “what went wrong"" in this chain of events, the authors of the method recommend using more systems to conduct "cause-effect" analyses. One of the easy-to-use options is the barrier theory [9], developed in the sense of identifying the "position" of the matrix in which the course of events leading to the accident can be changed or stopped.

Barriers (illustrated for the case made for discussions with arrows)) are technical, operational or organizational measures that either separately or together could have prevented or stopped the chain of events in question, or could have limited the accident in terms of consequences. This means that barriers can prevent non-compliances, prevent accidents by detecting / notifying nonconformities, prevent deaths and injuries by limiting the consequences.

In most specialized papers, when first classifying barrier types, taking into account their existence or non-existence, respectively their functioning at the time of the event can be divided into:

- barriers that were in place and worked;
- barriers that were in place but did not work (inefficient);
- barriers that had not been established at the time of the accident.

For an accident to occur, it is necessary that all the barriers in the chain of events leading to the accident are overcome due to the fact that they have not worked or because they have not been sufficiently strong.

Barrier analysis provides identification of the security features of investigated systems, barriers that could prevent or limit damage. By doing so, we can identify and prioritize areas of action to improve the safety of these systems.

After performing this type of analysis, the identified security issues are detailed to explain the links between event chaining and the contribution of safety factors at different organizational levels.

There may be factors that did not make an essential contribution to the accident but increased the risk of it occurring.

The next stage of the investigation, according to the AIBN method, is to analyze these safety factors, taking into account several elements: the human factor, the technical factors, the consequences (damages / victims) and how it could have diminished, the investigation of safety-related framework conditions, the organizational factors , etc., to determine which of them and the extent to which they have influenced the accident. In other words, a verification of the relevance of the factors in the accident is made to find out which of the previously identified safety issues can decisively affect the activity and which one characterizes an organization or an operational environment at a particular time. These can be considered as significant safety findings and are called "systemic safety issues" in specialized papers [10].

These are the directions to which the investigation commissions focus their attention on developing safety recommendations.

The "SMS Wheel" is a tool developed by the European Railway Agency for Railways, which was designed in principle to support the design, implementation and development of a safety management system for infrastructure managers and railway operators, making a comprehensive picture of the SMS elements contained in Annex III of Railway Safety Directive No. 49/2004. [11] SMS directive and guide.

This instrument can be used also in accidents investigation, by addressing of the elements that form SMS, according to Annex III of the Directive 2004/49/EC. The analysis will consider, in a structured way, all the processes that contribute to the design, planning, delivery and control of operations. It is important the way in which are choose that elements which had an influence in the accident occurrence and this is the role of the investigator. To achieve in-depth investigation, based on professional judgment, and experience the investigator will focus on the latent conditions that influenced the occurring of the accident.

Analysing each sector from SMS tool it can be identified some safety issues, that contributed to the accident, and from which it can be emerge safety recommendations.

3. Information on the accident covered in the Investigation Report

On 17.11.2016, around 1:25 p.m., on the railway network in Romania, on the Siculeni - Deda traffic section, at the end Y of the CFR Ditrău railway station, at km 162 + 600, in the area of the switch no.4 4 wagons from the freight train no.51720, (wagons 17, 18, 19 and 20 from the locomotive in the running direction of the train) derailed.

The derailment occurred in an area where works were carried out to replace the special sleepers at switch no. 4 at the Y end of the station. The works were performed by an authorized company (SC Euro Construct SA), which had a repair works contract with the infrastructure manager CNCF "CFR" SA.

According to the existing regulations, this event was classified as a railway accident and was investigated by the Romanian Railway Investigation Agency, the specialized body for conducting such investigations on the Romanian railway network.

The investigation report [12] drawn up for this accident shall include the findings made on site, the summary of the testimonies of those involved and other findings resulting from the consultation of the documents drawn up in connection with the execution of the works and of the train running. According to the investigation report, the derailment occurred on 17.11.2016, in an area where replacement work was carried starting to 06:45. The works have been previously scheduled as part of a contract between the infrastructure manager (owner) and the firm that ensure the works (contractor). From the findings of the investigation commission it was found that the derailment occurred because within the switch of the switch no.4 and the following wooden sleepers, after railway joint, the fastening between sleepers and rail was not done. This happened in the following circumstances:

- the performance of special wooden sleeper’s replacement work was carried out without requiring the closing of the traffic without protecting the work area;
- the contractor's staff worked within the track clearance without being supervised and coordinated, being surprised by the freight train no.51720.

At around 13:25 freight train no.51720 leaving Subcetate Mureş railway station and entering to line 4 in Ditrău railway station via the Y end, derailed. At that time, when was performed the train route for entrance in Ditrau railway station closing the traffic has approved by telegram.

The reason the train was scheduled at that time was that, although there was a telegram approval, nobody required to close the train traffic on the Y end before 13:00.

The freight train was to wait at line 4 for the reopening of the traffic on the area of the switches no.1 and no.5 (located at the X end of the station) and the passenger train no. 4507 at line III.

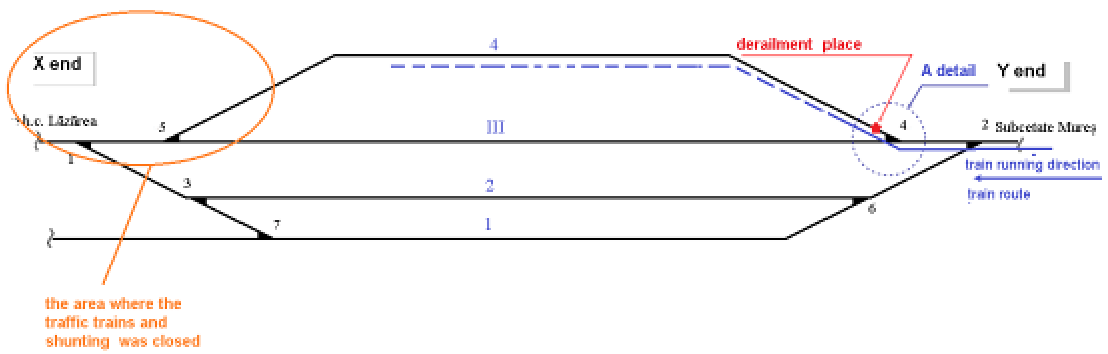


Figure 2 Ditrău railway stations- tracks layout adapted from [12]

At 1:25 p.m, the time of the route for receiving and stabling the freight train no.51720 at line 4, the team of SC Euro Construct SA worked without supervision on the switch no.4, located on this route. At the time of passing the train over the switch no.4, the fastening was not made at a number of six consecutive sleepers.

The sketch of the area on which the derailment occurred, the detail A of figure 2 is shown in figure 3.

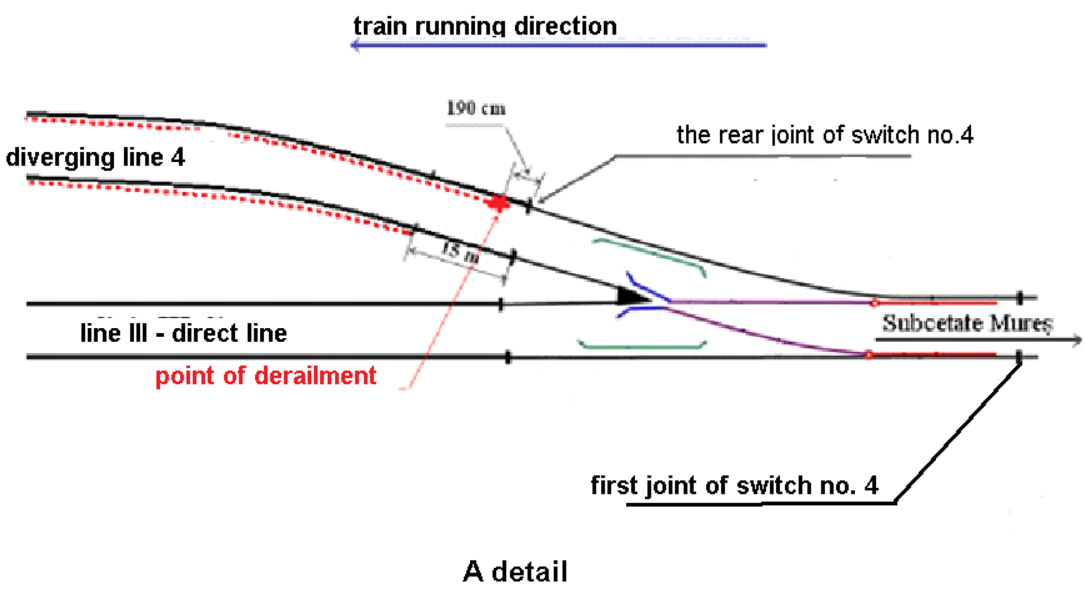


Figure 3 The sketch of the area on which the derailment occurred adapted from [12]

The conclusions of the investigation commission were as follows
” The derailment occurred as a result of inappropriate state of the track superstructure (because the lack of fastening rail-sleepers), which favored the increase of track gauge, under the action of dynamic forces. This increase made possible the fall between the rails of the wheels on the right side of the first bogie of the 17th wagon in the running direction and the derailment of the next four wagons. "

Technical condition of locomotives, wagons and the hauling mode of the train did not influence the occurrence of the accident.

The Investigation Report shows that the status of the works scheduled for 17.11.2017, according to the line closure approval telegram, was as follows:

- on the Y end of the station, in the area of the switch no. 4, replacement work of special sleepers, work done by the contractor, between 07:50 and 10:20 and 10: 50 to 13: 40, free intervals of movement;

- on the X end of the station, in the area of the switches no.1 and no.5, on the same interval replacement work of rail fasteners, work done by the staff of Infrastructure Manager.

On the morning of that day, the responsible for the safety of the contractor (hereinafter responsible SC) presented himself at the station at 06:45 and started the replacement work of the special sleepers by 2 consecutive pieces without registering it in the RRLISC (Revision of Lines and Traffic Safety Installations). National regulations in force provide that the execution of works of the type scheduled could not be performed without closing the line.

On the same day at 10:35, the district chief of the Infrastructure Manager requested closing the line only on the X-end of the station, where he carried out replacement rail fasteners. From the findings in the report, the Infrastructure Manager's representative did not request the closure of the line at the Y end. In the previous days, although the work in the same area of the station was carried out by the contractor, the line closure was also done by the district manager of the infrastructure manager.

According to the scheduled closure telegram, the SC's , clearance responsible and the re-opening for the appropriate points at the end of the X works were the district chief of the infrastructure manager and for the work at the end Y, the SC's contractor. The SC's responsible and re-opening, clearance for both works was the district manager of the infrastructure manager.

Although two different operators were working at both ends of the station, and the content of the telegram was detailed for each area, no reference was made to the person who had to request the closure of the line for each area, which what caused confusion. The clear mention of the SC responsible " safety officer", who should have asked RRLISC to close the line for the work done, would have avoided such an ambiguity.

The Investigation Commission concluded that this was corroborated with the lack of detailed prescriptions (at the Line District Ditrău - owner and the contractor), which stipulated different responsibilities for owner and contractor, the closing of the railway traffic, the check of the line after the execution of the works for the reopening of the traffic and the way of collaboration between owner and contractor during the performance of the works contributed to the confusion regarding the requirement to request the closing of the line and its inclusion in RRLISC.

In the same context, the investigation commission found that the provisions of the works contract concluded between the parties were inconsistent with the provisions of the codes of practice regulating this type of work as that it did not expressly stipulate the tasks of the parties to traffic safety

4. Analysis of the accident using the methods of investigation described above

Using the information contained in the Investigation Report, the graphical representation of the accident was made using the AIBN method described in chapter no. 2, figure. 4.

The actions of "actors" involved in the event were detailed, safety issues have been identified and then the safety factors that have had an impact on the accident have been established.

The identified security issues, which are also included in the investigation report, were as follows:

- How to set up the telegram to close the line;
- Distribution of the telegram to those involved;
- Lack of detailed working instructions for works performed at Ditrau Station;
- Lack of oversight of the works by the beneficiary;

Performance of certain works by the execution personnel of SC Euroconstruct without being supervised by a safety responsible (SC);
In the chain of events that led to the accident, some organizational barriers have been identified that could have prevented the event from occurring when these barriers functioned:

Barrier represented by the District Chief's duty to communicate non-commencement of works if they were no longer executed under the regulations in force. This instructional provision was not implemented in the days before the accident. A high level of awareness of the importance of safety rules (as outlined above) would have contributed to their implementation and would have avoided situations of that which have occurred in 17.11.2017, in which station staff did not know whether the works scheduled are running or not.

Physical barrier – Represented by the signalling elements and the way of protecting the works, which, if carried out, would have prevented the accident.

Then, starting from the identified safety issues, the safety factors were determined:

The wording of the telegram issued for line closure scheduling as well as the lack of means of communication to the first level (execution) staff led to ambiguities and uncertainties regarding the responsibilities of those involved in the works carried out at the Ditrau station.

Practice codes have not been complied with as to how works are required to close traffic and rail shunting, this being related to the safety management system at the level of the infrastructure manager. No third-party risk assessment has been carried out and control of all the risks associated with the activity of the Infrastructure Manager, including the provision of maintenance / use of subcontractors for the execution of these works, has not been carried out;

Limited awareness of the role of the infrastructure manager's oversight activities, including maintenance contractors / use of contractors to perform such works;

By analysing the identified safety factors, resulting two safety issues at company to which they were then channelled safety recommendations issued.

The two directions to which the investigation commission considered that the measures that the infrastructure manager should carry out were:

- analyse the opportunity to update its applicable regulations for the line closing, so do not exist ambiguities in the appointment of the traffic safety responsible for each part of the work, to avoid ambiguities;
- reassessment for all risks associated with the infrastructure manager's activity, including those cases where on the public railway infrastructure there are performed maintenance works with external companies.

Both issues listed above and to which the safety recommendations were formulated resulted from the findings of the investigative commission and are determined by the infrastructure manager's perception of the responsibility for its part of the system and the safe operation of the system. Both aspects reflect the level of safety culture within that organization.

Accident analysis using SMS tool

The first step, after collecting the information, is to identify the failures in the safety management system that led to the accident. In our case I started from the information in the Report and I marked with a red triangle the sectors of the Management System where there are deficiencies. Considering the statements in Chapter 5 of the investigation report:

- The Infrastructure Manager has failed to fulfil requirement C3 of Regulation (EU) No 1169/2010 -Responsibilities and tasks concerning railway safety are clearly defined, known and shared between the contractual partners and other stakeholders "

– From the testimonies of CNCF "CFR" SA, it was revealed that this requirement was not fully respected as there were problems regarding the distribution of the tasks related to the closing of line the trains during the execution of the replacement work in the row and the way of communication between the head of the train the local district of CNCF "CFR" SA and the representative of SC Euro Construct SA.

– The provisions of the Works Contract and Instructions 317/2004 were not sufficient for the safe execution performance of the maintenance works as well as for the execution performance of the railway traffic running of the train and shunting, and in this situation, it is necessary to draw up detailed prescriptions/procedures regarding the to how the parties involved (representatives of CN "CFR" SA and those of SC Euro Construct SA) should act.

As well as those in Chapter 6 of the investigation report:

- The execution of replacement wooden sleepers was carried out without the need to close the movement without protecting the working area;

There were marked on the SMS wheel Figure 5: elements 7.2.1 and 7.2.2 in the area of design and improvement processes:

Starting from the statements in the report

- the provisions of the works contract concluded between the parties are not in accordance with the provisions of Art.138 of the Instructions for Speed Limitations, no. 317/2004 respectively

- the works performed by the contractor have not been checked by the beneficiary for the reopening of the railway traffic;

elements 9.1.1 and 9.1.2 of the operating process area were marked:
Taking into account the underlying and root causes:

- The information sent by the regional leadership to the working level through the approval telegram on the conditions in which the line closure was performed was ambiguous and generated confusions.

- Unsuitable communication between the representatives of the infrastructure manager and the staff of the economic operators that perform works at the track superstructure, with reference to the assurance of the traffic safety conditions along the performance of the works, and implicitly of their associated risks.

There have been marked in the area of processes for implementation point 8.3.1.

- Configuration, control of safety information

These are areas where the investigation was focused and to which the safety recommendations were directed.

5. Conclusions on strengths and weaknesses of the two methods

Both methods allow an in-depth analysis of accidents:

- first taking into account the processes and interactions between them, by explaining and understanding the safety issues and the barriers that could prevent the accident,

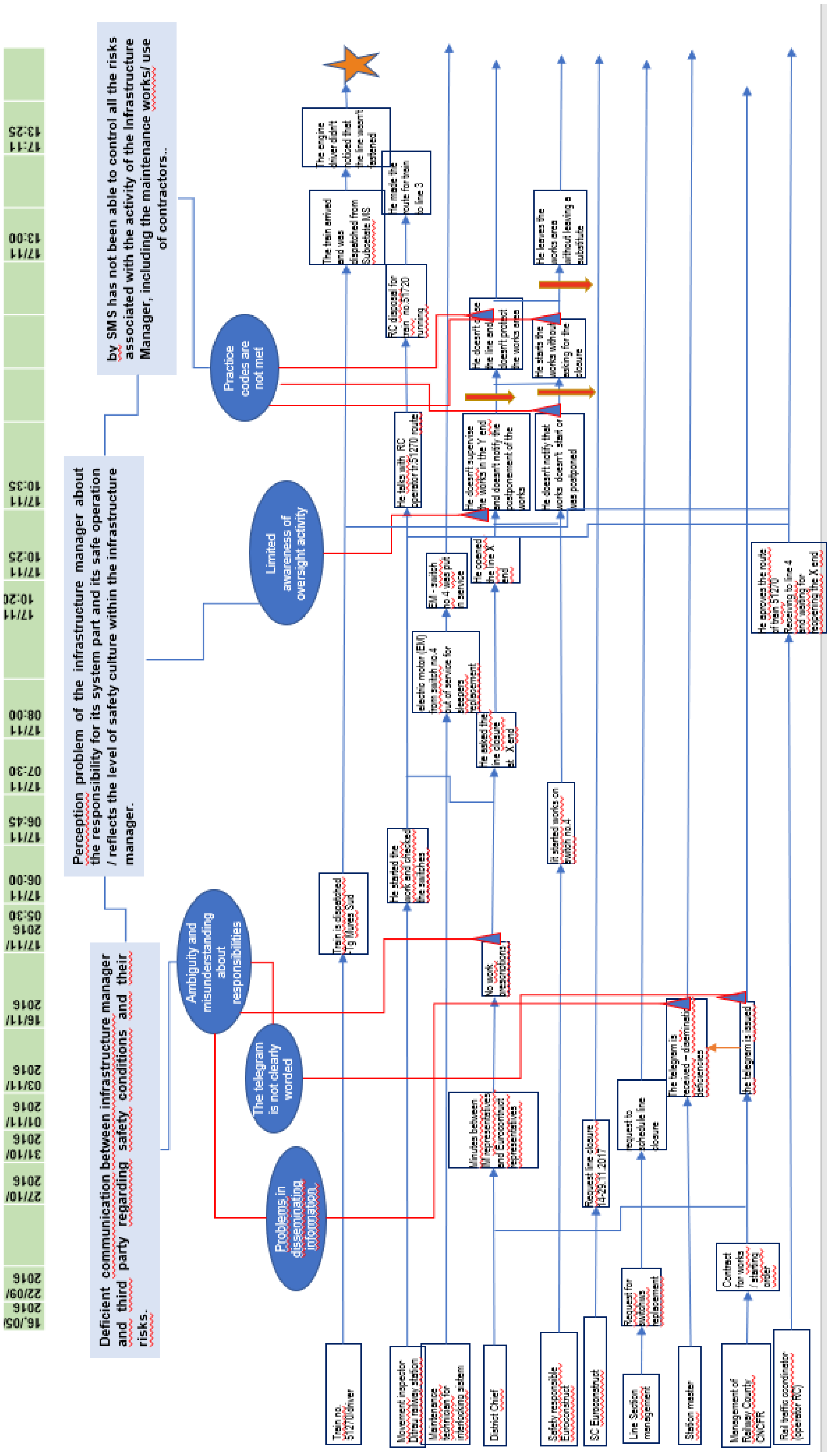
- the second making a thorough verification of the safety management system and its constituent elements, in accordance with Annex III to Directive No 49.

Using the SMS wheel tool, a task check is performed at all levels of management and all stages of the Plan Do Check Act, but the links between different processes can not be represented and a chronological representation of the events that led to the accident can not be achieved.

If the method AIBN factors they identify safety risks and then the in-depth analysis of the accident is much more focused on organizational and frame influences that impact on the effectiveness of risk control. Simplifying things, one can conclude that AIBN seems to be a systemic approach and the SMS wheel more systematically.

Both methods allow identification of areas in the safety management system and not only to which the safety recommendations should be addressed. The AIBN method facilitates the identification of those recommendations that stem from systemic factors and less of those based on local conditions (closer to the source of hazard) with a limited effect.

Figure 4 AIBN method applied to Ditrau accident



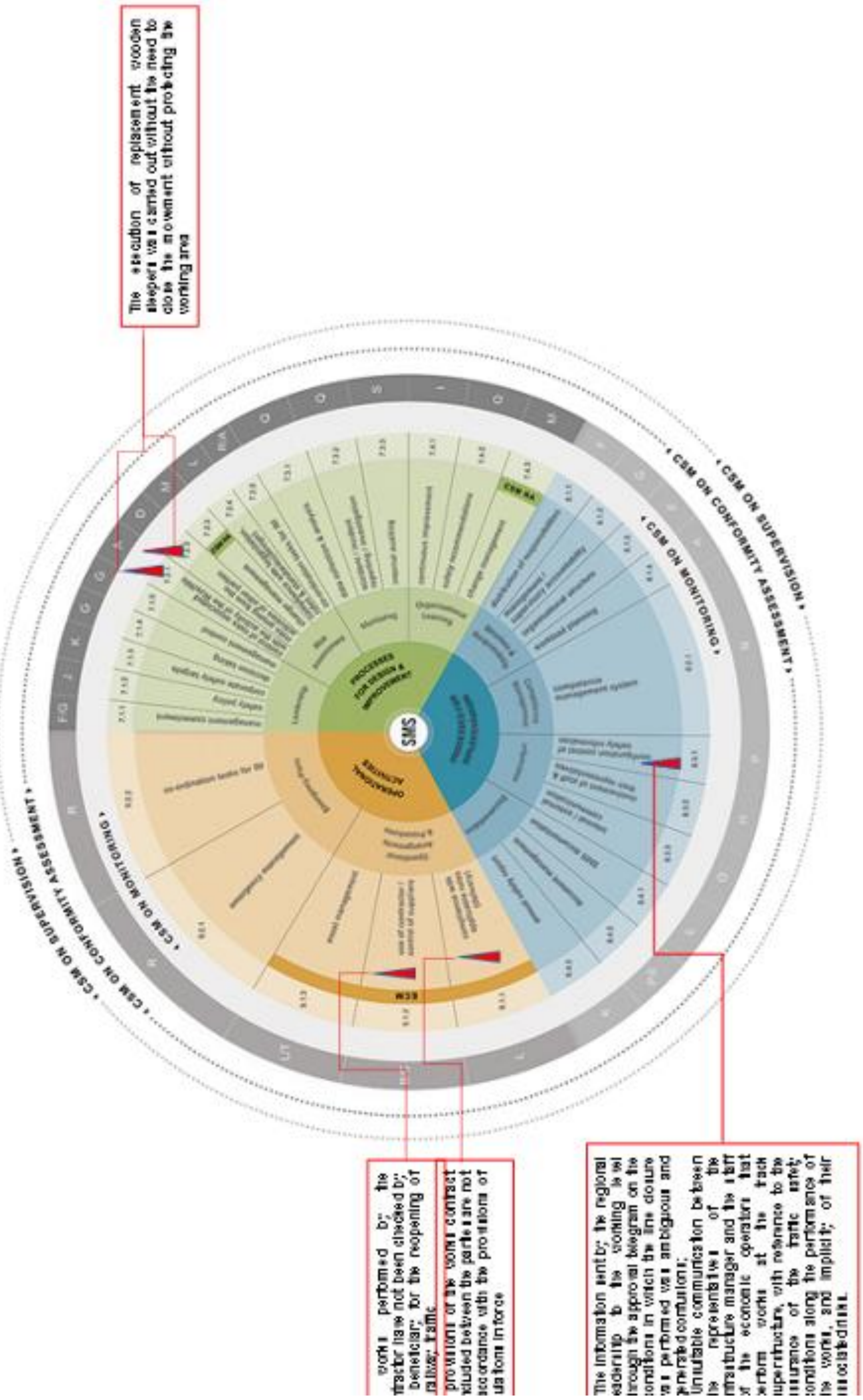


Figure 5 - SMS tool applied to Ditrau accident

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SESSION 7:

Going across sectors

Independence and Interdependence in Safety Investigations

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Abstract

Due to the current development of the transport industry, the quality of life and the environment are negatively influenced by chemical, noise, hydrocarbon residues from the use of non-renewable conventional fuels and, last but not least, by the consequences of accidents occurred in aviation, rail, maritime and on road.

The European Union, through its representative institutions in the implementation of development policy, paying particular attention to optimizing and maintaining safety standards in transport and making every effort to reduce accidents, has established at European level the conduct of safety investigation in the event of accidents and incidents occurred in air, rail and naval transport, apart from any other form of administrative or judicial investigation that seeks to establish liability or fault, in order to determine the causes and circumstances that led to their occurrence, their analysis and the prevention of other similar accidents and incidents. Thus, the setting-up of specialized national, permanent, safety-related technical investigation bodies at the level of each Member State of the European Union was required. In their activity, these safety investigation authorities should be independent in relation to any legal structure, regulatory or other safety authority, transportation operator or agent, as well as in relation to any other part of which interests may enter into conflict with the assigned tasks.

Keywords: safety investigation, accidents, multimodal, independence

1. Romanian safety investigation authorities

In Romania, the accidents and incidents occurred on the transport routes are investigated as follows: in civil aviation by the Civil Aviation Safety Investigation and Analysis Authority[90] (SIAA), in the railway field by the Romanian Railway Investigation Agency (AGIFER), and the road accidents are investigated by the Road Police. Also, the Naval Transport Safety Investigation Agency (AISTN) is currently being established in the maritime field.

[90] Former Civil Aviation Safety Investigation and Analysis Center, renamed as the Civil Aviation Safety Investigation and Analysis Authority, according to Romanian Government Ordinance no. 17/2018

European Union's civil aviation safety investigation authorities are organized in the European Network of Civil Aviation Safety Investigation Authorities (ENCASIA). ENCASIA was set up in January 2011 as an independent body without legal personality, thanks to the entry into force of the Regulation (EU) no. 996/2010 on the investigation and prevention of accidents and incidents in civil aviation.

ENCASIA is composed of the heads of the safety investigation authorities in each of the Member States and/or, in the case of a multimodal safety investigation authority, the head of its aviation branch, or their representatives.

Some Member State Safety Investigation Authorities are multimodal. This means that they not only investigate accidents and incidents involving civil aircraft but may also investigate other transportation modes such as marine and rail.

After analyzing the current situation in the 28 Member States of the European Union, we note that there are currently 14 states whose safety investigations authorities are multimodal: Austria, Croatia, Denmark, Estonia, Finland, Latvia, Lithuania, Luxembourg, the Netherlands, Portugal, Slovakia, Slovenia, Sweden and Hungary.

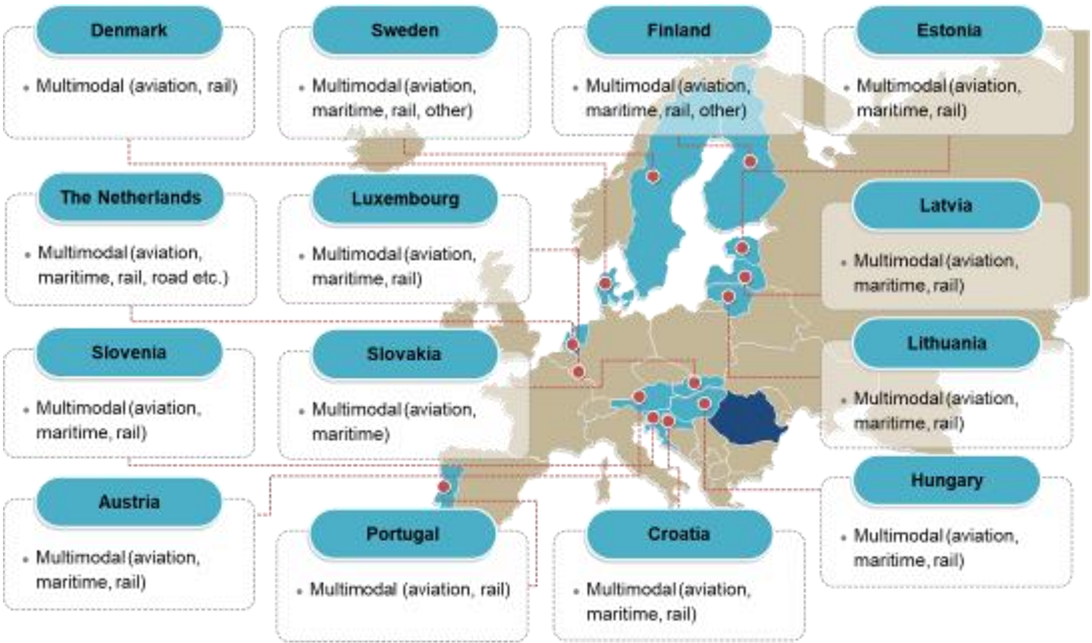

Figure 19. Multimodal safety investigations authorities in the European Union

In the United States of America, the National Transportation Safety Board (NTSB) is an independent Federal agency charged by the Congress with investigating every civil aviation accident occurred in the United States and significant accidents in other modes of transportation – railroad, highway, marine and pipeline. NTSB was founded in 1967 and is the first independent investigation agency in the world to cover all modes of transportation. Therefore, NTSB may be taken as a model when it comes to multimodal safety investigation authorities.

One of the main challenges faced by the multimodal safety investigation authorities is that of harmonizing accident investigation principles and practices across the various modes of transportation (aviation, rail, maritime, road, pipeline). But one of the basic principles of safety investigation activities that remains solid, regardless the means of transport in which accidents or incidents occur, is to conduct independent investigations. It is also important to provide statutory guarantees for all stakeholders to feel free to tell the truth (Just Culture principle).

2. How appropriate is to have a multimodal safety investigation authority in Romania? What are the advantages and disadvantages of such an organization in Romania?

Firstly, we have to take into consideration the fact that the history of independent safety investigations in Romania is still in its early ages, which can be both an advantage and a disadvantage. An advantage – as it is an opportunity to unify safety investigation authorities from different transport modes right from the beginning, into a multimodal organization; and a disadvantage, as the new role in conducting multimodal safety investigations will put new requirements to the skills, expertise and resources of the Romanian safety investigation authority.

Secondly, we have to consider the fact that Romania has a territory with an area of 238,397 km² and its landscape is almost evenly divided among mountains (31%), hills (33%), and plains (36%). These varied relief forms spread rather symmetrically from the Carpathian Mountains, which reach elevations of more than 2,400 meters, to the Danube Delta, which is just a few meters above sea level, as you can see in Figure 2.[91]

Figure 20. Topographic map of Romania

[91] Source: https://en.wikipedia.org/wiki/Topography_of_Romania

These topographical features mean that Romania has a relief with hard-to-reach areas in the event of accidents occurred in mountainous areas, especially during winter[92], when travelling by road, sea and air is much more difficult (being difficult also for the investigation teams to move to the accident scene as fast as possible).

These challenges also involve a sufficient number of safety investigators, well professional trained and updated with the latest technological breakthroughs in safety investigations, so that investigation activities to be carried out in good conditions.

From this perspective, a multimodal safety investigation authority can be a viable solution, as resources (investigation methods and techniques, procedures, processes and good practices that have proven to be effective) can be shared inside the organization so as to create a pool of useful information and know-how to be used when carrying out accident investigation activities in every transport mode. Multimodal workgroups can also be created so as to provide a wider perspective on the causes and circumstances of the occurrence of the investigated accidents.

3. Present and possible future concerning the independence and interdependence in safety investigations

The first major step has already made in this regard, as the Romanian Civil Aviation Safety Investigation and Analysis Authority (SIAA) will have a much more important role both in Romania and at European and international level in the field of civil aviation safety investigation and analysis activities, following the entry into force of the Romanian Government Ordinance no. 17 from August 29, 2018, defining a new self-financing structure (own revenues, attracted sources, donations and sponsorships) and establishing new attributions and responsibilities for the safety investigators, in accordance with the Regulation (EU) no. 996/2010 on the investigation and prevention of accidents and incidents in civil aviation.

Thus, the former Civil Aviation Safety Investigation and Analysis Center (CIAS) was also renamed, considering the need to ensure the independence of the civil aviation safety investigations, as well as the implementation of the concept of "investigation authority" as defined and imposed in the ICAO regulations (Annex 13 and Doc 9756), as well as in the applicable EU regulations. Changing the name from "Center" to "Authority" strengthens the fact that safety is at the heart of the investigation process and that its activity is of vital importance for determining the causes of an accident or incident, enabling its role in the region to become more important and creating the baseline and the perspective for a multimodal organization in the future.

The requirements of the new international regulations in the field are to continuously improve the safety investigation activity and, implicitly, to strengthen the capacity of each investigating authority in the Member States of the European Union by redefining and strengthening the functional capacity of the authorities with relevant expertise in the field, through the establishment of such authorities where they do not exist, and through the creation of regional organizations around well-developed investigation authorities, capable of effective

[92] For example, see the Final Report of the aviation accident occurred on January 20, 2014, near Horea village, Alba county, in Romania, when a civil aircraft having onboard a medical team has crushed in the mountains, in an area very difficult to reach and after which the pilot and a young volunteer doctor lost their lives: http://www.cias.gov.ro/images/rapoarte/2015.10.16%20Final%20Report%20-eng.pdf

cooperation with surrounding states, which is another main perspective of the Romanian SIAA. Especially as its evolution has been taken as a benchmark by other states in the region, offering the chance of an increasing importance and role in the region, Romanian SIAA already being able to provide logistical and professional support to surrounding countries.

Some aspects of the probabilistic versus risk evaluations of railways events

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Abstract

The railway events evaluations are performed with various methods, which are under continuous improvement, as defined now in this industry. However, it is considered that the use of methods already implemented in other industries, as for instance in nuclear, might bring a new light and possible future benefit for the present approaches. The paper proposes a new view on the existing approach for the railway events evaluation, based on a case study. The case study is based on real database existing in Romanian national railways events data. The results indicate that, there are possible positive effects on the interpretation of existing data if methods from other industries (as for instance from nuclear) are used.

Keywords: Insert here a maximum of 5 key pace before and after the keywords.

1. Introduction

The paper presents in a case study the possible impact of using diverse approaches (by comparison with the existing ones) in the event evaluations in railway industry. The proposed alternative is based on the experience from the nuclear industry.

2. Method and results

The case study is comparing two approaches: one based on the existing evaluation of the events statistics:

- One as used in this moment in the railway national evaluations of the events and
- The second based on the practice in other industries (as for instance in nuclear)

The current practice (as illustrated by internal documents [3] in the official designated organizations at national level) is aimed to comply with the existing national legislation [1]. In accordance with the national requirements the event review for the railway industry is organized and it is performed as defined in the national legislation. Criteria of the accidents classification

a. Collisions
b. Derailments
c. Impact on cars at railway passages
d. Impact on people/passengers
e. Fire

There are also defined classification criteria used for the accidents of categories a) and b) above, as follows:

- Severe accidents (deaths, injures, environmental impact etc.) (**AG**)
- Accidents non-AG (**A**)

Two other groups are considered in internal reviews for practical purposes:

- Incidents **(I)**
- Non-significant reports **(Inf)**

A very laborious work is performed for detailed analysis of each event. Apparently, a database based on the existing detailed reviews is yet to be developed. There are some internal assessments that could be used for some statistical type analyses (as illustrated in Table 1) [3].

Table 1. Extract from the internal event grouping for potential input to statistics database

Nr.	Data producerii	Data deciziei	Div	Prel	Nr zile de la data producerii pana la finalizare	Nr zile de la data deciziei/notei pana la finalizare	Data finalizarii	Regionala	Locul producerii	Operatori implicati			Încadrare	Art.
1	2/22/2007	3/7/2007			246	237	2/12/2008	Cluj	Dej Triaj	CFR	SNTFM		accident	
2	2/22/2007	3/7/2007			224	215	1/11/2008	Galaţi	Cricov	CFR	CTF		accident	
3	12/13/2007	12/14/2007			234	233	11/18/2008	Bucureşti	Comarnic	CFR	SNTFC		accident	
4	12/15/2007	12/17/2007			188	188	9/16/2008	Timişoara	Milova - Conop	CFR	UNIFERTRANS		accident	
5	2/5/2008	2/11/2008			156	152	9/16/2008	Braşov	Odorhei	RCCF TRANS	REGIOTRANS		accident grav	
6	3/13/2008	3/17/2008			294	292	5/18/2009	Craiova	Zăvideni	CFR	SNTFM		incident	
7	5/10/2008	5/12/2008			249	249	5/8/2009	Bucureşti	Valea Călugărească	CFR	SNTFC		accident grav	
8	5/26/2008	5/27/2008			158	157	1/12/2009	Cluj	Mogoşeni	CFR	SNTFC		accident	
9	12/16/2008	12/17/2008			251	250	12/15/2009	Constanţa	Basarabi	CFR	SNTFC		incident	
10	3/14/2009	3/16/2009			154	154	10/22/2009	Bucureşti	Comarnic	CFR	SNTFC		accident	
11	9/8/2009	9/23/2009			179	168	5/25/2010	Cluj	Ilva Mică	CFR	SNTFC		incident	
12	9/21/2009	9/23/2009			109	107	2/24/2010	Craiova	Banu Mărăcine - Malu Mare	CFR	SNTFC		accident	
13	10/17/2009	10/19/2009			89	89	2/23/2010	Constanţa	Lehliu - Săruleşti	CFR	SNTFM		accident	
14	11/2/2009	11/5/2009			63	60	2/1/2010	Cluj	Dealu Ştefăniţei - Fiad	CFR	SNTFC		accident	
15	12/5/2009	12/8/2009			69	68	3/15/2010	Bucureşti	Pantelimon	CFR	SNTFC		incident	
16	1/25/2010	1/27/2010			39	37	3/18/2010	Braşov	Malnaş Băi - Bixadu Oltului, Sucea	CFR	SNTFC		accident	
17	2/7/2010	2/8/2010			21	21	3/8/2010	Bucureşti	Ciocăneşti	CFR	SNTFC		accident	
18	3/18/2010	5/13/2010	Div		105	67	8/16/2010	Timişoara	Băniţa - Merişor	CFR	UNIFERTRANS		inf	N
19	3/18/2010	5/13/2010	Div		175	137	11/23/2010	Timişoara	Merişor - Crivadia	CFR	UNIFERTRANS		inc	7
20	4/7/2010	4/8/2010			93	92	8/17/2010	Cluj	Mogoşeni	CFR	SNTFC		accident	
21	4/13/2010	5/13/2010	Div		48	27	6/21/2010	Timişoara	Arad	CFR	SNTFC		inc	8
22	5/11/2010	5/18/2010			19	14	6/7/2010	Craiova	Amaradia	CFR	GFR		inc	8
23	5/16/2010	5/17/2010			106	106	10/13/2010	Bucureşti	Valea Largă - Sinaia	CFR	SNTFM		acc	7

However, at the practical level the development and improvement of techniques to correlate the evaluation of the statistics (as derived from a database) and the implementation of statistical type of connections into the further detailed reports might be in our opinion very useful.

In order to perform statistical analysis to be used for risk insights (as per [4]) and develop the input for a database, the information is reorganized illustrated in Table 2.

Table 2. Sample of the reorganized input from [3] for a statistical analysis of the railway events

Date of event	Area	Place	Type
2/12/2008	Cluj	Dej Triaj	a
1/11/2008	Galaţi	Cricov	a
11/18/2008	Bucureşti	Comarnic	a
9/16/2008	Timişoara	Milova - Conop	a
9/16/2008	Braşov	Odorhei	ag
5/18/2009	Craiova	Zăvideni	i
5/8/2009	Bucureşti	Valea Călugărească	ag
1/12/2009	Cluj	Mogoşeni	a
12/15/2009	Constanţa	Basarabi	i
10/22/2009	Bucureşti	Comarnic	a
5/25/2010	Cluj	Ilva Mică	i
2/24/2010	Craiova	Banu Mărăcine - Malu Mare	a
2/23/2010	Constanţa	Lehliu - Săruleşti	a
2/1/2010	Cluj	Dealu Ştefăniţei - Fiad	a
3/15/2010	Bucureşti	Pantelimon	i
3/18/2010	Braşov	Malnaş Băi - Bixadu Oltului, Suceava, Tuşnad	a
3/8/2010	Bucureşti	Ciocăneşti	a
8/16/2010	Timişoara	Băniţa - Merişor	inf
11/23/2010	Timişoara	Merişor - Crivadia	i

item	type
1	ag
2	ag
3	ag
4	ag
5	ag
6	ag
7	a
8	a
9	a
0	a
11	a
2	a
3	a
4	a
5	a
6	a
214	i
215	i
216	i
217	i
218	i
219	i
220	i
221	i
222	i
375	inf
376	inf
377	inf

The two approaches used for the case study are based on evaluations considering:

- The probability of occurrence of a certain type of event
- The risk impact of an event

The risk impact is based on general risk definitions in other industries, as for instance in nuclear [4] (as defined in formulas (1) and (2):

$$Risk(x) = Probability(x) * Damage(x) \quad (1)$$

$$Damage\ (x) = f\ (AG, A, I, Inf) \quad (2)$$

The nuclear industry has also criteria for event classification, as mentioned in [2] at art 16 on reporting criteria (that underlings the impact on nuclear safety measured by risk metrics) or in art 24 on ranking conclusions for operating feedback from event review and the use of external peer review for the whole process.

The starting point of the case study was the information from [3] reorganized as illustrated in Table 2. The results of the statistical reorganization of the information are represented in Figure 1.

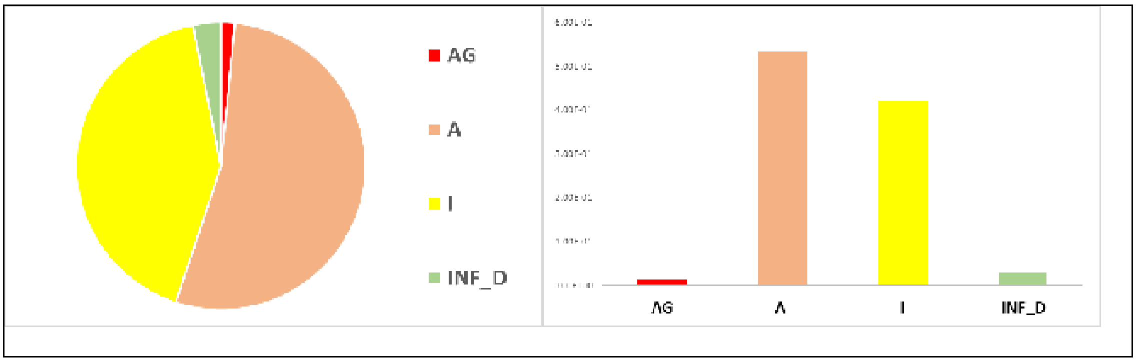

Figure 1. Event statistics as resulted from reorganized information from source [1].

Starting from the results represented in Figure 1 and based on the damage evaluation for risk analyses (as defined by formulas (1) and (2)) the distribution of probabilities and risks for the railways database of this case study are represented in Figure 2.

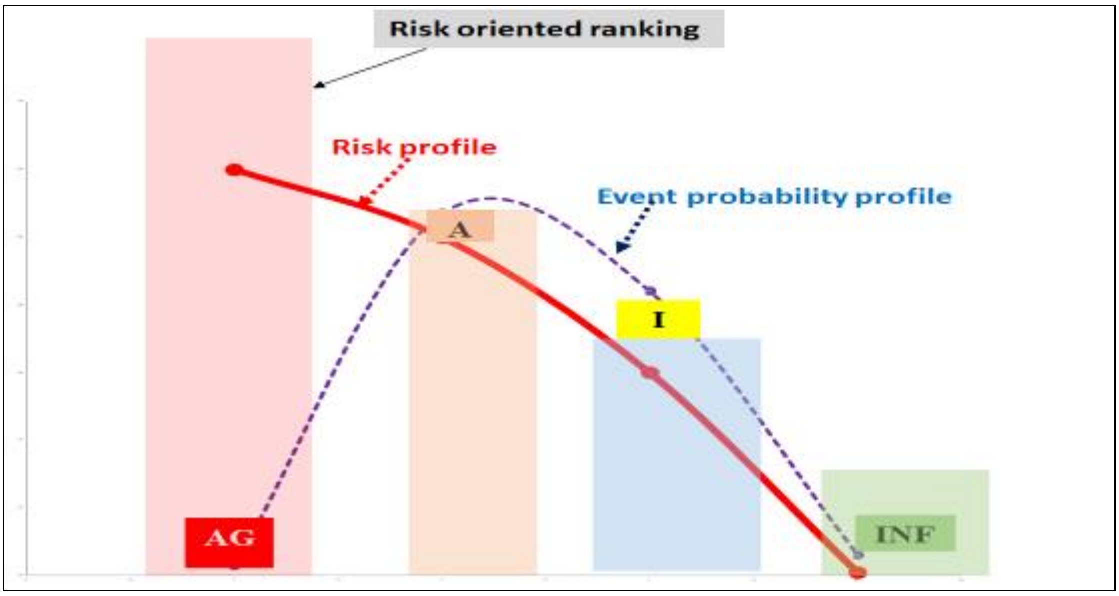

Figure 2. **Results of probabilistic versus risk evaluation of events statistics**

The further evaluation of the results is identifying the ranking defined by the two approaches: probabilistic and risk

The ranking results for this case study identify the fact that the severe accidents (AG) are of higher safety significance than the Accidents (A) if the risk approach is used. This might look as an obvious result. However, in this specific case study the statistics and the samples lead to a simple combination, which usually in large railway databases do not happen. For large railway database risk insights bring a better perspective on the events ranking.

Table 3. Ranking of the types of events

Type	Prob	Risk	Rank by probability	Rank by risk
AG	1.50E-02	0.6	III	I
A	5.35E-01	0.5	I	II
I	4.20E-01	0.3	II	III
INF_D	3.10E-02	0.005	IV	IV

3. Conclusions

The case study identify the potential useful insights for trend analysis of railway databases if risk approaches are used.

In order to benefit to the highest level of the aadvantages of using risk approaches, databases of the railways events have to be defined in detail and reorganized as proposed in this case study.

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Key Factors of the National Emergency Management System

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Abstract

In this paper, it is proposed to study a method for assessing the systemic management of emergency management in case of nuclear accidents. In order to identify the key factors in the emergency management system the chosen analysis method is a systemic one that deals with the interaction of component parts for defining sensitive elements of weak links that require more attention to improve them.

For this, a brief description of the National Emergency Management System [1] is needed to define it as a complex system.

1. Introduction

Von Bertalaffy (1956) defines a system as a complex of interacting elements. Von Bertalanffy fosters systems thinking in all disciplines in order to find general principles valid to all systems. It introduces "system" as a new scientific paradigm contrasting the analytical, mechanical paradigm, characterizing classical science (von Bertalanffy, 1950). A fundamental notion of general systems theory is its focus on interactions. The center in relationships lead to sustain that the behaviour of a single autonomous element is different from its behaviour when the element interacts with other elements.

This brief commentary was aimed at highlighting some elements of systems theories and their application in emergency management. Decision makers and Emergency Managers should become familiar with the concept of systems and the associated way of thinking. Decision makers and Emergency Managers have to plan structural adjustments to guarantee the survival of the whole system, constantly formulating new interpretations of the scenarios in order to find an adequate positioning, implementing (when necessary) periods of adjustment, transformation and redefinition the organizational structure, plans, resources etc.

The National Emergency Management System [1] is based mainly on 3 structures organized at all levels, namely national level, county level, local level and site level of the facility, plans and resources dedicated to each structure. These structures are:

- **The decision-making structure** are the emergency committees organized at all levels
- **Executive structure** defined by the Professional Emergency Services, acting as County Inspectorates, and on the facility operator has the obligation to establish and maintain its own emergency or radiological emergency response system containing an emergency response structure.
- **Operational structure** are emergency operational centers, organized at all levels, with the role of ensuring the monitoring in normal situation and support of the decision makers and coordination of the implementation of the protective action during the emergency situation.

For all levels, the emergency response management is organized based on the following principles [2]:

- **Common terminology**, which ensures that the terms used by all organisation are standard;
- **Scalable organization** and concept of operation, which gives possibility to the command and control structure to adapt to all types of events at all times;
- **Integrated communication** system is established and includes a communication plan, common for all structures with clear procedures, instructions and terminology;
- **Command control**, with clear reporting lines and hierarchy between the different units and individuals with a single commander-in-chief at all time;
- **Location/facilities designated** for response, these include operation centre, command and control post and, any other location/facility designated for response in emergency;
- **Optimal resources**, that aim at the maximization of resources potential.

2. THE MODEL OR EMERGENCY RESPONSE MANAGEMENT

The emergency response management is a complex system [3], [4], [5] represented in figure 1 and it is considered that is composed by the following subsystems:

- The sub-system 0 that manages the emergency response at the level of the operator (on-site),
- The sub-system 1 that manages the response at the local, county and national level (off- site) and
- A variable subsystem V that defines hypothetical emergency situations that would trigger the other two sub-systems f.

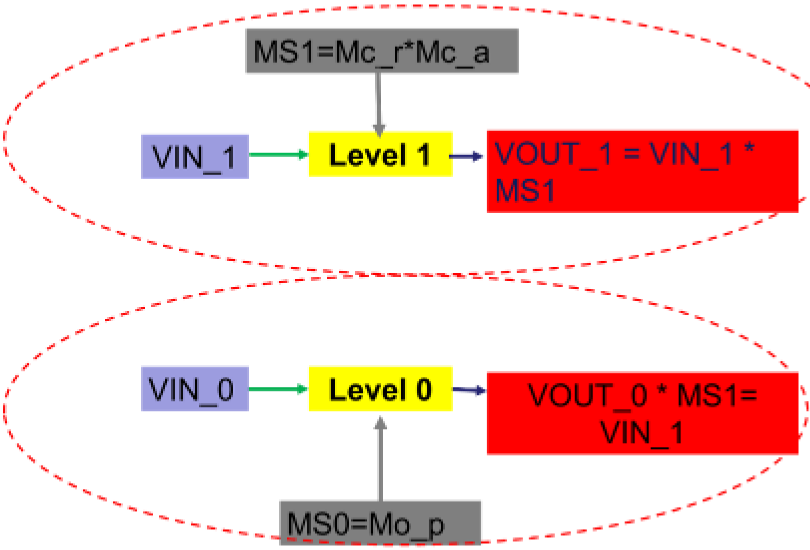


Figure 1. The model in the systemic approach used in the operational research

Level 0 = on-site level (facility)
Level 1 = off-site level (local, county and national)
S0 = on-site structural matrix
MS1= off-site structural matrix
VIN_0 = on-site Vector of perturbation

The first and the second are defined as matrixes of the on-site and off-site emergency management systems and the third is defined as a vector.

The systemic approach reflects in the fact that these systems describe matrixes. The interaction of the matrixes is described by the composition of these structures presented in matrix form, according to the rules of the operational calculation. Similar external disturbances are described by vectors, and their impact on structures is mathematically described by composing vectors and structural matrices.

For this study the structural matrix (MS) is defined by the equation (1):

$$(MS) = \begin{pmatrix} m_{11} & m_{12} & \dots & m_{1n} \\ m_{21} & m_{22} & \dots & m_{2n} \\ m_{m1} & m_{m2} & \dots & m_{mn} \end{pmatrix} \quad (1)$$

And perturbation vector (VIN) is defined by the equation (2)

$$(VIN) = \begin{pmatrix} v1 \\ v2 \\ v3 \\ v4 \\ v5 \\ v6 \end{pmatrix} \quad (2)$$

Description of the structural matrix of level 0, figure 2, consist of composition of elements representing the on-site emergency response organization and elements representing the on-site emergency response plan.

$$(Ms_{level0}) = \begin{pmatrix} o1p1 & o1p2 & o1p3 & o1p4 & o1p5 & o1p6 \\ o2p1 & o2p2 & o2p3 & o2p4 & o2p5 & o2p6 \\ o3p1 & o3p2 & o3p3 & o3p4 & o3p5 & o3p6 \\ o4p1 & o4p2 & o4p3 & o4p4 & o4p5 & o4p6 \\ o5p1 & o5p2 & o5p3 & o5p4 & o5p5 & o5p6 \\ o6p1 & o6p2 & o6p3 & o6p4 & o6p5 & o6p6 \end{pmatrix}$$

Simbol	Description of on-site emergency response plan
p1	Classification of the emergecy
p2	Mitigatory action
p3	Protective measures
p4	Medical response
p5	Security measures
p6	Recovery actions

Symbol	Description of emergency response team on site
o1	Shift Supervizer
o2	Members o emergency response team
o3	Emergency Director
o4	Control and Command Unit
o5	Technical Support Group
o6	Phisical Protection Unit

Figure 2. Structural matrix for level 0

The input for the matrix calculation for level 0 the element of the perturbation vector VIN_0 is defined in the table 1.

Table 1. Elements of VIN_0

Symbol	Elements
v01	Loss of cooling water
v02	Loss of national grid
v03	Loss of communication
v04	Station blackout
v05	Natural calamities
v06	Terrorist attack

$$(V\ level\ 0) = \begin{pmatrix} v01 \\ v02 \\ v03 \\ v04 \\ v05 \\ v06 \end{pmatrix} \quad (4)$$

$$(VIN\_1)\ X\ (Ms_{nivel\ 0}) = (VIN\_1) \quad (5)$$

$$\begin{pmatrix} v01 \\ v02 \\ v03 \\ v04 \\ v05 \\ v06 \end{pmatrix} \text{X} \begin{pmatrix} o1p1 & o1p2 & o1p3 & o1p4 & o1p5 & o1p6 \\ o2p1 & o2p2 & o2p3 & o2p4 & o2p5 & o2p6 \\ o3p1 & o3p2 & o3p3 & o3p4 & o3p5 & o3p6 \\ o4p1 & o4p2 & o4p3 & o4p4 & o4p5 & o4p6 \\ o5p1 & o5p2 & o5p3 & o5p4 & o5p5 & o5p6 \\ o6p1 & o6p2 & o6p3 & o6p4 & o6p5 & o6p6 \end{pmatrix} = \begin{pmatrix} v11 \\ v12 \\ v13 \\ v14 \\ v15 \\ v16 \end{pmatrix} \quad (6)$$

The structural matrix for level 1, MS, consists of the composition of the elements that describes the main elements of the National Emergency Management System (NEMS) in table 2, the resources of the National Emergency Management System in the table 3 and elements of the off-site emergency response plan in table 4.

Table 2. The main components of NEMS

Symbol	Elements
c1	Incident Commander (CA)
c2	Command and Control Unit (SCC)
c3	Planning Unit (SP)
c4	Operation Unit (OP)
c5	Logistic Unit (SO)
c6	Financial/Administrative Unit (SFA)

Table 3. Resources of NEMS

Symbol	Elements
r1	Trained personal
r2	Emergency facilities
r3	Monitoring, dosimetry and protection equipment
r4	Communication systems
r5	Tools and materials resources
r6	Documentation: procedures, contact lists, protocols, plans.

Table 4. Off-site emergency response plan

Symbol	Elements
r1	Trained personal
r2	Emergency facilities
r3	Monitoring, dosimetry and protection equipment
r4	Communication systems
r5	Tools and materials resources
r6	Documentation: procedures, contact lists, protocols, plans.

The first Intermediate Structural Matrix 1, MI1, for level 1 is the combination of the main components of NEMS and elements of resources of NEMS.

$$(MI_1) = \begin{pmatrix} c1r1 & c1r2 & c1r3 & c1r4 & c1r5 & c1r6 \\ c2r1 & c2r2 & c2r3 & c2r4 & c2r5 & c2r6 \\ c3r1 & c3r2 & c3r3 & c3r4 & c3r5 & c3r6 \\ c4r1 & c4r2 & c4r3 & c4r4 & c4r5 & c4r6 \\ c5r1 & c5r2 & c5r3 & c5r4 & c5r5 & c5r6 \\ c6r1 & c6r2 & c6r3 & c6r4 & c6r5 & c6r6 \end{pmatrix} \tag{7}$$

The second Intermediate structural matrix, MI2, for level 1 is the combination of the main components of NEMS and elements of the off-site emergency response plan.

$$(MI_2) = \begin{pmatrix} c1a1 & c1a2 & c1a3 & c1a4 & c1a5 & c1a6 \\ c2a1 & c2a2 & c2a3 & c2a4 & c2a5 & c2a6 \\ c3a1 & c3a2 & c3a3 & c3a4 & c3a5 & c3a6 \\ c4a1 & c4a2 & c4a3 & c4a4 & c4a5 & c4a6 \\ c5a & c5a2 & c5a3 & c5a4 & c5a5 & c5a6 \\ c6a1 & c6a2 & c6a3 & c6a4 & c6a5 & c6a6 \end{pmatrix} \tag{8}$$

The structural matrixes of level one I_2

MI_1 x MI_2 = MS level 1

$$\begin{pmatrix} c1r1 & c1r2 & c1r3 & c1r4 & c1r5 & c1r6 \\ c2r1 & c2r2 & c2r3 & c2r4 & c2r5 & c2r6 \\ c3r1 & c3r2 & c3r3 & c3r4 & c3r5 & c3r6 \\ c4r1 & c4r2 & c4r3 & c4r4 & c4r5 & c4r6 \\ c5r1 & c5r2 & c5r3 & c5r4 & c5r5 & c5r6 \\ c6r1 & c6r2 & c6r3 & c6r4 & c6r5 & c6r6 \end{pmatrix} \text{X} \begin{pmatrix} c1a1 & c1a2 & c1a3 & c1a4 & c1a5 & c1a6 \\ c2a1 & c2a2 & c2a3 & c2a4 & c2a5 & c2a6 \\ c3a1 & c3a2 & c3a3 & c3a4 & c3a5 & c3a6 \\ c4a1 & c4a2 & c4a3 & c4a4 & c4a5 & c4a6 \\ c5a1 & c5a2 & c5a3 & c5a4 & c5a5 & c5a6 \\ c6a1 & c6a2 & c6a3 & c6a4 & c6a5 & c6a6 \end{pmatrix} =$$

$$= \begin{pmatrix} s11 & s12 & s13 & s14 & s15 & s16 \\ s21 & s22 & s23 & s24 & s25 & s26 \\ s31 & s32 & s33 & s34 & s35 & s36 \\ s41 & s42 & s43 & s44 & s45 & s46 \\ s51 & s52 & s53 & s54 & s55 & s56 \\ s61 & s62 & s63 & s64 & s65 & s66 \end{pmatrix} \quad (9)$$

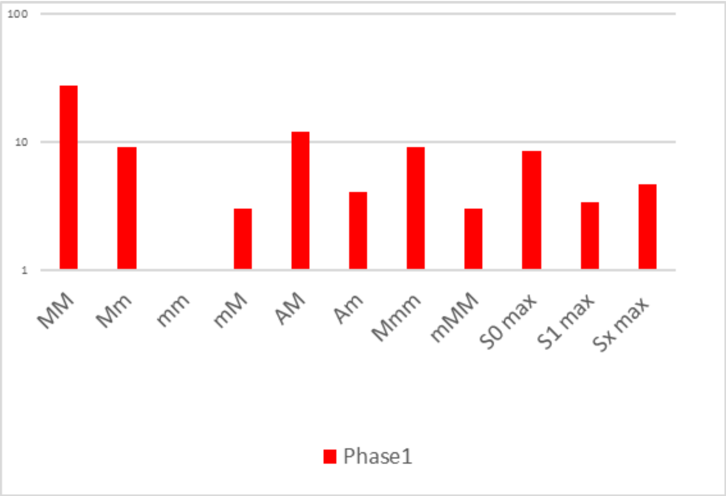
the equations (6) x (9) will result:

$$\begin{pmatrix} v11 \\ v12 \\ v13 \\ v14 \\ v15 \\ v16 \end{pmatrix} \text{X} \begin{pmatrix} s11 & s12 & s13 & s14 & s15 & s16 \\ s21 & s22 & s23 & s24 & s25 & s26 \\ s31 & s32 & s33 & s34 & s35 & s36 \\ s41 & s42 & s43 & s44 & s45 & s46 \\ s51 & s52 & s53 & s54 & s55 & s56 \\ s61 & s62 & s63 & s64 & s65 & s66 \end{pmatrix} = \begin{pmatrix} Vs1 \\ Vs2 \\ Vs3 \\ Vs4 \\ Vs5 \\ Vs6 \end{pmatrix} \quad (10)$$

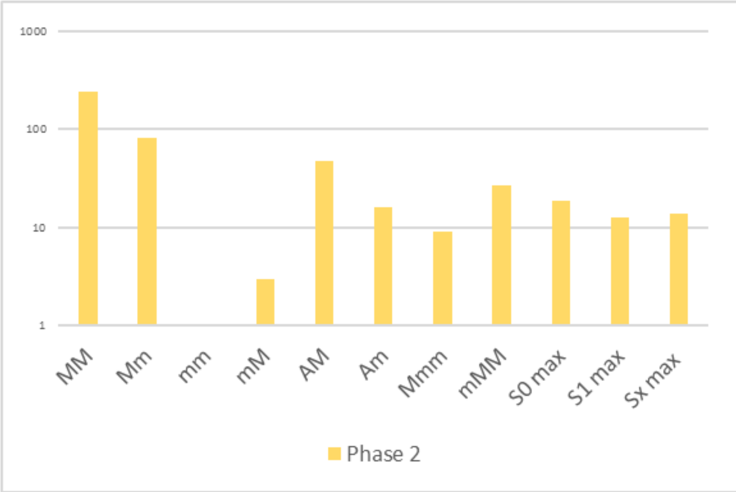
3. Results and conclusion

For variations of the input vector and in various configurations of the structures, by applying the methodology described above, we obtain full series of quantifiable results of the dominant sizes on the stability of the structures (Figure 3). These variations indicate acceptable areas and directions for improving structures.

CASE	Phase1
MM	27.1
Mm	9.04
mm	1
mM	3.01
AM	12
Am	4.02
Mmm	9.04
mMM	3.01
S0 max	8.37
S1 max	3.35
Sx max	4.69



CAZ	Phase 2
MM	245
Mm	81.7
mm	1
mM	3.02
AM	48.2
Am	16
Mmm	9.08
mMM	27.2
S0 max	18.9
S1 max	12.6
Sx max	13.7



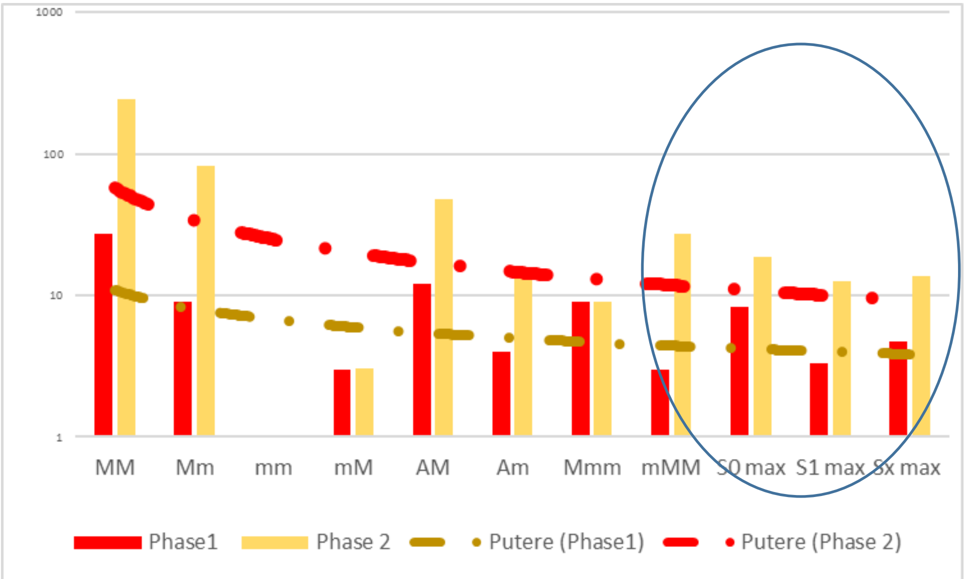
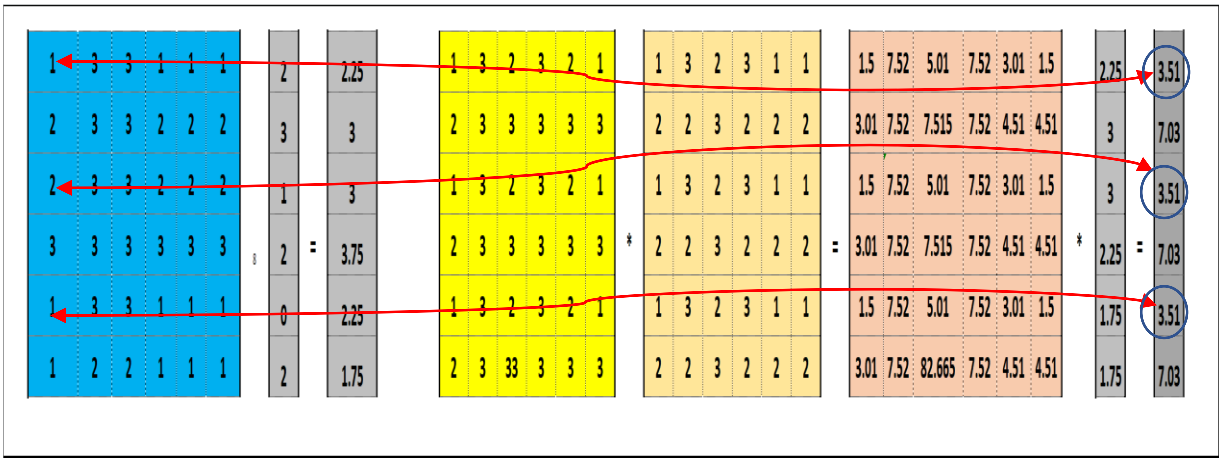


Figure 3. Examples of results and their variation

Case study. Natural disaster

A critical situation, if it occurs an earthquake, at the Nuclear Power Plant combined with the lack of equipment and / or communications, means at least one of the regional / national levels, leads to a major disturbance in the emergency management system.



Vector	Structural Matrix
1= no perturbation	1= inadequate
2= uncertainty	2= partial adequate
3= certainty	3 = adequate

Critical situation at level 0 (on-site):

Maximum deficiencies with impact on structural matrix elements.

- The Shift Supervisor (SS) may classify the emergency situation and reclassify the emergency situation
- The Emergency Director (ED) may reclassify the emergency
- The Technical Support Group (TSG) provides ED support for the reclassification of the emergency
- SS decides on preventive actions and emergency response emergencies
- ED decides emergency actions and measures and emergency response
- TSG supports the ED in taking decisions on actions and protective measures
- SS coordinates physical protection actions on site
- TSG will assist the DU in making decisions as regards physical protection actions on site

Medium deficiencies with impact on structural matrix elements:

- Emergency Response Team (ERT) acts in line with the emergency
- Command and Control Unit (CCU) coordinate the implementation of the protective actions
- Physical Protection Unit (PPU) acts in line with the emergency class
- ERT implements the protective measures
- CCU coordinating the implementation of the protective measures
- PPU implementing protective measures
- ERT collaborating with PPU
- CCU provides support for ED
- PPU implementing physical protection measures

4. CONCLUSION

a. Using the system theory by using matrix computation leads to quick, repeatable and verifiable results with many advantages over multi-criteria decisions and expert type analyses.
b. For variation of the input vector (perturbation) and different configuration of the sub-systems element, applying the methodology above described, it obtains a series of qualitative results of the dominant sizes on the stability of the sub-systems.
c. Optimization of the National Emergency Situation Management System, namely how structure elements at all levels can improve the effort to which various components of structural matrices are subjected, especially those that define human resources.

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Workshop

This chapter provides an overview of discussions during a workshop organized during the ESReDA seminar on Accident Investigation and Learning to Improve Safety Management in Complex System: Remaining Challenges organized in Bucharest on 9th and 10th October 2018.

This transcript of the workshop discussions is published in the spirit of sharing ideas; it does not contain consensus opinions or carefully analyzed statements.

During the workshop, participants were invited to describe problems and identify possible solutions that apply to the four main phases of accident investigation:

1. Establishment of the organizational prerequisites
2. Fact finding
3. Analysis and the preparation of recommendations
4. Follow-up on the recommendations.

For each phase, two posters were prepared, in English and Romanian language, as shown in the examples below.

The participants were divided into 8 groups: 4 with a majority of English speakers and 4 with a majority of Romanian speakers. Each group had a facilitator, who shared the group conclusions to the audience. The number of the persons in a group was about 20.

During the course of the day, the participants were free to stick as many post-it (one colour for problems, another colour for solutions) to the various posters, either in English or Romanian, with problems, based on the accident investigation phase. If the participant could offer a solution, it had to be linked to a challenge/problem.

To help the participants, for each phase, the organizers prepared some "trigger issues", for example:

1. organisational prerequisites:
    - ensuring readiness to investigate, resource issues;
    - tension between independence and competence;
    - guarantees offered to whistleblowers.

2. fact finding:
    - identifying causal factors (organizational, inter-organizational);
    - conditions of auditions and interviews;
    - dealing with media pressure.
3. analysis and recommendations:
    - human errors or system deficiencies;
    - linking causal factors and recommendations;
    - ensuring ownership of recommendations.
4. follow-up:
    - long timescale for organizational changes;
    - who needs to learn?
    - who is responsible for follow-up?

Before the workshop started, the posters were put onto the 8 designated tables. The participants had to dialogue with their group colleagues to PRIORITISE which were the more important PROBLEMS that need addressing and to see whether there were proposed SOLUTIONS already on the poster. If not, they were invited to identify possible solutions.

The most important problems/solutions have been communicated by the facilitators to the organizers, who presented them to all participants at the beginning of the second day of the Seminar. The text below provides a summary of the problems identified and the proposed solutions.

Phase 1: Organizational prerequisites

Problem:

- The investigation agency may lack staff with specialized skills in issues such as risk analysis, communication and organizational factors of safety.

Solution:

- Specialized training organized by investigation board targeting the sensitive fields/domains, and also with input from / collaboration with other investigation boards in order for know-how and experience to be acquired from other European countries.

Problem:

- Investigators' salary level needs to be improved. The legal status of investigation agencies often means that their employees (including investigators) are civil servants, whose salary is fixed by law or by decree (for example, law 153/2017 in Romania). The associated salary levels are often considerably lower than people with the same skills would obtain working in industry, meaning that it may be difficult for the investigation board to attract and retain staff with the necessary skills.

Solution:

- Start legal efforts so that investigators won't be impacted by this law any longer.
- Set up a multi modal investigative body reporting to the Parliament, and whose staff will benefit from special remuneration.

Problem:

- Accident investigators as "safety gods". We often put investigators in the position of "super knowers", or Gods with a perfect understanding of system operation, of features of frontline work that produce safety, and of ideal solutions to fix the issues identified (all this under time constraints). This is generated by the political configuration of accident investigation boards and by the illusion of the possibility of obtaining perfect knowledge.
- Allowing/triggering local debate among workers and managers on work performance and safety, exploring the articulation between top-down safety expertise and bottom-up situated expertise may be more productive than recommendations that the industry feel are not applicable.
- Note that judges and juries are allowed to state "insufficient evidence to generate a definite decision of culpability"; we should perhaps allow investigators leeway not to generate recommendations when they are not confident of having sufficiently general findings.
- Managing impact of financial considerations on effective independence. How does the way in which a regulator's budget is provided (taxpayer, fees on industry operators, mixed mode) impact its perceived and effective independence? How do we "keep the system honest"?

Other observations

Newcomers are obliged to undertake “safety archaeology” when trying to understand why a specific feature of a procedure or system design is present, because the underlying principles / axioms / reasons for recommendations and design choices are not saved and made transparent. However, too much transparency can lead to defensive attitudes and to unreasonably high demands on inspectors to justify their recommendations (“evidence-based decisions” vs “my experience tells me that this is a reasonable way forward”).

The status and protections accorded to whistleblowers have impacts on inspectors’ ability to obtain the truth on certain politically sensitive issues in the organization. The definition of “who is a whistleblower” (who deserves protection) is sensitive; the cultural and legal context has an important impact on the level of trust in guarantees provided to potential whistleblowers.

Distinction between legal and safety investigation:

- In objectives: the legal inquiry focuses on attribution of responsibility, liability and blame, whereas the safety inquiry aims to understand, to learn and to improve safety;
- In mindset: the legal inquiry has a mindset based on procedural compliance and deviations implying guilt, whereas the safety inquiry is typically based on a mindset that understands the difference between work as imagined and work as done (reasons for not following procedures to adapt to local constraints);
- In legal power: varies depending on national legislation, but typically the legal inquiry has precedence over the safety investigation, can sometimes limit the access of safety investigators to evidence, can seize documents and interview data collected by the safety investigation (which means that attempts to protect witnesses from a blame-oriented concerns cannot be guaranteed). But in some countries, legislation provides some protection and guarantees to the safety investigation, for example allowing

testimony to be protected from the legal inquiry under certain conditions. In the UK, the head of the RAIB is able to decide, on the basis of a number of published criteria, which information collected they keep for the safety investigation and which they transmit to the police to be used in the legal investigation. In Denmark, a constitutional modification after the Überlingen accident provides a guarantee of anonymity for testimony to the safety investigation under certain conditions (reports made within a certain timespan from the event, no people killed).

Useful associated initiatives/solutions:

- A useful practice is for legal inquiries concerning complex sociotechnical systems to be handled by specialized jurisdictions, where the prosecutors and judges have received special training and accumulate experience that helps them understand the factors that contribute to safety, develop a more subtle view of causality than simple linear consequences, and appreciation for how investigations should be run when there is no presumption of intent to cause harm.
- In aviation, Eurocontrol has been running a multi-year program that brings together prosecutors and safety investigators to discuss collaboration within the legal framework of different European countries. It is a promising initiative but it is unreasonable to expect rapid change to the situation.

Phase 2: Fact finding

Problem:

- Expert bias
  - *Does expert knowledge open or close your eyes during fact finding?*
  - *Depending on the case, expert bias can influence fact finding*
  - *It can also be the case that accident investigation is carried out mainly by technical people with no forensic expertise, so this can also be considered as an expert bias (e.g. the investigation leads to an event tree (i.e. WHAT happened?), but not going further and asking WHY that happened)*

Solution:

- For an open-minded multi-disciplinary team with a very clear scope and a dynamic terms of reference (ToR).
- It can happen that during the investigation the team will need to adapt and change the ToR (e.g. more time needed to question other witnesses) to be able to pursue truth as much as possible, creating an appropriate relaxed atmosphere for this process, where blame must be avoided, as much as possible.

Problem:

- Fake news and social media
  - ✓ *When an accident occurs, there is a risk that fake truths are fabricated and spread virally through social media. This can affect the fact finding process, putting unnecessary social pressure on the investigation team. (However, on the positive side, witnesses can more easily be found thanks to social media!)*

Solutions:

- Train media representatives to deal with media pressure and prepare in advance reliable press/civil information for each scenario identified, also with help of mock/simulation situations through role playing to help media representative be prepared (also for unforeseen scenarios).
- Prepare well in advance the mayor and local authorities on how to communicate the messages, before social media get a hold of any information that risk disrupting this constructive process and to avoid any unnecessary misunderstandings and confusion.
- Use the same social media tools to provide reliable information in a timely manner.

Problem:

- Addressing political bias and personal agendas
  - ✓ *It can happen that such agendas already predetermine the outcome of an investigation. Investigators could feel pressured and frustrated as they are not able to do their fact finding work in an open and free environment*
  - ✓ *E.g. insurance companies and companies, in general, may prefer to drive an investigation in a particular direction, preferring to compensate/pay off victims in order to have control (they often provide compensation to victims that is conditional on signing a contract stating that they will not sue the company responsible for the accident). Thus, they accept liability ASAP so as to avoid prolonging the process and not being able to know the outcome. Thus, accident investigators are put into a situation of unease, which can stifle their fact finding process.*

Solution:

- Clarify for witnesses the legal status of testimony. An inquiry is not equal to a legal investigation (if supported by organization).

Problem:

- Witnesses hide information and other obstacles to fact finding
  - ✓ *The people involved in an accident may hide certain information or provide information in a manner which serves their own interests or those of people they know.*

Solutions:

- Turn to other sources for evidence (CCTV footage, etc.) in order to identify the causes.
- Look for concurring favourable conditions, go back to the organizational level in order to find clues, create scenarios, and carry out other screenings.
- Conduct the interview as if it were a conversation. This puts people more at ease than just asking them to give a written account of the facts. Favour conversation over questioning because questioning comes with the risk of monosyllabic answers. Upside: they also might reveal more than they would normally tend to because they are relaxed.
- Record the interview and then get the interviewee's signature on the transcript. The possibility of recording should be provided for by the law.

Problem:

- Communicating with civil society + relieving media pressure
  - ✓ *Starting to communicate too soon holds the risk of communicating assumptions, rather than informed conclusions.*

Solutions:

- Maintaining transparency (at a moderate level nonetheless) by staying on a factual level and not going into too many technical details. Debate: how much is too much and what should be disclosed to the media;
- Do not reveal the investigator's identity. Inform that there is an investigation committee only once their job is finished.

Phase 3: Analysis and establishment of recommendations

Problems:

- Recognising root causes instead of direct causes;
- Analysis should not stop at "human error";
  - ✓ *Appropriate training should help investigators to distinguish direct causes from root causes;*
  - ✓ *It is important to avoid "human error" as term and use "human factor" or "human reliability" instead. Also, it is important to analyse system deficiencies contribution to human factor, ergonomic etc.*
- How to make recommendations really applicable;
  - ✓ *Recommendations should be made with implementation in mind. This means considering experience-based results, including causal factors, specific targets for recommendations and clearly identified ownership.*
- Multiple investigation methods as a problem;
- Analysis is uncertain because it depends on already uncertain factual basis which is not always easy to establish. Then recommendations are even more uncertain because they are not just depending on the analysis results but also on the interpretation. In addition, recommendations depend on communication, understanding and trust;
- Important to use the term "human factors" and to discuss organizational issues and to ensure that findings are deep enough to distinguish situations where human error is the direct cause but not a root cause.
- Are multiple investigation methods a solution or a problem?
- Obstacles at administrative levels: recommendations should be made in order to remove the obstacles;
- How to make the recommendations applicable: communication with the intended parties in order to discuss and put the recommendation into practice;
- Recommendations should be reliable;
- Risks have been identified, but elimination of the risk not possible due to funds.

  100 bridges with expired lifespan have been identified, solutions should be found to monitor the bridges so that risks can be minimized. The bridges should be planned, identified, prioritized for repair work.

- Gaps in the updating the safety culture: raising awareness of the management about the need to implement the latest European regulation (package: rail)

Solutions:

- Multiple investigation methods as a solution;
- Considering that "human error" is also part of human variability;
- Proper communication between involved parties in order to achieve an agreement.

Observation of the organizers

Multiple methods are both a problem and a solution (concerning analysis and recommendations). A number of methods exist for different domains and different problems need different approaches. What is important is that an APPROPRIATE METHOD IS USED for each particular case.

Phase 4: Followup

Problems:

- Lack of identification of target of recommendations;
- Resistance to safety recommendation;
    - ✓ *Concerning European and Romanian regulations, safety recommendations must be addressed to Railway Safety Authority. Sometimes, this authority (who have only to check and to ensure about implementation), refuse to do that and to implement safety recommendation, even that recommendation is for rail operators.*
- Improperly framed and scoped recommendation;
- Lack of safety training of managers;
    - ✓ *The investigations reports are finalized in general after one year. At the moment of accident, the rail operators which are not involved in the accident, don't have too much information to inform their employers, about what happened and about causes and contributing factors. When the investigation report for that accident is done, even if he is published on the Investigation Agency website, the managers of that operators, don't read the investigation report to check if they don't have similar problems, or to inform their employers about the causes, contributing factors and especially about the damages (every damage should be paid by somebody: person, company or society).*

- When to issue an urgent recommendation or a safety warning?
    - ✓ *An urgent recommendation should be issued when it's found a technical issue to a component of a rail vehicle (e.g. wheels, axle, or other component common on all rail vehicle from all rail actors). This urgent recommendation should be addressed to stakeholders.*
    - ✓ *A safety warning should be issued whenever it's found a supplementary observation which is neither causes nor contributing factor. This observation should not be a simple observation in a supplementary chapter.*

Solutions:

- Train managers on safety issues
  - ✓ *Because the stakeholders have the investigations reports and they are informed about safety recommendation, they should make their own analysis considering recommendation and to implement it, with or without acceptance from Safety Authority. They should make the analysis in according with their interest and risk assessment and not in according with an organization who is not involved directly (with real responsibilities) in their activity.*

- Work to generate changes in the safety culture
  - ✓ *Investigation reports should be analyzed by all actors, not only by those involved. For them, reports should be like a safety warning signal. They should check if the problems raised in the reports can be found in their activity. In this respect, they could make a scenario of an accident.*

- Structure interface with investigator, operator, authority so (draft) recommendations are explained, discussed, challenged to improve their relevance, operability;
  - ✓ *A draft of investigation report, before dissemination, should be discussed and analyzed with the rail actors involved in accident and with Rail National Safety Authority, face to face. The investigation commission could present the causes, contributing factors, system deficiencies and safety recommendations. In some cases, at the meeting, should be very good if the employers involved in accident will be present. The investigation commission could explain why their good activity would have been a barrier to the accident. The meeting might be a challenge for investigation commission in the respect that they should not hide behind of a paper which is send by mail.*
  - ✓ *The action should be divided in two parts:*
    - *With employers involved, rail actors' managers and Rail Safety Authority to discuss the human errors;*
    - *With rail actors' managers and Rail Safety Authority to discuss system deficiencies and safety recommendations;*

- Reduce turnover of managers so they "own" problems and monitor effects of implemented measures
  - ✓ *The manager's performance should not be counted in financial profit. In the railway sector, for example, it is easy to generate a profit if you have not invested in safety (e.g. rail vehicle reparations or new devices to prevent different accident with big damages or employers training). The manager's performance should be counted also in the company safety activity.*

BIOGRAPHIES

SEMINAR OPENING

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Biography

Luìs Andrade Ferreira graduated in Mechanical Engineering from the University of Porto (1980), received a Doctor-Engineer Degree in Mechanical Engineering by I.N.S.A. de Lyon, France (1985), D.Sc. equivalent by FEUP (2005).

He is involved in research, teaching and consulting in: Tribology and Maintenance of Physical Assets (lubrication, surface failure analysis); Safety, Reliability and Maintenance Models and Applications (RCM, RBI, Physical Asset Management). He has over 200 scientific publications, being 32 in journal papers (ISI). He supervised 55 graduated students, being 6 PhD's. Coordination of 16 competitive funding projects (national); team member of 3 international projects.

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SEMINAR OPENING

Vasile BELIBOU

General Manager

Romanian Railway Investigation Agency – AGIFER, ROMANIA

Biography

In 1979 I graduated Polytechnics Institute Iasi, Faculty of Constructions and Architecture, section Railways, Roads and Bridges. Between 1979 – 2002 I have worked in the railway infrastructure field, line sector, starting like engineer and continuing like department head, workshop head, track section inspector, regional safety inspector, track section head within CNCFR SA, being involved in repairs, maintenance of the railway infrastructure, monitoring of traffic in conditions of transport safety and security. From 2002 and up to 2015 I had different positions within Romanian Railway Authority – AFER, from Technical Inspector to Director of Romanian Railway Safety Authority– ASFR and General Manager of Romanian Railway Authority – AFER. From 2013 I coordinated the railway investigating activity as Director of Romanian Railway Investigation Body and General Manager of Romanian Railway Investigation Agency – AGIFER.

In 2000 I post graduated the PhD courses with the paper „Optimising of the periodicity of the maintenance and repair of the railway infrastructure” at the Polytechnics Institute Iaşi – Romania.

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SEMINAR OPENING

Eugen ISPAS

Deputy General Manager

Romanian Railway Investigation Agency – AGIFER, ROMANIA

Biography

I graduated in 1983 the Civil Engineering Institute București – Faculty of Railways, Roads, Bridges and Geodesy, specialty Railways, Roads and Bridges.

Until 1998 I have worked like engineer in the maintenance and construction of Romanian railway lines. In 1998 I contributed to the reorganization process of Romanian railways and to the setting up of Romanian Railway Authority - AFER, being its first general manager.
Between 2001-2012 I have been working within the Ministry of Transports, in departments for control and accident investigation, being also appointed state secretary and councillor of the Minister of Transports. In 2012 I was appointed Chief Investigator at Romanian Railway Investigation Body – OIFR, afterwards being actively involved in the reorganization of OIFR and its transformation into Romanian Railway Investigation Agency – AGIFER in 2015, being appointed deputy general manager.

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Vali Pătraşcu

Head of Department

Romanian Railway Investigation Agency – AGIFER, ROMANIA

Biography

I graduated in 2000 the Academy of Economic Studies, Faculty of International Economic Relationships, specialty International Transactions.
In started my activity in the railway field, that is into Romanian Railway Authority – AFER, where I worked 15 years, being responsible for the international relationships. During these 15 years within AFER I was responsible for the arrangements necessary for the participation of railway experts in international railway events and translation of different papers. I was also involved in different European railway projects, with European financing, dealing with accounting issues.
From 2015 up to know, I have been working into Romanian Railway Investigation Agency, resulted from the reorganization and partially splitting of Romanian Railway Authority – AFER, dealing with international relationships and human resources.

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SEMINAR OPENING

Raed ARAFAT

State Secretary

Ministry of Internal Affairs, ROMANIA

Operational analysis and projections in the prevention and management of emergencies

Abstract

The presentation will begin with a summary presentation of the Emergency Interventions Department – DSU, part of the Ministry of Internal Affairs – MAI, and of its tasks, respectively the coordination, permanently, at national level, of the prevention and management of emergency interventions, assuring and coordinating the human, material, financial and other resources, necessary to restore the normality. A part of Romanian critical infrastructure is the metro network in Bucharest – METROREX, consisting in 4 main lines with a total length of 69,25 km, double-track line and 51 stations. The emergency interventions within this network can be generated by earthquakes, floods, failures of different afferent equipment's, fires either in the train sets or in the tunnels, errors of the human factors and, not least, the terrorist attacks that are one of the world threats. The presentation will illustrate the legal and organization measures taken for the improvement of the emergency interventions, through a good cooperation between the institutions involved, the achievements and the future plans. The presentation will end with the operational analysis performed by DSU on the national situation of railway tunnels and bridges, in terms of the management of the emergency interventions and the need to draft some cooperation protocols.

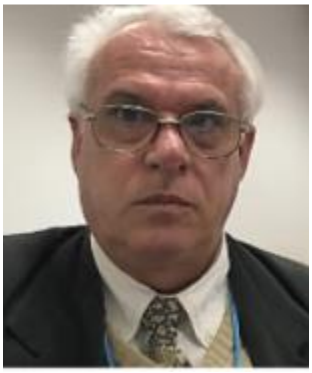
SESSION 1

Past, present, future

Dan ŞERBĂNESCU

Risk and safety analyst

Division of Logic and Models in Science - National Committee of History in Science and Technology - Romanian Academy,
Bucharest, ROMANIA



Biography

Dan Şerbănescu is a nuclear and high-risk industries safety and risk analysis expert, senior counselor at corporate level of the Romanian nuclear electricity company. He is responsible for the nuclear safety oversight at the corporate level and active participant by (courses development, independent research and papers presentation and publication) for the models in science projects of the Division of Logic and Models of the Romanian Academy, where he is a permanent member. His experience in the areas mentioned above, at various levels for the academic environment, industry, designers and regulators at national and international level is reflected in the books and papers published so far.

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Invited lecture I

On a possible approach for the multi criteria event analysis in complex systems events

Abstract

It is recognized that there are similitudes and the interconnections in the accidents investigation and learning processes, during various lifecycle phases and for various socio-political environments for systems, which are using different and diverse technologies. However, the use of systematic approaches for such evaluations would be an example of very useful application of multi, trans and inter disciplinarily methods for complex systems. A new approach is proposed for the evaluation of accidents by using multiple criteria. The approach is based on an analogy with some existing results and on the use of the topological description for systems and models.

SESSION 1
Past, present, future

John STOOP

Professor Forensic engineering and safety investigations

Kindunos Safety Consultancy Ltd, Gorinchem,
The NETHERLANDS

Biography

- aerospace engineer 1976 Delft University of Technology with PhD in 1990;
- managing director of Kindunos Safety Consultancy since 1990;
- professor Forensic Engineering and Safety Investigation at Lund University Sweden since 2007;
- guest professor at DUT since 2014, occurrent with University of Applied Sciences Amsterdam, Aviation Academy;
- 5 PhD students om technological innovation, disruptive adaptations and change management;
- Member of International Society of Air Safety Investigators, ESReDA, Resilience Engineering Association, Dutch Royal Institute of Engineers;
- At present I am writing a book for AIAA on air safety investigation methodology.

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Wim BEUKENKAMP

Inspector rail

Inspectorate for the Environment and Transport, Utrecht,
The NETHERLANDS

Biography

- Civil engineering, BSc 1980;
- Technics and Policy Management, specialising in transport safety, MSc, 2001;
- Transport Safety PhD, 2016

Wim is working as senior railway inspector and accident investigator for ILT since 2007. From 2001-2007 Wim was senior researcher at AVV/ Transport Research Department of the Ministry of Transport. From 1991-2001 Wim worked as security coordinator for the Dutch Foreign Office. From 1980-1991 Wim worked as engineer with Hoogovens (now Tatasteel) IJmuiden.

Interests: rail transport, accident investigation, safety sciences, security

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Railway Accident Investigation in a Globalising System

Abstract

Accident investigation as a national affair is changing rapidly because the EU has formulated comprehensive interoperability standards touching every part of the railway system. The Chinese policy to develop the Silk Route necessitates rail safety to rapidly progress from national, to continental and soon intercontinental level.

That poses major challenges for those in charge of the safety of railway systems, similar to those in the airline industry post WWII. Aviation safety investigation is a means to identify necessary fields of improvement, to learn from failure, covering both the national and global level. It is inevitable that the railway sector follows by establishing basic safety investigation standards, methodologies, responsibilities and reporting systems to cope with the globalisation of railway technology and industry.

SESSION 1

Past, present, future

Sverre RØED-LARSEN

Manager SRL HSE Consult

member of the ESReDA PG Foresight in Safety
Oslo,
NORWAY

Biography

Sociologist (Mag.art. from the University of Oslo 1973), has more than thirtyfive years of experience from consumer and product safety work in Norwegian public authorities, from the Norwegian State Railways and from work in the Work Research Institute Norway (AFI-WRI); most of the time in leadership positions in different ministries and directorates. In addition, he has been for many years chairperson/board member of the Interdisciplinary Safety Society (TSF), of the Norwegian Safety Forum (SF), and of the Norwegian Society of Safety & Security (Nosif). He has run his own self-employed business enterprise – SRL HSE Consulting – since 2000.

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John STOOP

Professor Forensic engineering and safety investigations

Kindunos Safety Consultancy Ltd,
Gorinchem,
The NETHERLANDS

Biography

See p. 316

From Sectorial to Multimodal Accident Investigation Boards – Some Lessons from the Development in the Nordic Countries

Abstract

During history, several large accidents have been followed by investigations or – often in modern times – by the setup of an **ad-hoc** investigation commission. These early kinds of investigations had several shortcomings and were often followed by **permanent** commissions within a specific sector. A third phase was characterized by the need to emphasize the **independence** of such commissions as well as the necessity of splitting the police inquiries and the civil investigations. A fourth phase was identified as the development of **broader,** independent accident investigation commissions. However, the developments in Sweden and Finland included even broader sectors than transport in their mandates for a national accident investigation board. Denmark and Norway have had a similar development, but more restricted. The paper presented especially the developments in the Nordic countries and discussed the role of international cooperation.

SESSION 2
Organizations and human aspects

Frank VERSCHUEREN

Process Safety Inspector

Ministry of Labor, BELGIUM

Biography

- 20 years industrial experience (several industrial sectors and management functions)
- 16 years' experience as Inspector Seveso-Industries, Major Hazards Industries
- 3 years co-vice chairman project group Foresight in Safety of ESReDA
- Lecturer at Universities of Brussels, Antwerp, Gent and speaker at events
- Major knowledge domains
  - Human and Organisational Factors (lecture university Brussels)
  - Chemical Reactor Safety (lecture university Gent)
  - Learning from Incidents (lecture universities Antwerp and Brussels)
  - Psycho-social aspects (Stress, Harassment, Burn-out)

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Learning from organizational dysfunctionalities

Abstract

"Some of the insights here presented are founded on my experiences as Inspector, but many of my insights are based on study work and international meetings within the ESReDA – "Foresight in Safety" – project

As such the content does not always reflect the opinion of my employer (Belgian COMAH Seveso Labour Inspection)"

Investigating major accidents proves that organisational factors are contributing in causing them. In an organisation starting to dysfunction, OF's become hidden latent causes, increasing exposure and probability of failures.

In my study of our audits of the SMS-element "Investigation of accidents", the shortcoming with the highest frequency was "NOT looking for organisational factors". When an organisation is bad in detecting its dysfunctions, it will be missing early warning signs on several levels.

To counter this, a functional analysis regarding an organisation's safety with its strategy, structure, assignment of resources, policy deployment (roles/responsibilities) was made.

SESSION 2
Organizations and human aspects

Simona WIST

Head of Communication and Public Relations

Civil Aviation Safety Investigation and Analysis Authority,
Bucharest, ROMANIA

Effective communication during and after an aviation accident

Biography

Simona WIST is the spokesperson of the Romanian Civil Aviation Safety Investigation and Analysis Authority and has a professional experience of over 15 years in marketing, communication and PR. She is also the co-author of the book "Communication Studies", published at Coresi CNI in Bucharest, at the end of 2009 (ISBN: 978-973-570-375-8). She graduated the academic courses of the Faculty of Communication and Public Relations from the National School of Political and Administrative Studies in Bucharest, having a BA in communication and public relations and an MA in broadcast communication.

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Abstract

Accidents result in material or human losses, deterioration of transport infrastructure, bottlenecks in transport routes, reduction of transport capacities, all of which lead to an increase in the operating costs, less efficiency, and other long-term negative effects. Accidents also have a considerable impact in the media, and may affect the public image of state authorities, and at international level may even affect the State's image. We should always keep in mind that the lack of communication could result in media speculation, with negative effects for the safety investigation activities.

SESSION 2_
Organizations and human aspects

Florence-Marie JÉGOUX

Organisational and Human Factors specialist

Developpement Systémique et Humain,
FRANCE

Biography

She is a former nurse, private pilot, Air Traffic Controller, ATCOs' Instructor and internal auditor. She has worked for an ANSP as a HF facilitator and specialist for 10 years. She is also a coach and is trained in systems theory.
She passed a HF University Degree in 2017 in the National Polytechnic Institute of Bordeaux. Her research has been conducted on "safety and risk perception, by field operators and managers, and organisational risk mitigation actions", in Air Traffic Control.
She is involved in the French Risk Management Institute in different working groups, in ESREDA seminars (European Safety and REliability Data Association). She gives lectures and facilitates HF courses in Health care and Risk Management masters.
She has been writing numerous articles for HindSight magazine, and is actually a member of the advisory editorial team.
She just joined the French Safety Coordination Office, in the French Civil Aviation Safety Authority (DSAC), as a safety analyst.

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Issues with lessons learned, seen by field experts and managers, and synergy between experience reporting and experience sharing

Abstract

The purpose of this communication is to get better understanding of lessons learned issues. One of these issues is the non-reporting of some safety events, by field experts. This issue will be analysed by both field experts and managers, who will try to give some reasons for it.

Often safety analysis is done on reports available, and it is rare that exhaustive data is available. We will try to determine why some events are not reported, and for what reasons. The cross-view from managers and from field experts may improve our understanding of the situation by adding different realities and perceptions to this fact.
The study involved semi-structured interviews with Air Traffic Controllers and their managers, who were asked about safety, risks, lessons learned. The interviews were recorded and transcribed, the transcripts were counted by

two people. The aim of the results is not to claim any truth, but rather to give food for thought on one's organisation.

The deep understanding of the reasons why some events are not reported may help us to find some root causes to that phenomenon, and therefore to find more relevant solutions to improve safety. One of these solutions is to develop experience sharing as well as experience reporting. These means complement one another and their synergy may help to develop safety. Organisational experience report may also help, as well as organisational bottom up and top down efficient communication and human factors training at all hierarchy levels.

SESSION 3
Methodological aspects

Yves DIEN

Researcher

Collectif Heuristique pour l'Analyse Organisationnelle de Securite (CHAOS), FRANCE

Biography

Yves Dien is currently a retired researcher from Electricité de France (EDF) Research and Development Centre. He is currently member of CHAOS association which gathers practitioners and researchers interested by "organisational analysis of safety".
His *academic background* is Human Factors, Ergonomics (postgraduate certificate).
He began his *professional career* during the late 70s at the Renault Cars Company. dealing with "introduction" of new technologies in industry.
In the mid-80s I was hired by EDF Research and Development Centre, being involved in several projects dealing with design and evaluation of assistance tools for operators in nuclear power plant.
During the mid-90s he became advisor for nuclear affairs in Central and Eastern Europe (EDF International Division).

From mid-2000 to his retirement he led a project in 2002, he came back to the Research and Development Center where for leading a research project about "Organizational Factors of Industrial Accidents".

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Method and Mindset: Two basic elements for accident investigation

Abstract

The role of accident investigations and, more generally, of event investigations, is to identify causes that have led to their occurrence in order to eliminate them by implementing corrective measures and thus improve the system. Unfortunately, according to the Columbia Accident Investigation Board, "[M]any accident investigations do not go far enough". The CAIB statement shows, among other things, that event analysis methods must be improved in order to address the real issues that led to the failure. In the paper we will present a method called "Organisational Analysis of Safety" which tackles three dimensions intending to cover the

whole scope of the situation: “the historical dimension”; the “organisational network”, and “work relationships channels” (interactions between the different strata of the organisation). Furthermore, we will also argue that, for a method to be effective, as relevant as it is, analysts as well as decision-makers must demonstrate a certain mindset, a certain open-mindedness.

SESSION 3
Methodological aspects

Zdenko ŠIMIĆ

Scientific officer

European Commission, Joint Research Centre (JRC), Petten, The NETHERLANDS

Biography

Zdenko Šimić is working as scientist at the EC JRC in the area of nuclear operating experience and safety. He worked as a professor at the University of Zagreb, Croatia, for energy technology characterization and related risk and reliability. He has Ph.D. from the same University. He was twice in the USA for several years and two-year visiting scientist at the EC JRC IET related to nuclear power risk and reliability. He has published more than a hundred scientific papers and expert study reports. He was distinguished lecturer and Chapter Chair for the IEEE Power and Energy Society and president of the Croatian Nuclear Society.

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Events groups' importance ranking with consistent preferences consideration

Abstract

This paper is focused on the analysis of groups of events with application of the analytical hierarchy process (AHP) to the database of nuclear related events. Events characterization scheme is presented first. Then the AHP application is described. Finally, selected results for the five years of events (~1500) are presented. Described application includes quantification of uncertainty. Initial results prove that AHP could improve consistency of the events database evaluation for ranking purposes. Future work might investigate important events selection for more than one group and how to look for important event groups regardless to parameters preferences.

SESSION 3
Methodological aspects

Tuuli TULONEN

Senior Officer

Finnish Safety and Chemicals Agency (Tukes), Tampere, FINLAND

Biography

Dr. Tuuli Tulonen is currently working as a Senior Officer at the Finnish Safety and Chemicals Agency (Tukes), the national authority in the fields of safety and reliability of products, services and industrial activities in Finland. She is responsible for the Agency's multi-sectorial accident database; her work concentrates on analyses of accidents occurred in sectors supervised by Tukes, e.g. chemicals, mining and electricity. Her background is in occupational safety research (Tampere University of Technology). She completed her dissertation on electricians' electrical accident risks in 2011.

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John STOOP

Professor Forensic engineering and safety investigations

Kindunos Safety Consultancy Ltd, Gorinchem, The NETHERLANDS

Biography

See p. 316

Ana Lisa VETERE ARELLANO

Scientific Officer

Technology Innovation in Security Unit
European Commission
Joint Research Centre
Ispra, ITALY

Biography

She graduated from University of Pavia as a geologist studying rock slides. As Marie Curie Fellow, she studied floods at University of Birmingham and HR Wallingford. She has worked at the European Commission Joint Research Centre since 2001, in different research areas: natural, environmental & technological risks, energy and information technology. Her expertise lies in risk management, working together with Competent Authorities, research centres, industry and international organisations and participated in several European research projects. She currently works in the knowledge management unit for security, space & migration. She has worked with ESReDA since 2005.

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Sever PAUL

Investigator

Romanian Railway Investigating Agency – AGIFER, Bucharest, ROMANIA

Biography

Sever Paul graduated in 1990 Polytechnics Institute from Bucharest – railways rolling stock.

From graduation until now I have been working only in Romanian railway. I started like engineer, at Romanian Passenger Railway Operator, and finished my activity there as head of locomotive depot. I worked on Romanian Railway Safety Authority like rail safety inspector in charge with the traffic safety, performing state inspections and controls. From 2010 until now I have been working in railway investigation domain within Romanian Railway Investigation Agency - AGIFER, being investigator.

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Biography

Milos Ferjencik graduated in nuclear engineering at Prague Technical University in 1981. Between 1981 and 1992 he worked as a fault-tree analyst in the Nuclear Research Institute, and in various positions in Temelin NPP. Since 1992 he focused on chemical risk analysis. In 1995 he started his own consultancy profession. In 2004 he started to work as a full-time assistant professor of safety engineering at the University of Pardubice. In 2015 he was habilitated as an associate professor. Since 2015 he is a head of Institute of Energetic Materials. He focuses on risk analysis and accident investigations.

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Milos FERJENCIK

University teacher

Institute of Energetic Materials, Faculty of Chemical Technology, University of Pardubice,

CZECH REPUBLIC

Biography

Mr. Matti Peippo is currently working as a Senior Officer at the Finnish Safety and Chemicals Agency (Tukes), the national authority in the fields of safety and reliability of products, services and industrial activities in Finland. His work is to surveil the safety of chemical and explosives industry, mainly by performing inspections and granting permits. Mr. Peippo holds a MSc degree within the field of environmental and energy technology (Tampere University of Technology).

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Matti Peippo

Senior Officer

Finnish Safety and Chemicals Agency (Tukes), Tampere, FINLAND

Erkki Teräsmaa

Senior Officer

Finnish Safety and Chemicals Agency (Tukes), Tampere, FINLAND

Biography

Mr. Erkki Teräsmaa is currently working as a Senior Officer at the Finnish Safety and Chemicals Agency (Tukes), the national authority in the fields of safety and reliability of products, services and industrial activities in Finland. His work is mainly surveillance and licensing of chemical installations (e.g. Seveso installations). His background is in analytical chemistry (University of Turku) and he has being working in Tukes since 1987.

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Reasonable recommendations

Abstract

Accident investigations are executed by e.g. authorities, insurance institutions and companies themselves. The scope and objectives of the investigation depend on who is investigating. The quality of the investigation and the results depend on several constraints, e.g. the knowhow of the investigators. The investigations that aim to improve safety in the future usually include recommendations that are directed to the companies involved and/or the industrial sector where the accident occurred. Sometimes recommendations may even be directed beyond the sector involved.

This paper aims to raise discussion on reasonable recommendations. That is, recommendations that are usable, realizable, and hopefully even measurable. What should be recommended and to whom? The paper presents, with examples, how the ESReDA Cube model may be used to systematically identify recommendations to improve safety on different organizational and societal levels.

SESSION 4
Lessons learned and historical perspectives

Zsuzsanna Gyenes

Deputy Director

Institution of Chemical Engineers Safety Centre, Rugby, UNITED KINGDOM

Biography

After graduating with a Master of Science in Biochemical Engineering from the Technical University of Budapest, Dr. Zsuzsanna Gyenes worked in disaster management for the Hungarian Government. During this time, she obtained a Postgraduate Diploma in Environmental Public Administration. She then moved into a role as a Seveso Site Inspector for Hungary, at this time she also obtained her PhD cum laude on the development of procedures and tools for the improvement of industrial safety against external effects from the National Defence PhD Institution in Military Technology in Hungary. Following her time as a Seveso Inspector, she was the Head of Section for nuclear Safety in the National Directorate General for Disaster Management in Budapest. Her most recent role was as a Scientific Technical Office for the European Commission Joint Research Centre, where she worked to assist member states on learning from incidents and Seveso implementation, including land use planning policy. She commenced as the Deputy to the Director if the IChemE Safety Centre in September 2017.

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Learning from incidents – the interactive way

Abstract

Learning from major industrial incidents is possible applying different methods. The approaches demonstrated in various literature can provide a new perspective of learning and implementing the lessons from past events. A completely new way of learning lessons without experiencing the same costly mistakes that could occur during a major incident is possible via interactive case studies. These case studies used as a training resource, developed by the IChemE Safety Centre are focusing on major incidents from different sectors, such as the oil, mining, space or even nuclear industries. The other advantage of the studies is that lessons from these events

can be retrieved and applied across various sectors because the fundamentals are the same. Also, topics such as management systems, corporate government, ethical decision, emergency response, organisational and human factors or safety culture are the core areas which are similar in many operations. The objective of the paper is to demonstrate the advantages of using interactive case studies to promote an active way of learning from past incidents without repeating the costly mistakes. The paper addresses different areas of interest where various industrial sectors can find relevant learning opportunities that can be implemented in their operation.

SESSION 4
Lessons learned and historical perspectives

Nicolas DECHY

Specialist in human and organizational factors

IRSN (French National Institute for nuclear safety and radiation protection), FRANCE

Biography

Graduated as a generalist engineer in 1999, he works since 2010 at the human, organization and technology department at IRSN that is the technical support organization to the French nuclear safety authority. He worked as an expert and researcher at INERIS. His expertise experiences and research areas are on investigating and learning from accidents from technical aspects to human and organizational factors (e.g. Fukushima, Toulouse), emergency response and crisis management (staffing, stress, unexpected), risk analysis, safety and subcontracting management in maintenance in nuclear and petrochemical industrial sectors.

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Jean-Marie ROUSSEAU

Head of Experience Feedback Management Unit

IRSN (French National Institute for nuclear safety and radiation protection),

FRANCE

Biography

Jean-Marie Rousseau is a cognitive psychologist. He spent 16 years as a consultant in French private companies, before joining the Institut de radioprotection et de sûreté nucléaire (IRSN) in 2003. Specialized in decision-making and safety management, he manages a unit dealing with Operating Experience Feedback (OPEX) and internal training. Among various activities, his unit leads a transversal project for renewing the IRSN OPEX system, regarding methods, organization, tools, competencies and new technologies (automatic language processing, big data).

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Alexandre LARGIER

Deputy Head of the Human and Social Sciences Research Laboratory at IRSN

IRSN (French National Institute for nuclear safety and radiation protection),

FRANCE

Biography

Alexandre Largier holds a PhD in sociology. His research focuses on the links between safety and work organization. More specifically, his work focuses on the way in which the skills to build safety and radiation protection are applied in a work situation. He worked for French railways (SNCF) for ten years in research and human resources department and at IRSN as an expert and as deputy head of the human and social science research laboratory.

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Stéphanie TILLEMENT

Associate Professor

IMT Atlantique, LEMNA, Nantes,

FRANCE

Biography

Stéphanie Tillement is Associate Professor of sociology at IMT Atlantique (former Ecole des Mines) in Nantes. Her research interests focus on the collective construction of nuclear safety, high-risk project management, decision-making and innovation processes related to future nuclear technologies. She coordinates the ANR / Investissement d'Avenir AGORAS research program on governance and management of nuclear safety, and pilots the research action on new nuclear reactors' design processes. She also actively participates to the RESOH Chair (REsearch on Safety Organization Human) and coordinates the thematic area on complex & high-risk project organizing. She participates to inter-disciplinary projects on the role electronuclear scenarios in policy-making. Dr Tillement is graduated of industrial Engineering (INP Grenoble), and holds a Master of Sociology (Paris Dauphine University, PSL) and a PhD in Sociology from Grenoble University.

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Jan HAYES

Associate Professor

RMIT University, Melbourne,

AUSTRALIA

Biography

Dr Hayes has 30 years' experience in safety and risk management. Her current activities cover academia, consulting and regulation. She holds an Associate Professor appointment at RMIT University where she is Program Leader for the social science research activities of the Energy Pipelines CRC and Future Fuels CRC. Dr Hayes is a former member of the Advisory Board of the National Offshore Petroleum Safety and Environmental Management Authority. Dr Hayes holds a Bachelor of Engineering (Adelaide) a Master of Business (Swinburne) and a PhD in Sociology from the Australian National University.

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Benoît JOURNÉ

Professor

University of Nantes, LEMNA, Nantes,

FRANCE

Biography

Benoît Journé is Professor in management at University of Nantes (IEMN-IAE-LEMNA). He leads a master 2 class in project management of information systems. He is an Associate Professor of at IMT Atlantique (former Ecole des Mines) in Nantes where he leads a research chair on risk management in high-risk industries especially nuclear industry. He graduated from Ecole Normale in economy and management and conducted a PhD at Ecole Polytechnique in management on nuclear operations. His research interests deal with high-reliability organisations, resilience engineering, industrial performance, management tools, subcontracting, negotiations.

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Using the knowledge of accidents in organizational diagnosis of safety management: a case study

Abstract

Industrial accidents continue to occur and do recur in some organisations (NASA, BP), with similar root causes and accidents patterns whatever the industrial sectors, the country, the culture and historical period. This empirical statement opens towards the possibility of accidents' lessons capitalisation into a structured 'knowledge of accidents' (Dechy et al, 2010) that includes the 'pathogenic factors' (Reason, 1997), and 'pathogenic organisational factors' within organisational diagnosis (Dien et al, 2004, 2012, Rousseau et al, 2008). Our goal is to address the challenge of using this knowledge of accidents in normal operations. The case study aims at describing how experts used in practice this knowledge to define the analysis framework of a safety management assessment conducted by IRSN for the nuclear industry.

SESSION 4
Lessons learned and historical perspectives

Anthony GARFORTH

Board Member

Noordwijk Risk Initiative Foundation,

The NETHERLANDS

Biography

Anthony Garforth has worked within the commercial aviation sector as a licensed aircraft maintenance engineer for over 20 years. In 2004 his interest in aviation safety led him to pursue a masters degree in safety and accident Investigation. Following graduation Anthony has held several posts within the aviation sector carrying out safety investigations and helping organisations to develop their safety management systems. Currently, Anthony works with aviation organisations independently and continues his research work with NRI.

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John KINGSTON

Board Member

Noordwijk Risk Initiative Foundation,

The NETHERLANDS

Biography

John Kingston's interest in safety began as an accident investigator with the London Fire Brigade. After studying Psychology, and then Ergonomics, in 1996 he gained his PhD for research into the evolution and regulation of safety management systems. He was a research fellow of Aston University in the UK, and a visiting professor at Delft Technical University. Through NRI and independently, Dr Kingston works in aviation, aerospace and the emergency service sectors. His work focuses on monitoring, accident investigation and organisational design.

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Petra Scheffers

Independent Safety Practioner

Noordwijk Risk Initiative Foundation,

The NETHERLANDS

Are structural weaknesses limiting the capacity to learn from incidents?

Biography

Petra Scheffers has a Bachelor in Business Administration and Safety education. Before Petra started as an independent safety practioner she worked at Delft University of Technology in the post master education of safety science. Nowadays Petra is a safety and training expert and supports organizations in the safety field. What distinguishes Petra from other safety experts is the ability to look at the primary process from an integrated perspective and the role of employees therein. Through coaching and guidance instead of control, employees grow in risk awareness, scenario thinking and control measures, and safe working practices are given a central place in daily practice.

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Abstract

Most of us aspire to investigate to high standards. But how do we get there? Good practices are seldom evidence-based, and depend on context. In reality, practitioners find out for themselves what works; but they need skills and support in that search. They told us that these needs are not met reliably, and are even undermined by workloads and bureaucracy. We advocate influencing practice 'in the direction of good' and recognition of the field as the place where the seeds of good practice are sown and harvested. But skill and support matter: we need to blend action with research and learning.

SESSION 5

Methods

Teodor GRĂDINARIU

Senior Technical Advisor

Union Internationale des Chemins de Fer (UIC), Paris, FRANCE

Biography

Teodor Grădinariu is, Head of Asset Management & Operations sector and technical coordinator within the Railways System Department of the International Union of Railways (UIC) in Paris.

He is an Electrical Engineer by profession and has a Master's Degree in Engineering Science from Polytechnic School of Bucharest, Transportation Faculty in 1981. In 1999, he follow-up at Utica University, NY, USA,training courses in management. Having spent his earlier years as a Signalling Engineer, he was later responsible, as a Technical Manager, Regional Safety Manager, Technical Director and General Director for Brasov Region in The Romanian National Railway Company (CFR). Since 1999 to 2000, he held position as Deputy General Director of the Romanian National Railways Company CFR SA. He has been involved in Infrastructure activities in the European area for over 18 years as a staff of Infrastructure Department and Railways System Department of the UIC. Becoming, 2008 he manages the new introduced Asset Management domain, within UIC. He served as ERRAC (European Railways Research Advisory Council) Secretary from 2012 to 2015. He has his Fellow degree of IRSE (Institution of Signal Engineers) since 1999, and recently associate member of IAM (Institution of Asset Management).

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Invited lecture II

Cyber security in railways, threats and challenges. Results of UIC project ARGUS

Abstract

The UIC decided to produce an enforced document in order to provide specific guidance to the 'Railway'. This guidance document is designed to support the rail industry in reducing its vulnerability to cyber-attack and to be able to ensure availability, integrity, confidentiality of railway system and data during all the life of the network.

The Safety-Security management System is a part of the Asset management strategy. For each railway necessity to include the security issues in the Asset management organisation especially: the physical access policy, the

subdivision of the network regarding the business and operation targets, empowerment of the different authorised people, out sourcing and developments policy.

The document is more a guide how to apply in the railway domain the ISO 27000 and other general norms.

UIC is able to guide the railways to anticipate the security issues related to the safety and availability of the "digital railway", including cyber, taking into account the railways specificities:

- unavailability lead to unsafety
- close link between safety and security of railway operation

Also, UIC can guide the railways to define they own cyber strategy for critical system regarding they own "type of business" - by sub networks with different objectives.

SESSION 5
Methods

Milos FERJENCIK

University teacher

Institute of Energetic Materials, Faculty of Chemical Technology, University of Pardubice,

CZECH REPUBLIC

Biography
See p. 330

Oldrich CIZEK

Chairman

Railway Museum Rosice nad Labem, Pardubice

CZECH REPUBLIC

Biography

Born in Pardubice. In 1992 he finished his studies of railway transport. Since 1992 he works for Czech Railways, now in the occupational safety risk prevention. Interested in railway history since 1980. Member of Association since 1992; chairman since 1995.

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Do not repeat old mistakes in learning from accidents: It`s better to prevent a runaway than be ready for it

Abstract

The article returns to relatively old, but very serious, accident from the Czech railways. It briefly reminds WHAT happened, and analyses HOW and WHY the causal factors leading to the accident were combined. It turns out that surprisingly, in the course of the lessons learning, the possibilities for the prevention of initiating the basic hazard, which realized in the accident, have not been thoroughly analysed. Therefore, it cannot be said that the accident was properly used as information to prevent similar accidents. Two recent media reports confirm that the basic hazard keeps being urgent.

SESSION 5

Methods

Bart ACCOU

Team Leader Safety & Operations

**European Union Agency for Railways
Valenciennes,
FRANCE**

Biography

As a civil engineer, Bart started his career at the Belgian railways (SNCB) in 1993, with the construction of the Eurostar terminal in the Brussels-Midi station. In 1994 he joined SNCB's internal audit team where he reported to the CEO and the Board on procurement and other operational processes. From 2005 on he was responsible for the team that was auditing the safety management systems of both Infrabel (the Belgian infrastructure manager) and SNCB.
Bart joined the European Railway Agency in September 2008 as project officer, working on classifying railway accident causes and guidance for writing accident investigation reports. In October 2009 he became head of the safety certification sector, in charge of the harmonisation of NSA and NIB activities, running their European network and developing an assessment scheme for monitoring their activities.
From June 2013 to June 2017 Bart was Head of Methods and Safety for Infrabel, the Belgian Infrastructure Manager, where he was developing and implementing an integrated risk management system.
Since June 2017, Bart rejoined the European Union Agency for Railway, where he is now leading the Safety and Operation team.

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Genserik RENIERS

Full Profesor

University of Technology, Delft,
The NETHERLANDS

Biography

Genserik Reniers, a Master of Science in chemical engineering, is Full Professor at the Safety and Security Science Group of the Delft University of Technology, in the Netherlands, where he teaches Risk Analysis and Risk Management. At the University of Antwerp in Belgium, he is a Full professor lecturing amongst others in chemistry, organic chemistry, and Technological Risk Management. At the Brussels campus of the KU Leuven, Belgium, he lectures as a Professor, amongst others, in Engineering Risk Management. His main research interests concern the collaboration surrounding safety and security topics and socio-economic optimization within the chemical industry. Amongst many other academic achievements and output, he has published 150+ scientific papers in high-quality academic journals, and has (co-)authored and (co-)edited some 35 books. He serves as an Editor of the Journal of Loss Prevention in the Process Industries and as an Associate Editor of the Journal 'Safety Science'.

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Analysing the depth of railway accident investigation reports on over-speeding incidents, using the SAfety FRactal ANalysis method

Abstract

With the publication of the public enquiry on the Piper Alpha disaster (1990), the concept of a safety management system (SMS) has found its introduction in high-risk industries. This concept went further than being “good practice” and became legally mandatory in some industries, where holding a certificate/licence, issued on the basis of a SMS, is necessary to operate. SMS requires continuous improvement, based on a combination of “knowing the unknown” (risk assessment) and “learning on experience” (occurrence analysis). To do so, accidents/incidents need to be reported and analysed and measures need to be taken to prevent future events. Additionally, national investigating bodies have been given the role of independently investigating serious events, with the same goal. Where a SMS is based on a holistic approach, with operational, supporting and controlling elements functioning together to improve safety, most reporting/investigation methods are not developed in line with a system thinking approach to accident causation. Also, how to link the top-down description of SMS requirements with the operational activities of the organisation that create these risks in the first place, is poorly understood. In result, the current practice in accident and incident investigation does not provide a systematic approach to analyse elements of SMS. As a direct consequence, the opportunity to use these investigations for introducing sustainable system changes is often missed. The paper briefly introduces the SAfety FRactal ANalysis (SAFRAN) method that is developed to guide investigators to identify where interventions might have the greatest impact for improving global system safety, by exploring the composing elements of the concerned SMS and the sociotechnical system surrounding it in a natural and logic way, starting from the findings close to operations that explain the occurrence – being the elements accident investigators are first confronted with. In addition, the proposed methodology provides an innovative visual representation of the investigation process. The SAFRAN method is then applied to review a selected set of published railway accident investigations, all reporting on occurrences related to over-speeding, possibly resulting in a (lethal) derailment. The depth and focus of the performed investigations is assessed and compared with findings that would result from an analysis that is applying the SAFRAN logic, demonstrating the need to focus accident analysis on an organisation’s capability of managing the variability that might put successful process performance at risk.

SESSION 5
Methods

Dan ȘERBĂNESCU

Risk and safety analyst

Division of Logic and Models in Science - National Committee of History in Science and Technology - Romanian Academy, Bucharest, ROMANIA

On some issues related to the railways event impact on other industries

Biography

See p. 315

Abstract

In some complex industrial systems, as the Nuclear Power Plants (NPP) the evaluation of the potential risks induced both by natural phenomena and man-made, like for instance railways events in their proximity, are of high importance.

This trend became even more important for NPP after the latest accident in Fukushima. Therefore, the re-evaluation of the risks induced by external events to the NPP became very important.

This is accompanied by a tendency to use new methods for external risk evaluations. One of these methods is to define the risk in a form of a hazard risk. The hazard risk curves derivations from external events in the proximity of NPP is, therefore, one of the current safety review activity performed as a result of Fukushima lessons learnt. It applies not only to the natural events, but also to events from other industries.

The paper presents a case study on deriving hazard curves for the railway's events in a proximity of an operating NPP and it is based on real situations.

The results are of benefit both for the NPP risk evaluation and for railways event review system.

SESSION 6
Case studies

Manoela GOMES REIS LOPES

Associate Professor

Federal University of Amapá – UNIFAP, Department of Biological and Health Sciences BRAZIL

Biography

Graduation at Physical Therapy. Master and PhD in Sciences by the Post-Graduation Program at Public Health at the School of Public Health of the University of São Paulo (FSP.USP) - Brazil. Professor at Federal University of Amapá - Brazil. Experience in the area of public health, health surveillance, worker health, prevention of work accident, ergonomics, Cultural-Historical Activity Theory (CHAT), research of developmental work and on intervention methodology called Change Laboratory.

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Rodolfo ANDRADE DE GOUVEIA VILELA

Senior Associated Professor

School of Public Health – Sao Paulo University, BRAZIL

Biography

Graduated in Mechanical Engineering from the Sao Paulo University (1977), a specialist in Occupational Safety Engineering from FAAP/SP, Specialist in Ergonomics from UNIMEP &UFMG (2006); Master (1998) and PhD in Public Health from the State University of Campinas (2002). Post-Doctorate completed in 2013 at Helsinki University, Center for Research on Activity Development and Learning - CRADLE supervisor: Prof. Yrjö Engeström. He was the coordinator of CEREST Piracicaba for 7 years. Full Professor at School of Public Health until March 2019; Senior Professor and Graduate advisor and postdoctoral supervisor at the School of Public Health of USP / SP capital - Department of Environmental Health. Works in the area of Ergonomics, Safety and Health of the Worker. He has experience in research, teaching, and public policies in the area of worker health, analysis and prevention of accidents, other risks related to work and technological risks, developing research with the methodology of the Change Laboratory. Has a productivity scholarship in Technological Development and innovative extension CNPQ.

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Ildeberto MUNIZ DE ALMEIDA

Assistant Professor

São Paulo State University (UNESP), Medical School, Botucatu, BRAZIL

Biography

Ildeberto Muniz de Almeida is assistant professor of Occupational Medicine at the Public Health Department. São Paulo State University (UNESP), Medical School, Botucatu.

Togheter with Rodolfo Andrade Gouveia de Vilela had created www.forumat.net.br na initiative of permanent education for accident analysis and prevention.

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Silvana ZUCCOLOTTO

Post-doctorate student

Affiliation São Paulo State University (UNESP), Botucatu BRAZIL

Biography

Graduated in Civil Engineering from the Federal University of Espirito Santo (1979), Master in Industrial Engineering from the Pontifical Catholic University of RJ (1982), Program ALFA - Latin America for Academic Formation (1999) in Laboratory of Ergonomics of Work Neurosciences - Conservatoire des Arts et Métiers (Paris), PhD in Production Engineering from the University of São Paulo (2002). Post-doctorate (in progress) at the - São Paulo State University (UNESP), Botucatu. Experience in projects using work ergonomics in Transport Companies and Industries, in Transport Engineering emphasizing the user service, incorporation and improvement of the abilities developed by employees in work process.

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Historical contradictions in railway sector work accidents in which workers are run-over by trains: analysis based on the Cultural Historical Activity Theory

Abstract

This paper aims at highlighting historical contradictions that might contribute to the occurrence of accidents in the railway sector. The analysis was based on the Cultural-Historical Activity Theory. Among the hypotheses there are: difficulties in coordination between different departments, the goals they are submitted to, and the material, technical and professional conditions for carrying out the activities; and technological quality changes and an increase in the demand for passenger transport and the flow of trains, which reduce the time available for maintenance and adjustments.

SESSION 6

Case studies

Bastien BROCARD

Researcher

Électricité de France - R&D, FRANCE

A historical and organizational point of view on Bretigny railway accident

Biography

After ten years of operational experience in a nuclear power plant and in EDF Nuclear Division headquarters, I joined EDF R&D in 2008 to work on the fields of industrial risk management, operating experience feedback, nuclear safety and human reliability assessments. In this context, I had the opportunity to analyse in depth several major disasters, whether in industry or transport. I am now using these skills within the EDF crisis organization, which I recently integrated.

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Abstract

In this paper, we propose a systemic and historical analysis of the train accident that occurred on July 12, 2013 in *Bétigny-sur-Orge*, south of Paris (France). We focus on organizational changes driven by a difficult economic context, to highlight factors and dynamics that, at different levels of the organization, can contribute to degrading the security of the system.

SESSION 6

Case studies

Mircea NICOLESCU

Head of Technical and Development Department

Romanian Railway Investigation Agency – AGIFER, Bucharest, ROMANIA

Biography

After graduating the "Politehnica" University Bucharest-The Faculty of Transports he worked as engineer to the Romanian national passenger railway undertaking – SNTFC "CFR Calatori" SA. Since 2004 until 2007 he activated in the Safety Department of the Romanian Railway Authority. Then he moved to the Romanian Railway Investigating Body, as investigator, where he was part of investigation team that have performed investigation of serious accidents and other accidents. He commenced as the Head of Technical and Development Department in 2015 when the Romnian Investigating Body has reorganised and has transformed in Romanian Railway Investigating Agency. Currently is doctoral candidate at the Faculty of Transports.

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A freight train derailment analyses using Accident Investigation Board Norway method and Safety Management System wheel tool

Abstract

The derailments of trains could have serious consequences related to service interruptions, property damage, including environment and possible victims, so the study of this occurrences through methods and models borrowed from other sectors of economy, may be beneficial for the railway sector. The paper has analysed a railway accident occurred through a freight train derailment on the Romanian railway network (the derailment of the freight train no.51720 occurred in the railway station Ditrău, on 17th of November 2016) using two working instruments: the investigation method developed by the Accident Investigation Board Norway and Safety Management System developed by European Union Agency for Railway. By applying these two methods it is shown their ability to a thorough investigation of the occurrence by analysing organizational and working environment as well as by identifying the key factors that contributed to the accident. It also highlights the action directions for improving the safety level on which the safety recommendations were designed.

SESSION 7
Going across sectors

Constantin VOICU

General Manager

Civil Aviation Safety Investigation and Analysis Authority, Bucharest, ROMANIA

Biography

Constantin VOICU is the General Manager of the Romanian Civil Aviation Safety Investigation and Analysis Authority. He has a professional experience of 44 years in civil aviation. He had his first contact with the aviation in 1975 and 10 years later he was awarded the "Golden C with two diamonds" distinction in gliding. Between 1978-1981 he attended the Military School of Aviation Officers and obtained a commercial pilot license. He has also an experience of 35 years and 4000 flight hours as a pilot instructor for light and ultralight aircraft and gliders and owns a Cessna 172 aircraft.

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Independence and interdependence in safety investigations

Abstract

The European Union, paying particular attention to optimizing and maintaining safety standards in transport and making every effort to reduce accidents, has established at European level the conduct of safety investigation in the event of accidents and incidents occurred in air, rail and naval transport, apart from any other form of administrative or judicial investigation that seeks to establish liability or fault, in order to determine the causes and circumstances that led to their occurrence, their analysis and the prevention of other similar accidents and incidents.

SESSION 7
Going across sectors

Alexandru STOIAN

Senior Engineer

National Nuclear Electric Company
Bucharest, ROMANIA

Biography

Nuclear Engineer with 19 years overall experience in nuclear engineering, safety case and analysis, regulation and project management: 5.5 years as safety analyst for Romanian Nuclear Regulatory Authority (CNCAN), 2 years as project manager for Center for Nuclear Safety (CENS – Bratislava, Sk), 7.5 years as project engineer for AMEC Nuclear Ro (Bucharest, Ro), 2 years as safety engineer for Belgian Nuclear Research Centre (SCK-CEN Mol, Be), 2 years as senior engineer at National Company Nuclearelectrica, dealing with safety and technical evaluations for Cernavoda NPP and with nuclear fuel management.

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Dan ȘERBĂNESCU

Risk and safety analyst

Division of Logic and Models in Science - National Committee of History in Science and Technology - Romanian Academy,
Bucharest, ROMANIA

Biography

See p. 315

Some Aspects of the Probabilistic Versus Risk Evaluations of Railway Events

Abstract

The railway events evaluations are performed with various methods, which are under continuous improvement, as defined now in this industry. However, it is considered that the use of methods already implemented in other industries, as for instance in nuclear, might bring a new light and possible future benefit for the present approaches. The paper proposes a new view on the existing approach for the railway events evaluation, based on a case study. The case study is based on real database existing in Romanian national railways events data. The results indicate that, there are possible positive effects on the interpretation of existing data if methods from other industries (as for instance from nuclear) are used.

SESSION 7
Going across sectors

Petre-Cornel Min

Head of CNCAN Emergency Operation Centre

National Commission for Nuclear Activities Control (CNCAN), Bucharest, ROMANIA

Biography

Head of CNCAN Emergency Operation Centre (December 2012 – present):

- Coordination, developing, maintenance of Emergency Response Centre of CNCAN;
- Emergency Controller for CNCAN emergency response team;
- Development of regulations in the area of EPR;
- Development of working methodologies, guidelines and procedures for radiological emergency situations;
- Preparation of emergency response plan in case of radiological emergency or nuclear accident, and associated emergency procedures;
- Regulatory review and approval of nuclear/radiological Emergency Response Plan submitted by licensees;
- Participation in the preparation of the National Response Plan in case of a nuclear accident or radiological emergency;
- Providing training for CNCAN Emergency Response Team;
- Coordination and participation in national exercises in the EPR field;
- Adviser in National Committee for Special Emergency Situations.

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Key Factors of the National Emergency Management System

Abstract

In the paper, it is proposed to study a method for assessing the systemic management of emergency management in case of nuclear accidents. In order to identify the key factors in the emergency management system the chosen analysis method is a systemic one that deals with the interaction of component parts for defining sensitive elements of weak links that require more attention to improve them.

SESSION CHAIRS
SESSION 1

Tuuli TULONEN

Senior Officer

Finnish Safety and Chemicals Agency (Tukes), Tampere, FINLAND

Biography

See p. 328

Sever PAUL

Investigator

Romanian Railway Investigation Agency – AGIFER, Bucharest, ROMANIA

Biography

See p. 329

SESSION CHAIRS
SESSION 2

Yves DIEN

Researcher

Collectif Heuristique pour l’Analyse Organisationnelle de Securite (CHAOS) FRANCE

Biography

See p. 325

Ana Lisa VETERE ARELLANO

Scientific Officer

Technology Innovation in Security Unit
European Commission
Joint Research Centre
Ispra, ITALY

Biography

See p. 329

SESSION CHAIRS
SESSION 3

Eric MARSDEN

Programme manager

FonCSI (Foundation for an industrial safety culture), FRANCE

Biography

Eric Marsden's work concerns the organizational aspects of safety management in high-hazard sociotechnical systems. His activities at the FonCSI involve managing research projects, organizing working groups and disseminating findings to stakeholders. He holds a PhD in dependable computing from LAAS-CNRS, France

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Bastien BROCARD

Researcher

Électricité de France - R&D, FRANCE

Biography

See p. 350

SESSION CHAIRS
SESSION 4

Sverre RØED-LARSEN

Manager SRL HSE Consult

member of the ESReDA PG Foresight in Safety
Oslo,
NORWAY

Biography

See p. 318

John STOOP

Professor Forensic engineering and safety investigations

Kindunos Safety Consultancy Ltd, Gorinchem,
The NETHERLANDS

Biography

See p. 316

SESSION CHAIRS
SESSION 5

Paulo MAIA

Specialist/Generalist Engineer

EDP Energias de Portugal, SA, PORTUGAL

Biography

I am a materials engineer from the Technical University of Lisbon since 1987. I am a post-graduate in Welding Engineering from the Portuguese Welding and Quality Institute and a post-graduate in Risk Assessment, Safety and Reliability from the Technical University of Lisbon.

I started my professional career as a production engineer at a steel foundry. In 1990 I joined EDP, where I have performed several functions as a materials engineer in R&D projects funded by the Commission of European Communities (CEC) in the field of material behaviour at elevated temperatures, advanced methods for non-destructive examination and remaining life assessment of critical components of conventional fossil-fuelled power stations. Since 2005 until the present day, I have been working as a risk manager on the conventional power generation sector, including both thermal and hydro power stations.

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Zdenko ŠIMIĆ

Scientific officer

European Commission, Joint Research Centre (JRC), Petten, The NETHERLANDS

Biography

See p. 327

SESSION CHAIRS
SESSION 6

Frank VERSCHUEREN

Process Safety Inspector

Ministry of Labor, BELGIUM

Biography

See p. 320

SESSION CHAIRS

SESSION 7

Nicolas DECHY

Specialist in human and organizational factors

IRSN (French National Institute for nuclear safety and radiation protection), FRANCE

Biography

See p. 334

Milos FERJENCIK

University teacher

Institute of Energetic Materials, Faculty of Chemical Technology, University of Pardubice,

CZECH REPUBLIC

Biography

See p. 330

ANNEXES

Annex A – 55th ESReDA seminar program

1st day, Tuesday October the 9th, 2018

8.00 – 8.30 Coffee + registration

8.30 – 9.20 WELCOME, OPENING
Luis Ferreira, ESReDA President
Raed ARAFAT, Ministry of Internal Affairs, State Secretary
Vasile BELIBOU, AGIFER General Manager
Eugen ISPAS, AGIFER Deputy General Manager

9.20 - 9.30 LOGISTICS, WORKSHOP
Ana Lisa Vetere Arellano, Tuuli Tulonen, Eric Marsden and Sever Paul

9.30 – 10.50 SESSION 1 – Past, present, future
Chairs: Tuuli Tulonen and Sever Paul

9.30 – 10.00 Invited Lecture I:
On a possible approach for the multi criteria event analysis in complex systems events
Dan Șerbănescu

10.00 – 10.25 Railway Accident Investigation in a Globalising System
John Stoop, Wim Beukenkamp

10.25 – 10.50 From Sectorial to Multimodal Accident Investigation Boards – Some Lessons from the Development in the Nordic Countries
Sverre Røed-Larsen, John Stoop

10.50 – 11.10 COFFEE BREAK

11.10 – 12.25 SESSION 2 – Organizations and human aspects
Chairs: Yves Dien and Ana Lisa Vetere Arellano

11.10 – 11.35 Learning from organizational dysfunctionalities
Frank Verschueren

11.35 – 12.00 Effective communication during and after an aviation accident
Simona Wist

12.00 – 12.25 Issues with lessons learned, seen by field experts and managers, and synergy between experience reporting and experience sharing
Florence-Marie Jégoux

12.25 – 13.25 LUNCH

13.25 – 15.05 SESSION 3 – Methodological aspects
Chairs: Eric Marsden and Bastien Brocard

13.25 – 13.50 Method and Mindset: Two basic elements for accident investigation
Yves Dien

13.50 – 14.15 Events groups' importance ranking with consistent preferences consideration
Zdenko Simic

14.15 – 14.40 Reasonable recommendations
Tuuli Tulonen, John Stoop, Ana Lisa Vetere Arellano, Sever Paul, Milos Ferjencik, Matti Peippo, Erkki Teräsmaa

14.40 – 14.50 Arrangement for the workshop

14.50 – 15.10 COFFEE BREAK

15.10 – 16.50 SESSION 4 – Lessons learned and historical perspectives
Chairs: Sverre Roed-Larsen and John Stoop

15.10 – 15.35 Learning from incidents – the interactive way
Zsuzsanna Gyenes

15.35 – 16.00 Using the knowledge of accidents in organizational diagnosis of safety management: a case study
Nicolas Dechy, Jean-Marie Rousseau, Alexandre Largier, Stéphanie Tillement, Jan Hayes, Benoît Journé

16.00 – 16.25 Operating experience program at CNE Cernavodă
Alexandra Tudor

16.25 – 16.50 Are structural weaknesses limiting the capacity to learn from incidents?
Anthony Garforth, John Kingston, Petra Scheffers

16.50 – 17.00 Arrangement for the workshop

17.00 – 17.20 BREAK

17.20 – 18.20 WORKSHOP: ***Debate about the Remaining Challenges of Accident Investigation and Potential Innovative Breakthroughs***

18.45 - Departure from Hotel Ramada to the restaurant by bus

20.00 - ESReDA 55th Seminar Dinner

2nd day, Wednesday October the 10th, 2018

8.40 – 9.00 Coffee

9.00 – 9.30 Invited lecture II
Critical infrastructure: the public transport network METROREX
Raed ARAFAT, Secretary of State, Romanian Internal Affairs Ministry

9.30 – 9.45 Reflection session: Discussion: ideas from the first day

9.45 – 10.15 Invited lecture III:
Cyber security in railways, threats and challenges. Results of UIC project ARGUS
Teodor Grădinariu

10.15 – 10.35 COFFEE BREAK

10.35 – 11.50 SESSION 5 – Methods
Chairs: Paulo Maia and Zdenko Simic

10.35 – 11.00 Do not repeat old mistakes in learning from accidents: It`s better to prevent a run away than be ready for it
Milos Ferjencik, Oldrich Cizek

11.00 – 11.25 Analysing the depth of railway accident investigation reports on over-speeding incidents, using the SAfety FRactal ANalysis method
Bart Accou

11.25 – 11.50 On some issues related to the railways event impact on other industries
Dan Serbanescu

12.00 – 13.00 LUNCH

13.00 – 14.15 SESSION 6 – Case studies
Chairs: Frank Verschueren and Miodrag Strucic

13.00 – 13.25 Historical contradictions at work accidents by trampling in railway sector: analysis based on the Cultural Historical Activity Theory
Manoela Gomes Reis Lopes, Rodolfo Andrade de Gouveia Vilela, Ildeberto Muniz de Almeida, Silvana Zuccolotto

13.25 – 13.50 A historical and organizational point of view on Bretigny railway accident
Bastien Brocard

13.50 – 14.15 A freight train derailment analysis using Accident Investigation Board Norway method and Safety Management System wheel tool
Mircea Nicolescu

14.15 – 14.35 COFFEE BREAK

14.35 – 16.15 SESSION 7 – Going across sectors
Chairs: Nicolas Dechy and Milos Ferjencik

14.35 – 15.00 Independence and interdependence in safety investigations
Constantin Voicu

15.00 – 15.25 Some Aspects of the Probabilistic Versus Risk Evaluations of Railway Events
Alexandru Stoian, Dan Serbanescu

15.25 – 15.50 Key Factors of the National Emergency Management System
Petre Min

15.50 – 16.15 Dose Level Evaluation in a Nuclear Power Plant Accident
Dominic Eugeniu Moraru, Ilie Constantin Prisecaru, Daniel Dupleac

16.15 – 16.30 Closing session - "Seminar takeaways"
Chairs: Sever Paul and TPC members

16.30 – 16.40 CLOSING SPEECHES
Luis FERREIRA, ESReDA President
Vasile Belibou, AGIFER General Manager

Annex B – About the seminar

Scope of the Seminar

Accident investigation and learning from events are fundamental processes in safety management, involving technical, human, organizational and societal dimensions. These activities are concerned by a number of challenges that limit their effectiveness and by a number of opportunities for improvement:

- Safety investigations in complex systems face challenges in understanding and investigating inter-organizational issues (such as governance, shared responsibilities, limits to information flow, role of competition and other economic incentives), in coping with the increasing role of media pressure and presence of civil society in investigations, and the evolving role of regulatory authorities.
- There are major challenges in bringing into practice a body of existing knowledge on accident investigation and learning to generate system change for safety improvement. This requires better understanding of the obstacles to practical application of good practices. Given differences in histories, technologies and culture, these obstacles are sometimes sector-specific, or peculiar to certain countries, or more generic. New strategies need to be identified to overcome the obstacles to sharing of good practice and improvement of the quality of safety investigations.
- New opportunities for safety investigation and learning arise from technological progress, such as the increasing use of big data and text mining tools, and the related analytics.

These questions apply to several aspects where margins for improvement are still expected:

- paradigms, models and methods for accident/event investigation;
- data and evidence collection, forensic techniques;
- investigators’ competencies, learning and safety management competencies for specialists and generalists;
- organisational readiness to investigate and to learn;
- dissemination of information, lessons and integration with knowledge management and safety culture,
- event databases, big data and related analytics;
- systemic approaches integrating technical, human and organizational factors;
- safety recommendations and engineering change;
- lessons learning processes (single case, stories, relationships with organisational learning),
- change management and integration with safety management and risk governance,
- interfaces with regulators and stakeholders from society.

The 55th ESReDA seminar will be a forum for exploring the questions mentioned above. The seminar goal is to discuss about the results in specific areas, and to share and explore the experiences of using other paradigms, approaches, methods, databases, implementation of safety systems across various industries. Authors are invited to present their works, proposals and discuss successes and failures in safety management.

Application domains

Papers for the seminar are welcome from various stakeholders (industrialists, regulators, investigation and safety bodies, universities, R&D organizations, engineering contractors and consultants, training specialists) and could address different sectors:

- Railway sector and other transport sectors;
- Energy (including nuclear, conventional and renewable, production and distribution);
- Process industry: oil and gas, chemical and petrochemical facilities;
- Critical infrastructures;
- Natural hazards;
- Health, Environment;
- Security and terrorism threats.

Seminar organisation

Location

Ramada Plaza Bucharest
Str. Poligrafiei nr.3-5, Sectorul 1
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Reservations: +40 21 549 2300
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Organization

The Seminar is jointly organised by ESReDA and AGIFER.

Chairman of the seminar

Luis FERREIRA, (ESReDA President, Professor at University of Porto, PORTUGAL)

The Technical Program Committee Chair:

Sever PAUL, (Investigator - AGIFER, ROMANIA)

The Technical Program Committee Members:

Bastien BROCARD (EDF, FRANCE)

Nicolas DECHY (IRSN, FRANCE)

Yves DIEN (CHAOS, FRANCE)

Antonio FELICIO (ESReDA, PORTUGAL)

Milos FERJENCIK (University of Pardubicze, CZECH REPUBLIC)

Paulo MAIA (EDP, PORTUGAL)

Eric MARSDEN (FonCSI, FRANCE)

Sverre RØED-LARSEN (SRL HSE, NORWAY)

Zdenko ŠIMIĆ (EC JRC, THE NETHERLANDS)

Dan SERBANESCU (Romanian Academy, ROMANIA)

Miodrag STRUCIC (EC JRC, THE NETHERLANDS)

John STOOP (Kindunos, THE NETHERLANDS)

Tuuli TULONEN (Tukes, FINLAND)

Frank VERSCHUEREN (Ministry of Labor, BELGIUM)

Ana Lisa VETERE ARELLANO (EC JRC, ITALY)

Opening of the seminar

Cătălin FORȚU (Secretary of State, Romanian Transport Ministry, ROMANIA)

Vasile BELIBOU (General Manager of AGIFER, ROMANIA)

Eugen ISPAS (Deputy General Manager of AGIFER, ROMANIA)

Closing of the seminar

Vasile BELIBOU (General Manager of AGIFER, ROMANIA)

Logistics

Vali PATRASCU (Head of Department – AGIFER, ROMANIA)

Sever PAUL (Investigator-AGIFER, ROMANIA)

Mircea NICOLESCU (Head of Department – AGIFER, ROMANIA)

About Romanian Railway Investigation Agency - AGIFER

The Romanian Railway Investigating Agency (AGIFER) is a public institution, financed completely from its own funds and set up in 2015.

AGIFER is a technical specialized body for the railway and metro field, subordinated to the Romanian Minister of Transports, that meets with all the tasks of the body in charge with the investigation of accidents and incidents set up in 2007, according to the Law no.55/206, that transposed into Romanian legislation the EU Directive no.49/2004 for the railway safety.

AGIFER has the following main tasks:
a) Investigation of major railway accidents;
b) Investigation of the incidents that arise during railway operations, coordinated by an investigator in charge, appointed from AGIFER;
c) Investigation of those accidents and incidents that, in slightly different conditions could lead to serious accidents, including the technical failures of the structural sub-systems or of the interoperability constituents, parts of European high speed and conventional railway system;
d) Other tasks specific to its activity field, entrusted through normative papers.

AGIFER can participate in projects in connection with the investigation or with the improvement of railway safety, financed through European funds, according to the legislation in force.

AGIFER employs 42 people, including 28 investigators or investigator in charge within the investigation commission, specialized for different railway areas: lines, equipment, wagons, locomotives, traffic. AGIFER also employs 2 psychologists in charge of the investigation of the human factors.

From its establishment in 2006 until today, AGIFER has performed 344 investigations of railway accidents and incidents.
www.agifer.ro

About the European Safety, Reliability & Data Association (ESReDA)

ESReDA is an international non-profit association with approximately 35 member organizations comprising companies from different industries, research organizations and universities working within the safety and reliability field.

ESReDA aims to promote the development and the exchange of data, information and knowledge through the promotion of Project Groups (PG) on subjects related to Reliability, Safety and Data Analysis. In these project groups, European specialists in these subjects are able to meet and, in a first time, to aggregate their knowledge and then to disseminate it for the sake of the scientific and technological communities. This dissemination can be made by organizing seminars twice per year and publishing the most important results of the Project Groups. Safety and Reliability Engineering is viewed as being an important component in the design of a system. However, the discipline and its tools and methods are still evolving and expertise and knowledge dispersed throughout Europe. There is a need to pool the resources and knowledge within Europe and ESReDA provides the means to achieve this.

Any interested party is welcome to contribute to ESReDA Project Groups. For more information on ESReDA, please visit www.esreda.org.

About ESReDA Project Groups connected with this seminar

The ESReDA project group "Accident Investigation" was operational from 2000 to 2008 to address accident investigation methods, practices, organizational conditions, institutional and regulations context.

The PG organized 2 seminars and issued three deliverables:
•The 24th ESReDA Seminar on "Safety Investigation of Accidents" in JRC, Petten, 2003
•The 33rd ESReDA Seminar on "Future challenges of accident investigation"; in JRC, Ispra, 2007
• "Accident Investigation Practices – Results from a European Study" (2003 – report edited by DNV);
• "Shaping Public Safety Investigations of Accidents in Europe" (2005 – ESReDA Safety Series – book edited by DNV);

• "Guidelines for safety investigation of accidents" (2008) available for free download on the ESReDA website.
•Guidelines for Safety Investigation of Accidents at ESReDA website.

The ESReDA project Group "Dynamic Learning as a follow-up from accident investigation" was in operation from 2009 to 2015. It worked on how lessons from events and accidents are learned.

The PG organized 2 seminars and issued four deliverables:
•The 36th ESReDA Seminar on "Lessons learned from accident investigations", EDP, Coimbra, Portugal, 2009.
•The 45th ESReDA Seminar on "Dynamic Learning from Incidents and Accidents, Bridging the Gap between Safety Recommendations and Learning", EDP, Porto – Portugal, 2013
• "Case study analysis on dynamic learning from accidents" ESReDA report,
• "Barriers to learning from incidents and accidents" ESReDA report,
• "Guidelines for preparing a training toolkit on event investigation and dynamic learning", ESReDA report
• "Challenges to the investigation of occurrences. Concepts and confusion, metaphors, models and methods". Essay by Prof. Stoop.

The 4 deliverables are available for free at the Project Group webpage on the ESReDA website.

ESReDA Project Group on Foresight in Safety
In autumn 2015 a project group was launched for 3 years to address Foresight in Safety. The project group meets twice a year. It gathers industry experts, researchers and consultants from: EDF-R&D (France), EDP-Gestão da Produção de Energia, S.A. (Portugal), IRSN (France), EC JRC (Italy and The Netherlands), Kindunos (the Netherlands), Tukes (Finland), FonCSI (France), SRL HSE (Norway), University of Pardubice (Czech Republic), Labor Ministry of Belgium, and AGIFER (Romania). It organised the 53rd Seminar in JRC at Ispra, Italy in November 2017.

Participating Organisations

Agenția de Investigare Feroviară Română (AGIFER), ROMANIA

Civil Aviation Safety Investigation and Analysis Authority Bucharest, ROMANIA

Collectif Heuristique pour l'Analyse Organisationnelle de Sécurité (CHAOS), FRANCE

Czech Railways, Pardubice, CZECH REPUBLIC

Division of Logic and Models Romanian Academy, ROMANIA

Électricité de France Recherche et Développement (EDF-R&D), FRANCE

European Commission Joint Research Centre (JRC), ITALY

European Commission Joint Research Centre (JRC), THE NETHERLANDS

European Union Agency for Railways, FRANCE

Finnish Safety and Chemicals Agency (Tukes), FINLAND

FOD WASO TWW ACR, BELGIUM

Fondation pour une Culture de Sécurité Industrielle (Foncsi), FRANCE

Freelance Human Factors specialist, FRANCE

Institution of Chemical Engineers Safety Centre, UNITED KINGDOM

Institut Mines-Telecom Atlantique, FRANCE

Institut de Radioprotection et de Sûreté Nucléaire (IRSN), FRANCE

Kindunos, Gorinchen, THE NETHERLANDS

National Commission for Nuclear Activities Control, ROMANIA

Noordwijk Risk Initiative Foundation, THE NETHERLANDS

Polytechnic University of Bucharest, ROMANIA

RMIT University, AUSTRALIA

Romanian National Nuclear Electricity Company, ROMANIA

SRL SHE Consulting, NORWAY

Transport and Environment Inspectorate, Utrecht, THE NETHERLANDS

Université de Nantes, FRANCE

University of Pardubice (UP), CZECH REPUBLIC

University of Sao Paolo, BRAZIL

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