Human Error Views: A Framework for Benchmarking Organizations and Measuring the Distance between Academia and Industry

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Abstract

The paper presents a framework that through structured analysis of accident reports explores the differences between practice and academic literature as well amongst organizations regarding their views on human error. The framework is based on the hypothesis that the wording of accident reports reflects the safety thinking and models that have been applied during the investigation, and includes 10 aspects identified in the state-of-the-art literature. The framework was applied to 52 air accident reports published by the Dutch Safety Board (DSB) and 45 ones issued by the Australian Transport Safety Bureau (ATSB) from 1999 to 2014. Frequency analysis and statistical tests showed that the presence of the aspects in the accident reports varied from 32.6% to 81.7%, and revealed differences between the ATSB and the DSB approaches to human error. However, in overall safety thinking have not changed over time, thus, suggesting that academic propositions might have not yet affected practice dramatically.

Keywords: safety thinking, human error, accident reports analysis

1. Introduction

Safety critical organizations have been highly concerned about their safety performance, which is monitored by various proactive and reactive methods, including the investigation of incidents and accidents; these are collectively known as safety investigations. Accident causation models have evolved from the root cause rationale to multiple cause analyses and systemic approaches (Katsakiori, Sakellaropoulos, & Manatakis, 2009). In parallel, the views of how humans contribute to failures have shifted from blaming the operator to understanding how the end-user decided and acted during an event (e.g., Dekker, 2006).

Although the new accident causation models and safety thinking are widely accepted in academic circles, there has been no study about the extent to which current practice has embraced such academic thinking. This paper presents a framework that includes aspects of the state-of-the-art safety thinking and can be used to evaluate the presence of those aspects in accident and incident reports, and compare views on human error amongst organizations.

2. Analysis Framework

The analysis framework was initially developed, calibrated and validated during a research project (Karanikas et al, 2015); thereafter, the framework was refined by de Jong and Palali (2015) and Vanderstappen and Zomer (2015). The aspects included in the framework sourced from literature review and regard the new views on human error as well the basic accident models, as those have been introduced and discussed by various academics. Nine of the aspects refer to the approach to human error during safety investigations (Table I) and one aspect regards the accident model followed by the investigators (Table II).

Table I: Old and New Views on Human Error (adapted from de Jong and Palali, 2015).

Framework Aspect	**Old View**	**New View**	**Literature Reference(s)**
Human Error seen as symptom.	Human Error is seen as the principal cause of accidents.	Searching for factors that contributed to Human Error.	Dekker, 2006
Hindsight bias avoidance	Looking to the event backwards and simply recording errors, inaccurate assessments and wrong decisions.	Consider why choices made sense to users at that time, and what options they had prior to the accident.	Dekker, 2006
Shared responsibility	Focus on end-user(s) without exploring influences of other organizational levels.	End-user is not the focal point; organizational factors are also investigated.	• Catino, 2008 • Dekker, 2006
Non proximal	Shared responsibility might be discussed, but investigators persist on investigating in detail the end-user level.	Equal investigation of all organizational functions.	Dekker, 2006
Lack of folk models	Adopting abstract statements (e.g., loss of situational awareness, complacency).	Decomposing and explaining the problems.	• Dekker & Hollnagel, 2004 • Dekker, 2006
Non Counterfactual	Merely comparing human performance against standards and procedures.	Exploring the reasons for deviating from standards. Examining the assumptions the standards were based on.	Dekker, 2006
Non judgemental	Actions are compared with norms expectations (e.g., knowledge, experience and training).	Exploring the reasons for not meeting expectations. Examining the validity of established norms an expectations.	Dekker, 2006

Framework Aspect	Old View	New View	Literature Reference(s)
Safety-II	Humans are predominantly seen as a hazard. Emphasis on explaining failures.	Humans are seen as a resource necessary for system flexibility and resilience. Focus on explaining past success.	Hollnagel, 2014
Control loops	Inadequate investigation about feedback mechanisms.	Feedback mechanisms between different involved parties are considered.	Leveson, 2011

Table II: Basic Accident Model Families (adapted from Vanderstappen and Zomer, 2015).

	Sequential models	Epidemiological models	Systemic models
Search principle	Specific causes and well-defined links.	Carriers, barriers and latent conditions	Tight couplings and complex interactions.
Analysis goals	Eliminate or contain causes.	Make defences and barriers stronger.	Monitor and control performance variability.
Literature Reference(s)	• Underwood & Waterson, 2013	• Underwood & Waterson, 2013 • Reason et al., 2006	• Underwood & Waterson, 2013 • Hollnagel & Goteman, 2004 • Leveson, 2004, 2011

3. Methodology

The framework was applied to air accident reports published online by the Dutch Safety Board (DBS) and the Australian Transport Safety Bureau (ATSB). Two pairs of researchers recorded and analysed the accident reports dated from 1999 to 2014, resulting to a sample of 52 DSB reports (de Jong and Palali, 2015) and 45 ATSB reports (Vanderstappen and Zomer, 2015). For the scope of this paper, the records of the two samples were combined in order to provide an overall picture of the frequency of the framework aspects and conduct statistical calculations. It is clarified that:

- The researchers recorded each new safety thinking aspect based on the wording used in the reports and the overall approach followed in each accident case.
- Regarding the Safety-II aspect, the researchers assigned it as present whenever at least one reference to successful barriers and defences was identified.
- The Control Loop aspect was recorded in the cases where any feedback mechanisms were addressed in the reports, regardless whether those were structurally presented (e.g., hierarchy of controls).
- The pilot application of the framework resulted to an inter-rater reliability of about 80%. This score was achieved after proper familiarization of the researchers with the new safety thinking aspects.
- Cases of reports where a framework aspect was not applicable or evident were excluded from the calculations.

- The framework aspects were confirmed as collectively exhausted, based on the review of current literature, as well as mutually exclusive.

Depending on the sample sizes, Chi-square and Fisher Exact tests were performed as means to explore differences between the DSB and ATSB approaches, between accidents with and without direct end-users' involvement, and between accidents with and without fatalities. In order to explore any differences over time, the sample was divided into two periods, 1999-2006 and 2007-2014 since the time between the accident dates and the release of the reports was calculated to 2 years (median value) and most of the state-of-the-art literature about human error and new accident models was published after 2004. The significance level for the statistical calculation was set to 0.05. Table III summarizes the sampling frame.

Table III: Sampling Frame

	Time period		**End-user involvement**		**Fatalities**	
	1999-2006	**2007-2014**	**YES**	**NO**	**YES**	**NO**
DSB reports	26	26	29	23	4	48
ATSB reports	24	21	25	20	9	36
Remarks:	Used to explore differences over time		Used to assess if approaches had changed depending on end-user's direct engagement in the accident		Used to evaluate if safety views differed due to emotional pressure.	

4. Results

The application of the framework resulted to the frequencies of aspects, shown in Table IV as percentages for the total sample and per publishing authority. It is noticed that a systemic model was used into only 1 out of the 97 reports analysed; hence, Table IV and the statistical calculations presented later in the paper refer only to the frequencies of epidemiological and sequential models use.

Table IV: Frequencies of Framework Aspects.

Framework Aspect		**DSB**	**ATSB**	**TOTAL SAMPLE**
Human Error seen as symptom.		69.4%	77.8%	73%
Hindsight bias avoidance		45.7%	93.3%	72.5%
Shared responsibility		59.1%	76.9%	67.5%
Safety-II		14%	53.3%	32.6%
Control loops		72%	75.6%	73.7%
Lack of folk models		78.7%	87.5%	81.7%
Non Counterfactual		65.8%	81.8%	74.4%
Non judgemental		63.2%	86.4%	75.6%
Non proximal		53.7%	75%	64.2%
Accident model	Sequential	50%	31.1%	40.6%
	Epidemiological	50%	68.9%	59.4%

The results of the statistical calculations are shown in Table V. The significant results have been bolded and underlined. The *p* values marked with an asterisk (*) refer to Fisher Exact test results, while the rest of the values refer to Chi-square test results.

Table V: Statistical Calculations Results.

Framework Aspect	**Independent Variables**			
	Publishing Authority	**Time Period**	**End-user Involvement**	**Fatalities**
Human Error seen as symptom	p= 0.328	p= 0.212	*p= 0.458	*p= 0.134
Hindsight bias avoidance	**<u>p= 0.000</u>**	p= 0.456	p= 0.123	*p= 0.570
Shared responsibility	p= 0.067	p= 0.406	p= 0.326	*p= 0.328
Safety-II	**<u>p= 0.000</u>**	**<u>p= 0.008</u>**	**<u>p= 0.012</u>**	*p= 0.132
Control loops	p= 0.437	p= 0.525	**<u>p= 0.013</u>**	*p= 0.463
Lack of folk models	*p= 0.287	p= 0.585	*p= 0.185	*p= 0.322
Non Counterfactual	p= 0.080	p= 0.597	p= 0.365	*p= 0.294
Non judgemental	**<u>p= 0.014</u>**	p= 0.302	p= 0.101	*p= 0.607
Non proximal	**<u>p= 0.038</u>**	p= 0.164	p= 0.058	*p= 0.530
Accident model	p= 0.057	p= 0.279	**<u>p= 0.018</u>**	**<u>p= 0.041</u>**

The frequencies of the framework aspects which differed significantly between the publishing authorities have been already mentioned in Table IV. The rest of the independent variables concerned, the corresponding frequencies are shown in Tables VI, VII and VIII.

Table VI: Frequencies of the Significant Differences between Time Periods.

Framework Aspect	**1997-2006**	**2007-2014**
Safety-II	32.3%	67.7%

Table VII: Frequencies of the Significant Differences across the End-user Involvement Variable.

Framework Aspect		**End-user Involvement**	**No End-user Involvement**
Safety-II		38.7%	61.3%
Control loops		64.3%	35.7%
Accident model	Sequential	41%	59%
	Epidemiological	64.9%	35.1%

Table VIII: Frequencies of the Significant Differences across the Fatalities Variable.

Framework Aspect		No Fatalities	Fatalities
Accident model	Sequential	94.9%	5.1%
	Epidemiological	80.7%	19.3%

5. Discussion

The overall results suggest that all framework aspects were identified in the accident reports published by the DSB and the ATSB, however with various frequencies. The three mostly represented aspects were the avoidance of the folk models, the non-counterfactual approach and the non-judgmental attitude; these findings might be considered as positive since they indicate the endeavours of the investigators to explain in depth human performance and avoid the mere attribution of accidents to non-compliance to procedures and non-fulfilment of expectations. Safety-II was the most underrepresented aspect, showing that the focus on failures is dominant during safety investigations. It must be noticed that the concept of exploring and explaining success has been introduced recently in the literature and it was expected that it has not been widely disseminated in the industry. This was confirmed by the fact that Safety-II was the only aspect that changed significantly over time, and it was present more in the accident reports after year 2007. Also, the increased use of epidemiological models compared to the sequential ones indicate a positive step towards addressing multiple contributing factors in the accident investigation reports; however, systemic models were not applied even during recent accident investigations.

The comparison between the DSB and the ATSB showed that the latter has followed all new views on human error and the epidemiological models more frequently than the former. As resulted by the statistical calculations, there was a significant difference between the two authorities regarding the aspects of hindsight bias avoidance, Safety-II, non-judgmental attitude and non-proximal approach, which the ATSB accident reports included remarkably more often than the DSB. Those differences could be due to various reasons, such as safety training syllabus, acceptability of new theories, cultural differences etc.

Interestingly, apart from Safety-II, the frequencies of the rest of the framework aspects have not been significantly altered over time. Although the new views on human error were introduced mainly after 2004, it seems that industry practice had already adapted them at various cases and with diverse intensity, and that the perspectives of investigators and authorities were not drastically influenced by the academic literature and research.

The cases where the end-user was directly involved in the accident scene affected three of the framework aspects. The results suggest that:

- Successful barriers and defences were discussed more in the cases of non-direct involvement of the end-user, meaning that investigators emphasized more on failures when human error had been identified in the operational frontier.

- Feedback mechanisms were addressed mostly in the cases of operators' contribution to accidents. The study of the reports revealed that the principal control mechanism discussed in such accidents was the communication between air crew members and ATC personnel.
- The sequential models were applied more frequently in the events with non-direct involvement of the end-user. Those cases regarded mostly mechanic failures, where the use of a linear model was more preferred. On the other hand, whenever operator's human error was present at the accident course, epidemiological models were employed more often.

Lastly, it seems that human losses due to accidents did not affect the views of investigators, thus, implying an increased professionalism that requires a control of adverse emotional effects. The results also showed that fatalities triggered investigators to follow epidemiological models instead of sequential ones.

6. Conclusions

The framework presented in this paper has the potential to uncover the extent to which new views on human error and modern accident models have been embraced by investigators, organizations and authorities. Therefore, the value of the framework can be considered as two-fold: it might be used for evaluating the distance between theory and practice, and it might be exploited in the assessment of differences among authorities, companies etc.

Although a gap between academia and industry practice is inevitable, such a distance in the context of safety and human factors thinking had not been previously quantified. Certainly, any measured distance is not self-explanatory; thus, it must be seen as a stimulus for exploring the underlying reasons. Resistance to change, limited access to state-of-the-art literature, misbelief to academic research, pressure for compliance with established standards might comprise few of the reasons on the industry side. Lack of effective and continuous communication with the industry, the suggestion of extremely complex and resource demanding tools and models, and inadequate on-field experience of academics could be some of the factors that might have negatively affected the relation between academia and practice.

Furthermore, the differences revealed by the application of the framework to accident reports, are not definitely related to variations of safety performance. The new views on human error express a more human-centred approach, and modern accident models address the challenges organizations face in our complex and dynamic world. To date, there are no sufficient research results linking the implementation of state-of-the-art models and views with increased safety performance. However, doubtlessly humans are the critical factor of successful systems design, operation and maintenance, and the variability and flexibility are deemed as critical factors for organizational sustenance and viability. Therefore, it is a premise that literature that considers the human element as the most valuable and determinative component of systems might drive organizations to challenge their corresponding perspectives and consequently revisit their safety initiatives.

The application of the framework will be extended to the analysis of accident reports published by other civil aviation authorities as means to enrich the sample and draw results that might be generalised.

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