Enhanced Context of Accident Analysis and Classification – Digging Root Causes behind Causes

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Accident investigation must “dig deep to get the truth”. Whereas accident prevention should be “precautionous beforehand; guard against creeping malpractice”. Bounteous efforts have been dedicated to an investigation of accident and dissemination of conclusions, but these efforts may not tell us the causative context we need to know in accident reports. The purpose of this study was to reveal the enhanced contextual analysis and classification of accident that lead the preventive direction towards the underlying causes and the right remedial strategies. In this paper we resolved and reconstructed the investigation report of Colgan Air Flight 3407 accident occurred on February 12, 2009, and dig corresponding human factors depending on sequential timed events, factual data, investigative evidence and causal analysis interpretation.

**Keywords:** Human factors gaps; Enhanced context; Root causes; HFACS

1. **Introduction: Background, motivation and objectives**

In order to understand the underlying causes of all levels in past socio-technical system accidents, it is important to reveal a more thorough analytic context. For some incomprehensible reasons, causative factors and latent conditions that should be able to assess and judge were still potentially lurked inside another similar system, even did not detect and eliminate until fatality happen again. In other words, it could be understood why lots of accidents didn’t be prevented due to the lessons drawn from others’ mistakes. The prospective efficiency of recommendations coming from investigation report was not achieved, either what more do we need to learn in case-based accident investigation?

This phenomenon highlights unceasing and substantial efforts dedicated to accident investigations, but these efforts may not tell us in-depth causative context we have to know, and in fact people still miss some critical lessons that should be learn in accident reports and recommendations (Kletz, 2009; Lindberg, Hansson and Rollenhagen, 2010; Hovden, Størseth and Tinmanvsk, 2011; Lundberg, Rollenhagen, Hollnagel and Rankin, 2012; Dien, Dechy and Guillaume, 2012).

The primary goal of this study is to ensure that multilevel learning effects and a preventive mechanism could be built by means of revealing the enhanced context of human factors analysis and classification. This led the preventive direction towards the underlying causes and the right remedial strategies. Furthermore, as noted by Llory (1996) and Llory et al. (2007), we have to avoid both the ‘retrospective bias’ and ‘hindsight bias’, because these biases were so deep-rooted that impact on accident analysis can be limited avoid.

Given the theoretical positions taken for the study and the status of the field as briefly reviewed above, the questions for the research were:

I. How to find and fill human factors gaps which still existed in the investigation process and the analysis results?
II. Can an approach provide a clearer insight into an enhanced context of the underlying causes?
III. How to reveal the verifiable process of digging root causes in sample accidents?
IV. What prospective advantages of this article could help readers in the broader sociotechnical context to prevent similar events to recur?

2. **Theoretical framework and case study**

In order to assist in achieving organizational resilience to prevent disaster recurrence, lessons from a crisis event by appropriate analytical methods is absolutely necessary. A qualitative case study approach, context
analysis, and two human factors accident analysis methods were conducted to gain in-depth and holistic understanding of enhanced accident context. In this study, several theories and human factors discipline were conjugated in the analytic process to clarify its relevance of methods to research purposes. The innovative application of existing methods is one of the greatest contributions of our research.

It seems to be a generally accepted fact that the Human Factors Analysis and Classification System (HFACS; Wiegmann and Shappell, 2003) and risk management framework (Rasmussen, 1997) has massive empirical support both at theoretical and applied levels. However, due to the lack of literature reporting in-depth context for learning from those accident analysis methods, this research was designed as a case study to provide sympathetic insight into the issue. As Salmon et al. (2010) point to a major drawback of HFACS is that its scope don’t cover failures and human factors outside of organization, Harris and Li (2011) put forward a hybrid model HFACS-STAMP (System-Theoretical Accident Model and Processes) to make up the limitations of inter-organizational errors. In addition, the presence of outside influences factors (e.g. air traffic control, regulatory, maintenance, airport/airport personnel) was introduced into factors at any levels of original HFACS model (Inglis, Smithson et al., 2010). However, the most critical issue of existing human factors methods is that the training threshold is too high to learn and apply in causes mining in occurrence database for accidents, and conducive to organizational learning and to reveal the context of accidents.

Therefore, the integrative and hybrid methodology presented below is expected to provide a verifiable process of how to reveal enhanced context of human factors gaps analysis and classification in selected accidents.

2.1 Background of the case
To screen a representative sample of accident investigation report and make sure the case study would allow generalization of findings, we tried to set up few criteria as follows may help the selection was restricted to international accidents based on an expected element of common context:

I. The sample accident was noted for obvious human factors problem involved in complex sociotechnical systems.

II. Investigation results were broadly similar to events in the past, coverage factors especially from systemic causes in the organization to human error in the front line.

Before considering which method was suitably used in this study, the first challenge is “how to select the critical case”. Through various observations of major accident cases, this review mainly focus on category “Level I unsafe acts” of generic framework of the HFACS model, then flight 3407 accident were analyzed using the enhanced context of HFACS to elucidate the root causes of error, because it was the casualty of a commercial airliner and high-profile accident in the United States since the August 2006. Exploratory cum experimental research design was chosen for inductive content analysis and a case study in the framework ofEnhanced HFACS. In the project group are two ergonomics experts and one doctoral candidate. In addition, there are four prospective graduate students participate in the project. This far most important data have been participant own observations about human error and failures, data coding from U.S. National Transportation Safety Board (NTSB) aircraft accident report.

According to the NTSB/AAR-10/01 accident report, at Eastern Standard Time 2217 the night of Feb. 12, 2009, Colgan Air Bombardier DHC8-402 Q400 (Flight 3407) approaching Buffalo-Niagara (New York, U.S.) International Airport crashed as a result of the captain’s inappropriate response to a stick shaker activation, which led to an unrecoverable aerodynamic stall and loss of control on an instrument. The flight was a 14 Code of Federal Regulations Part 121. Night visual meteorological conditions prevailed at the time of the accident. Including two pilots, two flight attendants, 44 passengers, one off-duty pilot, and a person in the house into which the plane crashed were perished. (NTSB 2010, p.152).

The NTSB investigation of the accident concluded that:
“… the probable cause of this accident was the captain’s inappropriate response to the activation of the stick shaker, which led to an aerodynamic stall from which the airplane did not recover. Contributing to the accident were (1) the flight crew’s failure to monitor airspeed in relation to the rising position of the low-speed cue, (2) the flight crew’s failure to adhere to sterile cockpit procedures, (3) the captain’s failure to effectively manage the flight (inappropriate training for stall avoidance and recovery), and (4) Colgan Air’s inadequate procedures for airspeed selection and management during approaches in icing conditions (NTSB, 2010, p. 155).”
The accident was explained as being caused mainly by the failures of the humans at the sharp end, that is, "it's the last straw that breaks the camel's back", and with some blame also going to the Colgan Air. The following description of the accident and accident timeline (see Fig. 1) are adapted from the report.

![Accident Timeline Diagram](image)

### 2.2 Model used in the study

#### 2.2.1 Accident human factors analysis and classification

The HFACS was subsequently derived from Reason's Swiss Cheese Model, the major contribution was the well-definition and explanation of its taxonomies of latent failures involved in accidents, and provide a guideline for analysts classify the errors that across the following four levels: (1) Unsafe acts; (2) Preconditions for unsafe acts; (3) Unsafe supervision; and (4) Organisational influences.

When we review the past decade studies, one of the most fruitful areas of HFACS research has focused on the effectiveness and reliability of human errors coding taxonomy that arises from the disparity between individuals and group decision process, categorical variable and logistic regression were also widely regarded as reliable methods to evaluate association and to predict relationships between failure pathways (Li, Harris and Yu, 2008; Inglis, Smithson et al., 2010). In addition, within the field of accident analysis and prevention, a gradual but marked shift in the focus of HFACS applications research has taken place, and gotten considerable attentions not only from failure correlation across different levels of the model but also from case-based perspective (Xi, Chen, Fang and Hu, 2009; Celik and Cebi, 2009). Nevertheless, research that has empirically documented the link between analytical ratiocinative process of root causes and hierarchical learning in the organization is scant.
To overcome the absence of human factor gaps in an analysis of investigation that should give better insight into the causes of accidents and the measures to prevent them. This study proposed a coherently contextual analysis process about tracking the latent causes behind causes found in evidentiary analysis, and primary tools are described below (Table 1 and Fig. 2). Two examples of active failures behavior and phenomenon on the first column of Table 1 were specifically extracted and transcribed from accident report by analysts. At the same time, we detailed record the number of pages and rows as a basis for follow-up inspection, and also listed all safety-related personnel. Finally, preliminary analysis and judgment in accordance with the context of the whole accident sequences would explain why we did reach a conclusion of human factors categories and sub-categories.

2.2.2 Contents analysis and contextual integration of investigation report

Content analysis is a well-established method that has been widely accepted in many academic disciplines. In the first step of this study, a documentary analysis is also regarded as the basis of follow-up works, and the quality of investigation report is also an essential requirement for this research. Thus, when asked, "How to consider biases of survey methods, techniques, and of investigators’ subjective judgment? ", the case selection according to accident investigation report of U.S National Transportation Safety Board to avoid an adverse impact of the analysis documents. On the other hand, to understand the depth of sample case carried out, analysts have to survey the accident report in detail, resolve and reconstruct critical events depend on sequential time, factual data, investigative evidence and causal analysis interpretation etc. until dig all of corresponding contributory factors and identify linkage of failures within and between levels.

Many latent conditions of noticeable mishaps were caused by routine tasks and the existing regulatory framework even existed month prior. From the evidence shows most of existing system were still not sensitive enough to actively detect the presence of prior signs of causal factors, even though the concept of resilience engineering already pre consider in system design and evaluation phase. Therefore, the case study attend to highlight the need for contextual integration after accident analysis, the practicality of the proposed methodology is demonstrated through enhanced human factors contextual analysis, thereby promoting individuals to supervisor to achieve organizational learning effectiveness. In this new view, we developed a “step-by-step guide” for analyst in order to contextualize, to recognize the differences between reports’ findings and comprehensive understanding of analytical context and those represented in the text, so that analyst could more clearly identify human factors gaps.

Table 1. Two examples of accident/incident human factors classification and analysis as it is practiced in the case

<table>
<thead>
<tr>
<th>Description of specific behavior &amp; phenomenon</th>
<th>Coding data</th>
<th>Related personnel</th>
<th>Possible factors</th>
<th>HFACS Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>The captain did not recognize the stick pusher's action to decrease angle-of-attack as a proper step in a stall recovery, and his improper flight control inputs to override the stick pusher exacerbated the situation.</td>
<td>P.152 4</td>
<td>Captain; First officer; Instructor</td>
<td>Inadequate knowledge; CRM Training; Startle &amp; Confusion</td>
<td>Inadequate knowledge of system/procedures</td>
</tr>
<tr>
<td>(02/09) The captain was stayed overnight in the crew room before a 2-day trip to begin the next day. (02/11) The captain was again staying in the crew room. The captain used the crew room for overnight sleeping on 02/09 and 02/11.</td>
<td>P.105 3; 18 P.110 6–7</td>
<td>Captain; Colleagues; Supervisor; Colgan safety personnel</td>
<td>Organizational Climate; Risk Management; Fatigue management Program</td>
<td>Failed to correct a known problem Failed to correct inappropriate behavior/identify risky behavior</td>
</tr>
</tbody>
</table>
Next, let’s introduce contextual integration process via an example of “Routine violation” state the following (Fig. 3):

“Violation of orders, regulations, SOPs”: The captain and the first officer of Flight 3407 accident engaged in a nonpertinent conversation for much of the flight, even during the final minutes of the descent, they failure to adhere to Sterile Cockpit rule and procedures (14 CFR 121.542, “Flight Crewmember Duties”), the rule prohibiting extraneous conversation during critical phases of flight (all ground operations involving taxi, take-off and landing, and all other flight operations conducted below 10,000 feet MSL, except during cruise flight).

I. First step start from active failure that depends on “how the findings and probable causes are defined?”, e.g. Violation (Categories of Level 1- Unsafe Acts). Start at the direct consequence of behavioral perspective and ask, “What did the person’s behavior or action poses a possible threat to cause the violation?”. In this case, the most unusual is that non-pertinent conversation during all phases of flight, even during the final minutes of the descent, then two serious errors which occurred followed by extraneous conversation: (1) Distracted them from their operational tasks and visual scan; (2) Deviated from standard operating procedures with the timing of checklists.

II. Next, follow up previous question on a quest for further evidence behind direct consequence, we ask, “What’s the person’s intention?”. If we stay in investigation perspective, it is still difficult to identify a precise and exact cause for this unusual behavior. In addition, we should think about what’re in-depth reasons contributed to flight crew’s noncompliance with standard operating procedures. What’s atmosphere created in the cockpit? Did pilots intentionally create an atmosphere? Is it useful to enhance mutual understanding, co-operation or to inspire confidence? This is what is called the “Psychosocial perspective”.

III. The third stage is“Cognitive perspective”, the question are raised “Did the person aware of ... made him distract from primary tasks?”. It’s necessary to focus on human capabilities about perception, cognitive workload, attention resource allocation, risk assessment, distractions, and
interruptions, etc. Let us try to imagine the situations just when pilots talked about their flight career, salary and position one hour before Flight 3407 crashed, they could control the plane at the same time because of during cruise flight. However, even though they had received professional training to enable them have an ability of resources allocation than most people, it’s obviously the same principle that mobile telephones use on driving is prohibited by law.

IV. Ultimately, it is often difficult to isolate the causes of errors from one perspective or under a separate entity concept. Hence, taking a close look at causes under systems perspective and giving a problem the whole picture is absolutely necessary. In retrospect, it’s easy to see why flight crew’s performance during the flight including the captain’s deviations from standard operating procedures, the first officer’s failure to challenge these deviations, and crew’s poor understanding of icing system, stall recovery. These are signs that poor co-operation and human-automation interaction in this case.

Figure 3. An example of contextual integration process of the Enhanced HFACS

3. Results of case review study: Content analysis and human factors classification

The results from the content analysis of the Colgan Air 3407 accident investigation report, the highest proportion that total 13 contents were classified into level 1 “Unsafe acts” committed by front-line operators that led to accident, and 6 breaches in the report were classified as level 3 “Unsafe supervision”. The same problem is addressed by level 4 “Organizational influences” which a high degree of a significant indicator, the report identified 6 contributory factors at this level. In addition, at least 5 contents also provided a potential percentage in level 2 “ Preconditions for unsafe acts”.

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During the data collection and analysis, contextual description of specific behavior and phenomenon was divided into four main categories that include of routine and exceptional violations (20%) were the more frequent categories of unsafe act, followed by decision errors (13.3%) and skill-based errors (10%). Skill-based errors were highlighted the problem that inadequate knowledge and poor quality for the decision maker. Skill-based errors were typically related to poor technique or airmanship and failure to see and avoid, whereas decisions to undertake inappropriate maneuvers or procedures and to undertake tasks that exceeded abilities in training were typical of decision errors.
Table 2. Results from the content analysis of accident report regarding human factors category

<table>
<thead>
<tr>
<th>HFACS Level</th>
<th>Main-Category</th>
<th>Sub-Category (Frequency)</th>
<th>Proportion of Main-Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 4</td>
<td>Organizational Process</td>
<td>Oversight (2)</td>
<td>6.7%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Training (3)</td>
<td>13.3%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Selection (1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resource Management</td>
<td>Failed to track qualification (1)</td>
<td>13.3%</td>
</tr>
<tr>
<td>Level 3</td>
<td>Inadequate Supervision</td>
<td>Planned inappropriate operation (1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Failed to provide current publications/adequate technical data (1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Loss of supervisory situational awareness (1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Failed to Correct a Known Problem</td>
<td>Failed to correct inappropriate behavior/ identify risky behavior (1)</td>
<td>6.7%</td>
</tr>
<tr>
<td></td>
<td>Supervisor Violation</td>
<td>Failed to enforce rules and regulations (1)</td>
<td></td>
</tr>
<tr>
<td>Level 2</td>
<td>Adverse physiological states</td>
<td>Physical fatigue (2)</td>
<td>6.7%</td>
</tr>
<tr>
<td></td>
<td>Personal Readiness</td>
<td>Failure to adhere to crew rest requirement (1)</td>
<td>6.7%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pattern of poor risk judgment (1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Crew Resource Management</td>
<td>Lack of teamwork (1)</td>
<td>3.3%</td>
</tr>
<tr>
<td>Level 1</td>
<td>Routine Violations</td>
<td>Violated training rule (1)</td>
<td>10.0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Failed to comply with departmental manuals (2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exceptional Violations</td>
<td>Accepted unnecessary hazard (2)</td>
<td>10.0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Failed to obtain valid weather brief (1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decision Errors</td>
<td>Wrong response to emergency (2)</td>
<td>13.3%</td>
</tr>
<tr>
<td></td>
<td>Skill-based Errors</td>
<td>Inadequate knowledge of system/procedures (2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Breakdown in visual scan (1)</td>
<td>10.0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inadvertent use of flight controls (1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Failure to see and avoid (1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>

4. Conclusions

One of the main conclusions of this study is that we aim to trace the sequence and comparable elements of content to reconstructed the enhanced HFACS to fit the accident case. The dissecting process was employed in this study can be the fundamental basement to apply in various situation.

Undoubtedly, the accident prevention tasks has been investment in terms of their practices of risk management, and has regarded as active approach to avoid similar accidents happening again, whether from the two extreme opposite views on theoretical model of human error or human contribution (Reason, 1990; 2008). Since risks associated findings, probable causes, and potential causes of incidents or accidents could get through safety investigation; however, the accident investigation itself is a very complex activity, and thus different investigators and teams will depict different events investigation process (Dien et al., 2012). For example, in the investigate directions and final results of Singapore Airlines Flight SQ006 accident at Taipei on 31 October 2000 were totally different by Aviation Safety Council of the Republic of China (R.O.C.) and Singapore Ministry of Transport investigation team, it also worth using enhanced HFACS theory and in its concrete step.

The main contribution of this study to concretely restore the original appearance of the accident through a systematic methodology enhanced HFACS, and made a profile of human factors gap that was disappeared, not clearly defined in the investigation report, even not be filled when previously issued recommendations reiterated in this report.
Acknowledgements

The National Science Council of Taiwan, R.O.C. is greatly acknowledged for the financial support through the project. This work is a part of a three-years (2010/08–2013/07) research project (NSC: 99-2221-E-007-087-MY3) “Using Enhanced Human Factors Analysis and Classification System to develop an analysis method for root causes of human error.”

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