How useful is linking between error causes in human error analysis?

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Abstract

As finding root causes of human error in safety-critical systems is a cognitively demanding and time-consuming task, it is particularly necessary to develop a method for improving both the quality and efficiency of the task. Although a number of methods such as CREAM (Hollnagel, 1998) have suggested causal linking between error causes (or performance shaping factors) as a method for enhancing the quality and efficiency of human error analysis, no published research to date has evaluated how useful the causal links are. This paper presents a study for evaluating the effectiveness and efficiency of the causal links between over 100 error causes by a meta-analysis of 78 railway accident investigation reports from the UK. Two measures, coverage and selectivity, were used to evaluate the effectiveness and efficiency of the links, respectively. About 96% of error causes actually included in the accident reports were found by just following the causal links, and among the total of 121 error causes, the number of error causes to be examined further was reduced to one-tenth (about 13) on average.

Keywords: human error analysis, accident investigation, performance shaping factor (PSF), CREAM

Introduction

As analyzing human error in safety-critical systems (e.g., nuclear power plants, rail, and aviation) is a cognitively difficult and time-consuming task, there has been a strong need to develop a method for improving both the quality and efficiency of the task. A number of methods such as the Cognitive Reliability and Error Analysis Method (CREAM) [1] and the Human Error Analysis and Reduction (HEAR) [2] have suggested causal linking between error causes (or performance-shaping factors) as a technique for enhancing the quality and efficiency of human error analysis. On the surface, such links between error causes seem to be useful for analysis. However, no published research to date has evaluated the effectiveness or efficiency of linking between error causes. Therefore, this study evaluated the effectiveness and efficiency of the CREAM links between error causes.

Method

To evaluate the effectiveness and efficiency of the CREAM links between error causes, 78 investigation reports of UK railway accidents, which were published by the Rail Accident Investigation Branch (RAIB) from 2008 to 2010, were analyzed. As Hollnagel [1] noted, for practical use in a particular domain, the elements in each group of error causes, especially “organization”-related causes, and links between them should be extended. Thus, error causes and their links of CREAM were partly revised. In total, 121 error causes were used for evaluation.

From each investigation report, erroneous actions of

front-line operators (e.g., train drivers, signalers, track workers) were derived, and for each error, candidate causes were found by the predefined links between causes. Among the candidate causes, only those that were actually included in the report were regarded as effective causes. Error causes, which were described in the report but were not covered by the causal links, were also examined.

Two measures – coverage and selectivity – were used to evaluate the effectiveness and efficiency of the CREAM links, respectively. In this study, “*coverage*” is defined as the degree to which the causal links support analysts to find correct error causes. Its value, which varies between 0 and 1, is given by the following expression. The nearer the coverage value is to 1, the more causes, which are described in the investigation report, are covered by the causal links.

$$\text{Coverage} = \frac{\text{Number of causes covered by the causal links}}{\text{Number of causes included in the report}}$$

If the causal links find too many candidate causes, the coverage value is generally expected to be high; thus, the selectivity (or efficiency) of the causal links was also measured. In this study, “*selectivity*” is defined as the degree to which the causal links reduce the scope of error causes to be examined in detail. Its value, which also varies between 0 and 1, is determined by the following expression. Contrary to coverage, selectivity is better as its value is nearer to zero.

$$\text{Selectivity} = \frac{\text{Number of candidate causes derived by the causal links}}{121 \text{ (total number of error causes)}}$$

Table 1 shows an example of the evaluation of the links between error causes. Among the six causes of the error that are included in the report, five were found by the causal links and the other, “inadequate team support” was not covered.

Table 1. An example of the evaluation of linking between error causes

Report Number	24/2009		
Report Title	Freight train collision at Leigh-on-Sea		
Date of Accident	April 26 th , 2008		
Human Error	The train driver did not control the speed of the train so as to be able to stop short of the stationary train on the line ahead.		
Error Type	Delayed interpretation		
Error Causes	1 st level	Fatigue	No/Inadequate procedure
	2 nd level	Irregular working hours	Inadequate QC (procedure)
	3 rd level	Shift work	N/A
	4 th level	N/A	N/A
Factors not covered by candidate causes	Inadequate team support		
# of candidate causes by the links (A)	13		
# of effective candidates (B)	5		
# of the actual causes in the report (C)	6		
Coverage (B/C)	0.833		
Selectivity (A/121)	0.107		

Results

Among the 78 railway accidents examined, 10 accidents did not involve any erroneous actions of front-line operators. The other 68 accidents (87.2%) involved at least one human error; in total, 97 errors were used for evaluation.

Table 2. Overall results

Average number of candidate causes by the links	12.98
Average number of effective candidate causes	3.38
Average number of the actual causes in the report	3.56
Average coverage	0.961
Average selectivity	0.107

Table 2 shows the overall evaluation results of the links between error causes. On average, about 13 candidate causes, for each error, were found by the causal links. The number of effective candidates, which were actually included in the investigation report, was on average 3 to 4. The RAIB investigation reports

described on average 3.56 causes for each error examined here, which were slightly more than the effective candidate causes. Note that the average coverage is less than 1. Although the coverage values of the causal links were 1 for most errors (82 out of 97; 84.5%), the values were less than 1 for 15 errors (15.5%). For the 15 errors, some of its causes described in the report (e.g., “lack of risk assessment”, “insufficient liaison between staff”, and “inadequate team support”) were not covered by the causal links.

The average selectivity value was 0.107, which means that the predefined links between error causes reduced the number of error causes to be examined in detail to one-tenth on average. This result indicates that linking between error causes is very efficient for human error analysis.

The most frequent cause of errors was “no/inadequate procedures” (50 out of 97; 51.5%), followed by “inadequate quality control of procedures” (30.9%), “inadequate training” (24.7%), and “insufficient knowledge” (21.6%). The most frequently used link was “no/inadequate procedures → inadequate QC of procedures,” which occurred in 30 out of 97 (30.9%) errors. “Maintenance failure → no/inadequate procedures” (24.7%) and “insufficient knowledge → inadequate training” (15.5%) followed.

Conclusion

In this study, the effectiveness and efficiency of the CREAM links between over 100 error causes were evaluated by a meta-analysis of 78 railway accident investigation reports from the UK. About 96% of the error causes actually included in the accident reports were found by just following the causal links, and among the total of 121 error causes, the number of error causes to be examined in detail was reduced, on average, to one-tenth. This result implies that the predefined links between error causes can significantly reduce the time and effort required to find the multiple levels of error causes and their causal relations without losing the quality of the results.

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