Something for everyone: A generic AcciMap contributory factor classification scheme

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ABSTRACT

AcciMap is now arguably the most popular accident analysis method with applications across a wide range of domains; however, one limitation of the method is the absence of a classification scheme to support analysts in identifying and classifying contributory factors. This potentially limits the reliability of the method and prevents the aggregation of data when the method is used to analyse multiple incidents. In response to this, this paper presents a generic AcciMap contributory factor classification scheme that was developed based on a review and analysis of the AcciMap analyses published in the peer-reviewed literature. The classification scheme comprises seventy-nine contributory factor types spanning the standard six AcciMap system levels and is generic in nature so can be applied in any domain. To close we discuss the implications for accident analysis and prevention activities and in particular encourage other analysts to apply the classification scheme in future applications. Aggregating accident analyses across the safety critical domains is recommended as an important area for future research.

KEYWORDS

Accidents, AcciMap, Accident analysis, Classification scheme

Introduction

Within ergonomics, and indeed safety science more broadly, practitioners involved in accident analysis and investigation activities are increasingly using Jens Rasmussen's risk management framework and accompanying AcciMap method (Rasmussen, 1997; Svedung & Rasmussen, 2002). Since its introduction in 1997, AcciMap has been applied for accident analysis and investigation purposes in all manner of domains ranging from road, rail, aviation and maritime to outdoor recreation, space exploration, and public health (Hulme et al., 2019; Waterson et al., 2017). Strengths of the AcciMap method include its alignment with state-of-the-art models of accident causation, its ease of use, and the fact that it is generic and can be applied in any domain (Salmon et al., 2011; Stanton et al., 2013).

Whilst its popularity shows no signs of slowing, AcciMap is not without limitations. One criticism levelled at the method is that it does not provide analysts with a contributory factor classification scheme to support the identification and classification of contributory factors (Goode et al., 2018; Salmon et al., 2012; Stanton et al., 2019; Waterson et al., 2017). This potentially impacts the method's reliability and validity, and also prevents aggregation of incident data (Salmon et al., 2012). As a result, it is difficult to use AcciMap as part of incident reporting and learning systems or accident and incident databases (Goode et al., 2018; Salmon et al., 2012). Moreover, it is difficult to aggregate analyses both within and across domains in order to identify accident causation trends or to test general assumptions around accident causation. A generic AcciMap contributory factor classification thus represents an important extension of the method that would not only facilitate further applications but also help enhance the knowledge base on accident causation both within and across the safety critical domains (Salmon et al., 2012; Under revision).

In this paper we present a generic AcciMap contributory factor classification scheme that was developed as part of a broader study involving a review and synthesis of the AcciMap analyses published to date in the peer reviewed literature (Hulme et al., 2019; Salmon et al, Under revision). Contributory factors and relationships were extracted from published AcciMap analyses and recoded to form a generic contributory factor classification scheme. The intention was to provide researchers and practitioners with a classification scheme to support future AcciMap applications in any domain.

Method

The study involved a review and synthesis of all AcciMap analyses published in the peer reviewed literature since 1997 (when the method was first introduced in the peer reviewed literature). The contributory factors and interrelations identified in each published AcciMap were extracted and coded to create a generic AcciMap contributory factor classification scheme.

AcciMap

AcciMap is based on Rasmussen’s (1997) proposition that behaviour, safety and accidents are emergent properties of complex sociotechnical systems. These emergent properties are created by the decisions and actions of all stakeholders within a system – politicians, chief executives, managers, safety officers and work planners – not just by front line workers alone (Cassano-Piche et al, 2009). The method is thus used to support analysts in identifying and representing this network of systemic contributory factors and where in the wider sociotechnical system they emerged. Typically, six hierarchical levels are used to represent the structure system in question: government policy and budgeting; regulatory bodies and associations; local area government planning & budgeting; technical and operational management; physical processes and actor activities; and equipment and surroundings. Contributory factors are identified, mapped to one of the six levels, and then linked between and across levels based on cause-effect relations. An example AcciMap for the 2009 Air France 447 crash is presented in Figure 1.

As demonstrated in Figure 1, AcciMap’s key strengths are that that it supports consideration of the contributory factors across the entire work system (up to and including government) as well as the interactions and relationships between contributory factors. These features go beyond other contemporary methods that do permit description or analysis of the interactions between contributory factors or do not go beyond the organisational level when identifying contributory factors (Hulme et al., 2019; Salmon et al., 2011; 2012).

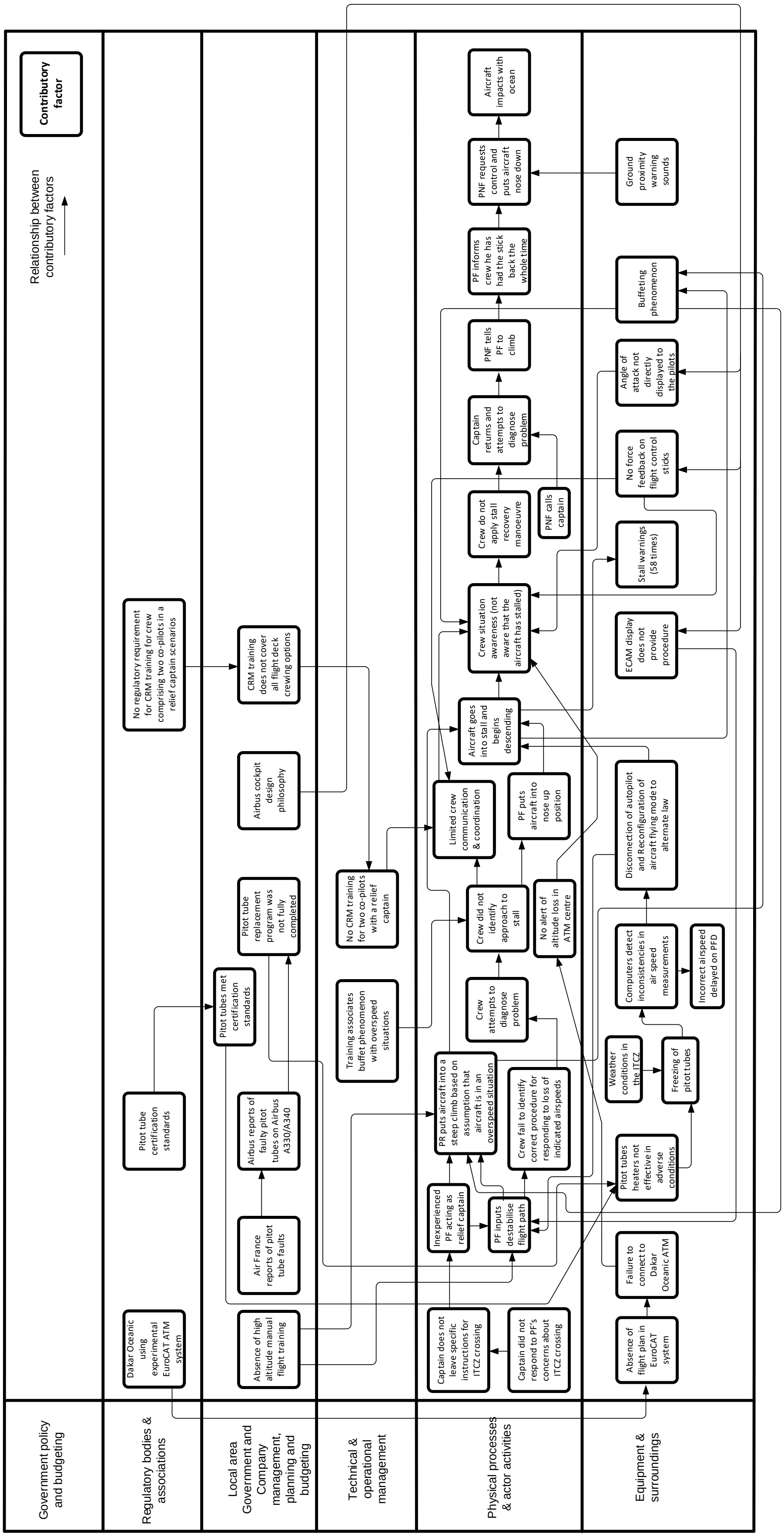

Figure 1. Example AcciMap based on Air France 447 incident.

Selection of AcciMap studies

Two recently published reviews were used as a basis to identify potentially eligible studies (Waterson et al., 2017, Hulme et al., 2019). The first, undertaken by Waterson et al. (2017), involved a review of 27 AcciMap studies undertaken between 2000 and 2015, including those published in peer reviewed journal articles, conference articles, and the grey literature. The second was a broader systematic review of systems thinking-based accident analysis methods and was undertaken by the authors of this article. The systematic review identified 21 AcciMap studies published in the peer reviewed literature since 1990 (Hulme et al., 2019).

Eligible studies involving an application of AcciMap were selected from Waterson et al. (2017) and Hulme et al. (2019). To be eligible for inclusion in the present analysis, the studies described in Waterson et al. (2017) and Hulme et al. (2019) were required to comply with the following criterion:

1. The study involved an application of the AcciMap method to analyse an accident or set of accidents.

The studies were excluded if they complied with the following criteria:

1. The study used AcciMap to analyse work-as-done or near miss incidents that did not involve an adverse outcome (i.e. the study was not focussed on an accident event). For example, Donovan et al. (2017) used AcciMap to analyse the factors which enabled the management of a large-scale mining landslide incident;
2. The study involved an enhancement of another accident analysis method via the integration of certain aspects associated with AcciMap; and
3. The study was reported in a conference or symposium presentation or paper, industry report, or article published in a language other than English.

Data extraction

Each eligible study was screened by two of the authors. The following data were extracted from each article: (i) authors; (ii) date of publication; (iii) domain; (iv) contributory factors; and, (v) relationships between contributory factors.

Coding of contributory factors and relationships

Each individual contributory factor was coded by one of the authors to build a generic classification scheme. The resulting classification scheme contained a total of 79 nodes across six AcciMap levels and was developed iteratively via the use of a qualitative software package (Nvivo 11 for Windows). The classification scheme was subsequently reviewed by the other authors prior to a reliability test of the contributory factor coding.

Inter-rater reliability analysis

An inter-rater reliability analysis of the contributory factor coding was undertaken on five of the AcciMaps. This involved a second analyst coding the contributory factors identified in each of the five AcciMaps. A total of 156 individual factors were independently coded by two authors using the classification scheme. Percent agreement and Cohen’s kappa (k) statistic were calculated based on comparing the coded contributory factors across the two analysts. Across the five studies the analysts achieved a high level of agreement (75.64%, K = 0.749, 95% CI 0.6804 to 0.8176).

Results

Studies included

Twenty three AcciMaps were included in the final analysis. The AcciMaps spanned various domains including road and rail transport (e.g. Newnam and Goode, 2015), off-road beach driving (Stevens & Salmon, 2016), public health (e.g. Woo and Vicente, 2003; Vicente and Christoffersen, 2006), counterterrorism (Jenkins et al., 2010), disaster response (e.g. Salmon et al., 2014a), maritime (Akyuz, 2015), outdoor recreation (Salmon et al., 2017), aerospace (Johnson and de Almeida, 2008), and civil engineering (Fan et al., 2015).

The majority of the studies included in the analysis present an AcciMap of a single accident event. Three of the studies present AcciMaps which cover multiple incidents from a larger dataset (Salmon et al., 2014b; Newnam and Goode, 2015; Salmon et al., 2017). For example, Salmon et al. (2014b) presents an AcciMap representing the contributory factors involved in 1014 led outdoor recreation injury incidents contained within the New Zealand National Incident Dataset.

In total 5,587 contributory factors were extracted from the 23 AcciMaps and were subsequently coded to form the generic AcciMap contributory factor classification scheme.

Generic AcciMap contributory factor classification scheme

The generic AcciMap contributory factor classification scheme is presented in Table 1. As shown in Table 1, the generic AcciMap contributory factor classification scheme includes 79 contributory factor types spanning all six AcciMap levels.

Table 1. Generic AcciMap Classification Scheme

Equipment, environment and surroundings	**Local area government, planning and budgeting and company management**
EES 1. Animal, plant & biological hazards	**LAGCM 44. Communication & coordination**
EES 2. Built environment & infrastructure	**LAGCM 45. Compliance with procedures, violations & unsafe acts**
EES 3. Equipment, technology & resources	**LAGCM 46. Culture**
EES 4. Information & data	**LAGCM 47. Financial pressures**
EES 5. Noise & visibility	**LAGCM 48. Judgement & decision-making**
EES 6. Other	**LAGCM 49. Other**
EES 7. Physical & natural environment	**LAGCM 50. Personnel management & recruitment**
EES 8. Time-related	**LAGCM 51. Planning & preparation**
EES 9. Weather & climate	**LAGCM 52. Policy & procedures**
EES 10. Work environment	**LAGCM 53. Qualification, training, experience & competence**
Physical processes and actor activities	**LAGCM 54. Risk assessment & management**
PPAA 11. Accident event	**LAGCM 55. Supervision**
PPAA 12. Activity, work & operations	**LAGCM 56. Time-related**
PPAA 13. Adverse events	**Regulatory bodies and associations**
PPAA 14. Communication & coordination	**RBA 57. Audits & inspections**
PPAA 15. Compliance with procedures, violations & unsafe acts	**RBA 58. Communication & coordination**
PPAA 16. Delayed discovery & response	**RBA 59. Compliance with procedures, violations & unsafe acts**
PPAA 17. Equipment, technology & environment	**RBA 60. Culture**
PPAA 18. Group & teamwork	**RBA 61. Financial pressures**
PPAA 19. Judgement & decision-making	**RBA 62. Judgement & decision-making**
PPAA 20. Other	**RBA 63. Planning & preparation**
PPAA 21. Personnel management & workloads	**RBA 64. Qualification, training, experience & competence**
PPAA 22. Physical & mental condition	**RBA 65. Regulatory structures & services**

PPAA 23. Planning & preparation	**RBA 66. Risk assessment & management**
PPAA 24. Qualification, training, experience & competence	**RBA 67. Standards, policy & regulations**
PPAA 25. Risk assessment & management	**RBA 68. Time-related**
PPAA 26. Situation awareness	**RBA 69. Unclear roles & responsibilities**
PPAA 27. Supervision & leadership	**Government policy and budgeting**
PPAA 28. Time-related	**GPB 70. Action omitted & failure to act**
PPAA 29. Weather, climate & natural processes	**GPB 71. Budget & finance**
Technical and operational management	**GPB 72. Communication & coordination**
TOM 30. Communication & coordination	**GPB 73. Culture**
TOM 31. Compliance with procedures, violations & unsafe acts	**GPB 74. Judgement & decision-making**
TOM 32. Culture	**GPB 75. Policy, legislation & regulation**
TOM 33. Equipment & environmental design	**GPB 76. Political structures & services**
TOM 34. Financial pressures	**GPB 77. Priorities**
TOM 35. Judgement & decision-making	**GPB 78. Qualification, training, experience & competence**
TOM 36. Other	**GPB 79. Supervision & enforcement**
TOM 37. Personnel management & recruitment	
TOM 38. Planning & preparation	
TOM 39. Policy & procedures	
TOM 40. Qualification, training, experience & competence	
TOM 41. Risk assessment & management	
TOM 42. Supervision	
TOM 43. Time-related	

Discussion

This paper has presented a generic AcciMap contributory factor classification scheme that was developed based on a review and synthesis of 23 AcciMap analyses published in the peer-reviewed literature. Based on 5,587 contributory factors, the resulting classification scheme comprises 79 contributory factor types spanning the six standard AcciMap system levels.

It has been argued that the utility, reliability and validity of AcciMap could be enhanced through the provision of a classification scheme to support analysts in identifying and coding contributory factors (Salmon et al., 2012; Goode et al., 2018 Newnam et al., 2017; Stanton et al., 2019). A contribution of this study is therefore the provision of a new classification scheme that can be used by analysts to classify contributory factors in future AcciMap analyses. It should be noted that we do not recommend that analysts use the classification scheme to support development of the initial AcciMap. Rather, the intention is to provide a classification scheme that can be used to code and analyse AcciMaps once developed as per normal practice. It is therefore recommended that, once analysts have developed their AcciMap, each of the contributory factors identified are classified using the new classification scheme. This will enable the original AcciMap to include all of the required details for each contributory factor, whilst the second coded AcciMap can be integrated into a dataset to support aggregation of multiple AcciMaps (e.g. Goode et al., 2018; Salmon et al., 2017). The classification scheme can also be used as a template to support accident investigation activities whereby investigators seek information on the potential involvement of each of the 79 contributory factor types. It is also worth noting that the classification scheme is non-domain specific and was developed based on AcciMap studies across multiple domains. As a result, it can be used to support future AcciMap analyses in any domain. Future applications of the classification scheme will enable a comparison of AcciMap studies both within and across domains and will allow researchers and practitioners to analyse multi-incident data sets using AcciMap (e.g., Newnam et al., 2017; Salmon et al., 2014; 2017).

Applications of the classification scheme could be used to explore the similarities and differences in accident causation across different domains, which in turn could provide important advancements to accident causation models. Although most accident causation models are generic and can be applied in any domain, the idea that accident causation is homogenous across safety critical domains is an assumption that has received relatively little testing (Hulme et al., 2019; Salmon et al., Under revision). Turner (1978) examined the contributory factors involved in major accidents and disasters and found that man-made disasters share a set of common characteristics. Grant et al. (2018) synthesised state-of-the-art accident causation models and identified fifteen common accident causation tenets. Further analyses using the classification scheme presented here to explore similarities and differences in accident causation across domains are important, as this will help determine whether domain specific accident causation models and accident analysis methods are required (Salmon et al., 2012). Further, if similarities are identified this could have implications for accident prevention strategies that could be transferrable across domains. Comparisons of AcciMap analyses undertaken in different domains therefore represent an important future area of research.

Study limitations

This study has three limitations that should be noted. First, the inclusion and exclusion criteria led to the exclusion of several AcciMap analyses published in conference articles and the grey literature. As a result, the review was not entirely comprehensive; however, exclusion was required to ensure that the AcciMaps included were developed to a standard required for publication in the peer reviewed literature. Second, as the review was completed in 2018, it may be that recently published AcciMap studies have been overlooked. Third and finally, the analysis was based on AcciMaps developed by other researchers, some of which tested aspects such as reliability and validity of their analysis, some of which did not. As such, it is not possible to verify the validity of all AcciMaps included in the present study.

Conclusion

This study involved the development of a generic AcciMap contributory factor classification scheme. The resulting classification scheme comprises 79 distinct contributory factor types. It is recommended that the generic classification developed through the present study is used to support future AcciMap analyses, both to build a multi-domain accident dataset and to explore similarities and differences in accident causation across domains.

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