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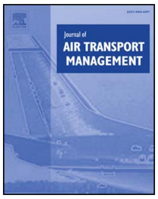

General model analysis of aeronautical accidents involving human and organizational factors

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ABSTRACT

This paper presents the development of a general model of accident analysis according to the principal factors which influence aeronautical accidents. This study aims to develop a general model of accident analysis able to assess any aircraft accident, taking into account the pilot's abilities, as well as human, organizational, and environmental factors the data of this research was collected through literature, aircraft accident report analysis, technical visits to the center of certification of commercial aircraft pilots, survey of pilots and consultation with industry experts. From this model, it is possible to evaluate the influence of these factors and identify their dependence and relationship, and how they influence the system. With the aid of the Bayesian Networks technique, it is also possible to quantify the factors and assess which ones have more impact on the system. The results show the relationship between the factors that can influence the performance of the pilots and, therefore, they may indicate how these factors can impact on the success or failure of tasks related to flight procedures. The identification of the factors in each category (abilities, performance shaping factor, management and organizational factors, environmental factors) that are relevant to the sector. The identification and quantification of the relationship of dependence (arcs in BN and respective CPT) are also part of the innovative contribution of the paper. The results also may indicate subsidies for mitigating actions, collaborating to the management of operational safety of air transport and to assess the overall impact of the factors that determine any accident.

1. Introduction

Safety is an intrinsic component of aviation. In addition to the key aspects of technical and human performance, the concept of organizational accidents developed in the 90s, should also be taken into account in the efforts for contemporary safety. This concept does not only consider the active faults of individuals developed in front line operations, but also latent conditions inevitably present in any system. One of the oldest models of accident causes is “Heinrich's Domino Theory” proposed by Heinrich in 1940, which describes an accident as a chain of discrete events that occur in a particular temporal order (Heinrich et al., 1980). According to Leveson (2003), this theory belongs to a class of sequential accident models based on accident events that gave allowances for most of the accident analysis models introduced subsequently. These models became known as Failure Mode and Effect Analysis (FMEA), Fault Tree Analysis (FTA), Event Tree Analysis (ETA), and Cause-Effect Analysis. Part of this approach was subjected to fierce criticism because it was based on causal relationships between events (Rasmussen, 1997; Hollnagel, 2004; Leveson, 2004).

According to Qureshi (2008), the traditional approaches for accident models are not suitable to analyze accidents that occur in modern socio-technical systems, in which the cause of the accident is not the result of individual component failure or human error. It can be said that such models limited the ability to explain the cause of accidents in complex systems developed in the last half of the twentieth century. That is, they work well only for losses caused by failure of physical components or human errors in simple systems. The author also considers that socio-technical systems should be treated as an integrated whole. Research and interdisciplinary studies are needed to understand the complexity of socio-technical systems. In addition, the multidimensional aspects of safety can be understood through a broad system view, later to achieve the modeling of accidents in socio-technical systems.

A series of new methods has been developed in the recent years to

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better meet the research needs of socio-technical systems and to respond to the introduction of new technological systems (Aven and Zio, 2011). Many of the methods introduced allow greater levels of detail and accuracy in modeling phenomena and processes covering physical phenomena, human and organizational factors. Also, the use of software, made the analysis more dynamic (Luxhøj et al., 2001; Mohaghegh et al., 2008; Ale et al., 2009; Røed et al., 2009). Other methods are devoted to improving the representation of risk analysis and related uncertainties, according to decision analysis. Examples of newly introduced methods are Bayesian Belief Network (BBN), Diagram Digits, Multi-State System Reliability (MSSR), Petri Nets and advanced Monte Carlo simulation tools.

A systemic view requires much more than listing a given number of factors which caused certain event, it must explain how the factors are interrelated and what factors are related. This answer comes before an analysis of an accident. The nature of these factors must be clarified before the analysis starts. With this purpose, the objective of this study is to develop a general model for risk analysis in aeronautical accidents according to a probabilistic approach, considering the human factors in the pilot's performance and organizational factors within the framework of commercial aviation passengers. Therefore, this paper presents an important innovation: the identification of the factors in each category (abilities, PSF, MOF, EF) that are relevant to the sector. The identification and quantification of the relationship of dependence (arcs in BN and respective CPT) are also part of the innovative contribution of the paper. The identification of the factors was performed based on a proposed methodology, including a field word, bibliographical survey, accident/incident history evaluation and expert consultation.

2. Background

As from the 50s, many efforts have been made in research to document the precise location of aircraft accidents, so that it could be possible to obtain an effective planning of airport operational safety and its surroundings using these data.

The highlight is “The Airport and Its Neighbors” report (The Report of the President's Airport Commission, 1952) in which it was conducted one of the first studies on the impact of Safety relations and noise effect within neighboring communities. Despite the limited data, this report led to the establishment of “Clear Zones” which are currently known as “Runway Protection Zone”. Another important study was “Air Installation Compatible Use Zone (AICUZ) Program” of the US Department of Defense in 1973. This study served to define significant areas of potential accidents for military aircraft, known as “Accidents Potential Zones (APZs)”. Additionally, Ashford and Wright (1992), in surveys conducted by the Airline Pilots Association, in the period from 1967 to 1992, indicated that 5% of accidents occur in route and 15% occur in the vicinity of airports. The remaining 80% occur in the landing and takeoff areas or clear zones.

The studies cited until now, highlight the positive effects generated post-analysis in order to mitigate or reduce the impacts caused by aircraft accidents. Moreover, the positive effects also caused several other studies on accidents increase by means of agencies and safety bodies worldwide. Overall, the conclusions or impacts of these studies are limited to the time when the statistical survey database was performed. Despite the importance of those data, the survey of the causes of accidents is valid only for the time period of analysis. In other words, the findings related to a particular accident data can not currently be applied as it is observed that the technology used in the flight control systems of aircraft is constantly changing, for example.

To reduce these negative effects, it is observed that studies are being conducted with an increasing number of samples (accidents or incidents). As examples, it can be cited accident analysis studies developed by the International Air Transport Association (IATA, 2014), California Airport Land Use Planning Handbook (CALTRANS, 2011), ACRP 3 (Hall et al., 2008), Report of the Runway Safety Initiative (FSF, 2009), ACRP 50 (Ayres et al., 2011), Report of the Boing Company (Boeing, 2010) among others, such as studies with criteria based on safety events in airport runways (Gonçalves and Correia, 2015, 2016). Despite the important contribution with a large number of samples, they present limited conclusions because they do not evaluate the relationship between occurrences and human performance factors or organizational factors. They were concerned only with accidents and/or aeronautical incidents analysis based on spatial location.

Within a systemic view, the studies Greenberg et al., (2005), Greenberg (2007), Roelen et al. (2011) and Martins and Maturana (2013) can be mentioned. Such studies have emphasized a probabilistic approach analyzing human factors, organizational factors and other factors associated with the environment and pilot's abilities. Greenberg (2007) developed a general model of quantitative analysis related to aviation accidents using Bayesian networks. However, the model of the proposed accident analysis does not highlight the procedures of the operation, but only factors that increase the threats of an accident. Despite all the efforts of the author, the proposed general model can not cover all possible types of accidents.

Roelen et al. (2011) developed a hybrid model for risk analysis together with the Eurocontrol and the Federal Aviation Administration (FAA). In summary, the model shows the union of the technical fault tree and event tree to the method of Bayesian networks. The model describes the top event (accident) which is broken down into event tree to obtain the description of the accident scene, according to its sequence of combination of events. Each category of accidents is represented by a fault tree (that is, according to the taxonomy of the accident). The basic elements of the fault tree which are described as “human factors” are developed using Bayesian network. Despite the traditional techniques unable to relate to the Bayesian network method, only part of the model can be quantified according to a probabilistic analysis (human factors). Thus, the interference that other variables may suffer from the actions of human factors are not observed. That is, the interference of the human factor-top event is “static.” It would be ideal if the whole model were converted into a Bayesian network; thus, it would be possible to obtain a quantification of the basic elements according to the event-top and vice versa.

Martins and Maturana (2013) analyzed the human error contribution for ship collision taking into consideration the activities performed by the crew and it is focused on the operation of an oil tanker in the Brazilian coast. This paper quantitatively evaluates human error using the Bayesian network method and the results identify the major human and organizational factors that influence in tankers collision accidents. The author searched evidence related to the occurrences of the possible human errors (not found in literature) according to the routine of the ship thus obtaining the necessary data to build the network. The authors consider environmental factors in the analysis, because the interference in the operations conducted by crew members may impact on their decision. For operations in airplanes, these factors strongly interfere in the flight crew's decisions, so do the pilot's performance.

Currently, most modern methods present in analysis of aircraft accidents, mainly used to evaluate human error and probable human factors involved are: SHELL Model, Human Factors Analysis and Classification System (HFACS) and Australian Transport Safety Bureau (ATSB) Model. Hawkins developed the concept into the “SHELL Model” which name was derived from the initials of its components (Software, Hardware, Environment, and Liveware) with an introduction of another Liveware into the original concept, “SHEL Model” (Hawkins, 1987). The SHELL model emphasizes on the interfaces between a person (center Liveware) and the other four components rather than their components themselves. However, it is inapplicable in this model to cover the interfaces which are outside human factors such as Hardware-Hardware, Environment-Software (Reinhart, 1996).

The HFACS classification system is divided into four levels: organizational influences, unsafe supervision, preconditions for unsafe acts, and unsafe acts. The HFACS taxonomy was developed to provide a