Safety Science 63 (2014) 18–33

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

Airport surface operations: A holistic framework for operations modeling and risk management

Sabine Wilke *, Arnab Majumdar [1], Washington Y. Ochieng [2]

Imperial College London, Department of Civil and Environmental Engineering, Centre for Transport Studies, South Kensington Campus, Skempton Building, SW72AZ London, United Kingdom

ARTICLE INFO

Article history:
Received 29 January 2013
Received in revised form 3 September 2013
Accepted 19 October 2013
Available online 16 November 2013

Keywords:
Airport surface operations
Business process modeling
Safety Management System (SMS)
Risk management

ABSTRACT

Air transport is a key driver for social and economic development and its demand has increased steadily over the years. One crucial element of the air transport system is airports, and in particular, the airport surface, which facilitates the ground movements of aircraft and provides the link between ground and air. The nature of surface operations is such that it requires the input, coordination and cooperation of various actors. The complexity of these operations makes the system vulnerable, and therefore, the development and implementation of an effective Safety Management System are required. The current approach to surface safety management, however, is piecemeal and not integrated. Typically, a single occurrence type is investigated from the perspective of an individual stakeholder with the consequence that resulting proposals for safety mitigation measures are biased and limited in terms of their impact. This paper proposes a framework for a holistic risk assessment of airport surface operations that integrates the actions of all relevant stakeholders. Firstly, a process model of surface operations is developed using the conceptual framework of Business Process Modeling and the input of various data sources to achieve triangulation. Secondly, the causal factors underlying accidents and incidents are determined based upon a reference data set that combines 12 databases from airports, airlines, Air Navigation Service Providers, ground handling companies and regulators. The factors are summarized in a new taxonomy. Finally, a macroscopic scenario tool that supports the management of change, training and education, and safety communication functions of the SMS is introduced.

1. Introduction

Air transport is a key driver for social and economic development and its demand has increased steadily over the years. Since the mid-1980s, passenger numbers have more than doubled and freight traffic has increased almost three-fold (ATAG, 2005). This trend is expected to continue over the next 20 years, with world passenger traffic (by revenue passenger-kilometers) expected to grow 5% annually and air cargo (by revenue tonne-kilometers) 5.2% per year (Boeing, 2012).

A key element of the air transport system is airports, whose main function is the provision of a safe and efficient transition of passengers and goods between the ground and airspace. The operations on the airport surface (i.e. runways and taxiways) are crucial to the achievement of this function. From an operational perspective, airport surface operations require the interaction of five main stakeholders (airport authority (i.e. airport operator), pilot, air traffic control (ATC), ground handling, regulator) both to facilitate the ground movement of aircraft and vehicles, and to maintain the surface in a working condition. One key performance indicator (KPI) of such operations is safety, which can be defined as 'the state in which the possibility of harm to persons or the property damage is reduced to, and maintained at or below, an acceptable level through a continuous process of hazard identification and safety risk management' (ICAO, 2009). Safety is one of the International Civil Aviation Organization's (ICAO) strategic objectives to foster a global civil aviation system that consistently and uniformly operates at peak efficiency and provides optimum safety, security and sustainability (ICAO, 2012).

Because of the complexity of aircraft and related operations, the airport surface, however, has proven to be vulnerable and at risk of failure with the consequence that accidents and incidents may occur. A study by the Flight Safety Foundation (FSF) showed that from 1995 to 2008, a total of 1429 commercial transport aircraft were involved in aviation accidents. Approximately 30% of these accidents were runway related and led to 973 fatalities (FSF, 2009). In addition to accidents, incidents also occur on the airport surface and, therefore, the development and implementation of an effective Safety Management System (SMS) are required to ensure

* Corresponding author. Tel.: +44 (0) 2075942705.
E-mail addresses: s.wilke09@imperial.ac.uk (S. Wilke), a.majumdar@imperial.ac.uk (A. Majumdar), w.ochieng@imperial.ac.uk (W.Y. Ochieng).
[1] Tel.: +44 (0) 2075946037.
[2] Tel.: +44 (0) 2075946104.

0925-7535/$ - see front matter
http://dx.doi.org/10.1016/j.ssci.2013.10.015

the highest level of safety for surface operations. In fact, airport surface safety has been acknowledged to be a key area of aviation safety by stakeholders worldwide (e.g. ICAO, 2010; NTSB, 2012).

The current way of addressing surface safety is characterized by an ad-hoc piecemeal approach. Previous initiatives to mitigate the risk of surface operations have addressed the topic from different viewpoints including regulatory bodies at a national and international level (e.g. ICAO, 2007), multinational aviation safety organizations (e.g. FSF, 2009), Air Navigation Service Providers (ANSPs) (e.g. FAA, 2010), aircraft manufacturers (e.g. Airbus, 2009), as well as action plans at a local airport level (e.g. training and awareness campaigns). These initiatives highlight both the divided attention directed towards surface safety and the biggest limitation in the safety management of surface operations: i.e. that current initiatives focus on single accident or incident (i.e. occurrences) types and take on the viewpoint of a specific aviation stakeholder. For instance, the Federal Aviation Administration's (FAA) 'Runway Safety Report' (FAA, 2010) contains the results of an analysis of incursions and their causal factors. It is based on an internal FAA database for incursions, with most occurrences reported by ATC. Although the current focused approach is understandable given the different responsibilities and interests of the involved stakeholders, it cannot be sufficient, as any safety mitigation strategy is biased through the viewpoint that is taken. Such an approach neglects the operations of the other relevant stakeholders, and the interactions and dependencies between them. Therefore, a holistic and robust safety assessment of airport surface operations that follows the requirements of SMS is needed.

This paper proposes a framework for a holistic risk assessment that integrates the actions of all relevant stakeholders in the context of surface safety. The framework comprises a process model of surface operations, the determination of causal factors underlying failure modes of these operations, and a macroscopic scenario tool to evaluate changes in the system architecture. The model is applicable to all relevant stakeholders in the context of surface safety and allows identifying the key drivers to surface safety. Based upon this effective safety mitigation strategies can be developed.

2. Background

The airport surface (i.e. manoeuvring area) is 'the part of an aerodrome to be used for take-off, landing and taxiing of aircraft, excluding aprons' (ICAO, 2004a). It is defined by its infrastructure and five main stakeholders that act and interact upon it (Fig. 1).

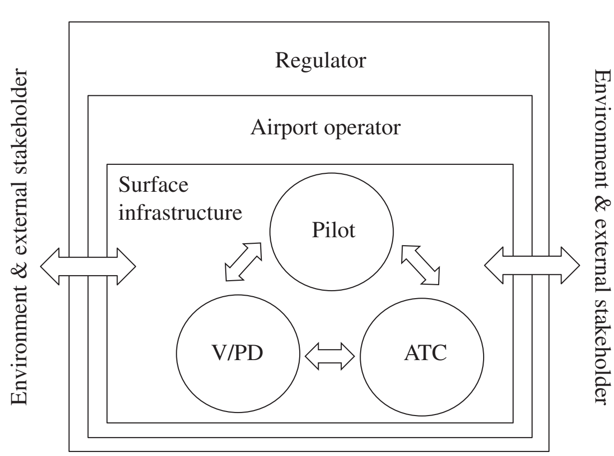

Fig. 1. Airport surface actors.

The manoeuvring area is used primarily by aircraft for landing, taxiing and take-off. Inbound flights land on a runway and then use the surface to taxi to their assigned ramp at the apron, where ground handling (i.e. servicing) takes place. Departure flights use the manoeuvring area to taxi from their ramp at the apron to an assigned runway for take-off. Pilots manoeuvre the aircraft. Besides aircraft, also vehicle drivers and pedestrians (V/PD) use the runway and taxiway system. The majority of vehicles and attended airport personnel are operating on the apron (e.g. ground handling vehicles and equipment). However, certain vehicles are allowed to enter the manoeuvring area. These vehicles include for instance tugs for towing aircraft, vehicles involved in maintenance and construction work, or snow removal equipment in wintertime. In addition, ATC plays a significant role for the safe flow of ground-movements. ATC's primary objective is the prevention of collisions between two aircraft in the air, or a collision between an aircraft and an obstacle on the ground, while expediting and maintaining an orderly flow of air traffic (EUROCONTROL, 2005). The airport authority is responsible for the management and oversight of an airport's operations. In terms of surface safety that means the management and maintenance of the airport surface, i.e. the provision of the infrastructure in working conditions. The airport authority operates on the airport surface in form of V/PD. Last, regulatory bodies oversee the system by providing a framework of rules and regulations and ensuring compliance of the different aviation stakeholders to those. In addition, the stakeholders are interacting with their environment.

The operations of the five stakeholders are dependent on each other. For instance, ground handling is responsible for servicing the aircraft (e.g. loading, fueling) while it is parked on the ramp. Only after the servicing is completed the aircraft can leave its parking position and start to taxi. To do so, the aircraft needs to be cleared from ATC. Thus, successful surface operations require the interaction of the various stakeholders. These interactions can be direct or indirect. For instance, pilots are in contact with ground handling over the dispatcher (US: 'The Lead'). Pilots are also in direct contact with ATC, e.g. to ask for pushback clearance. Ground handling, however, is linked only indirectly to ATC. In this example, the pilot needs to obtain pushback clearance from ATC and communicate it to the tug driver, who will eventually initiate the pushback.

Because of the complexity of the system, airport surface operations are vulnerable. To ensure that safety risks (including e.g. accidents/incidents) are identified, assessed and appropriately mitigated, aviation stakeholders are required to implement a Safety Management System (SMS). A SMS is a systematic approach to managing safety that is based on the four cornerstones of safety policy and objectives, risk management, assurance, and safety promotion. A SMS is a framework that provides an organization with the adequate tools to ensure that any drift by the organization towards a lower safety performance is prevented. At the heart of a SMS is the operational safety management (safety risk management), which supports the development of evidence-based measures for the overall safety management process. Safety risk management in practical terms is concerned with hazard and occurrence identification through reporting and data collection, investigation, and subsequent data analysis (ICAO, 2009). In particular, airport surface risk management is concerned with the collection, investigation, and analysis of four main accident/incident types: excursions, incursions/collisions, wildlife strikes, and Foreign Object Damage (FOD).

SMS is a systematic approach to safety and strives to assess and continuously improve the safety of an entire system. It therefore requires the assessment of all system components and their interactions for hazards and associated safety risks. Although airport surface safety has been addressed extensively in the past, previous research shows major limitations. To date no research exists that