UNIVERSIDADE DA BEIRA INTERIOR
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Risk Management Program Implementation

In Airline Company Maintenance and Engineering Department

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This part will be written in Portuguese, native language of all the persons to who I dedicated this work.

Dedico este trabalho aos meus pais e ao Bernardo, por tudo o que fazem por mim e pela sua presença constante em todos os bons e maus momentos.

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Resumo

Este trabalho surge aquando da necessidade crescente de criar sistemas de gestão de risco em operações com aeronaves, de forma a melhorar a cultura de segurança por parte dos Operadores Aéreos.

A motivação surgiu da parceria com uma empresa dedicada a operar aeronaves pesadas por todo o mundo. Foi estudado o caso particular da gestão de riscos associados ao Departamento de Manutenção e Engenharia e criado um programa (ou mais concretamente um conjunto de procedimentos, unidos por uma base de dados) para auxiliar os membros deste departmento a controlar situações que ameacem a segurança, aeronavegabilidade e rentabilidade da sua frota.

Foi feita a análise da legislação aplicável ao caso concreto da Manutenção e Engenharia, assim como estudados programas aplicados em diversas áreas para gestão de riscos. Posto isto, foi delineado o procedimento geral assim como os diversos componentes que completam a análise e mitigação de eventos negativos associados com as actividades deste departamento.

A implementação deste programa foi acompanhada durante um ano no âmbito deste estudo, sendo aqui apresentados os resultados obtidos da análise da informação recolhida.

Este trabalho veio assim aumentar a cultura de segurança deste departamento, assim como ajudar na implementação da legislação mandatória, introduzida pelas diversas autoridades que regulam o sector no âmbito da operação deste operador.

Palavras-chave

Aeronave, Engenharia, Manutenção, Legislação, Segurança, SMS, Risco.

Abstract

This work arises from the increasing need of systems to manage risks associated with aircraft operations in order to improve the culture of Safety by the Aircraft Operators, particularly in the case of the Department of Engineering and Maintenance of these operators.

The motivation for this study began with the partnership with a company dedicated to operate heavy aircraft worldwide. It was studied the case of risk management associated with the Department of Maintenance and Engineering airworthiness and created a program (or more specifically a set of procedures, connected by a database) to assist the members of this department controlling situations that threaten the safety, airworthiness and profitability of their fleet.

The analysis of applicable legislation in the case of Maintenance and Engineering Department was made, as well as studied programs for risk management in different contexts. After that, we have outlined the general procedure as well as the various components that complete the analysis and mitigation of adverse events associated with the activities of this department.

The implementation of this program was followed for one year in this study being presented here the results obtained from the analysis of the collected information.

This work increased the safety culture of this department, as well as assisted in the implementation of mandatory legislation, introduced by the various authorities that regulate the operation of this operator.

Keywords

Aircraft, Engineering, Maintenance, Legislation, Safety, SMS, Risk.

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Acronyms

A/C	Aircraft
ACMI	Aircraft, Crew, Maintenance, Insurance (included in A/C leasing contract)
AOG	Aircraft on Ground (due to not be airworthy)
BARS	Basic Aviation Risk Standard
CAST	Causal Analysis using System Theory
CRM	Crew Resource Management
DDI	Deferred Defect Item
EASA	European Aviation Safety Agency
ECAST	European Commercial Aviation Safety Team
FC	Flight Cycles
FH	Flight Hours
FOD	Foreign Object Damage
FMEA	Failure Mode and Effects Analysis
GASP	Global Aviation Safety Plan
ICAO	International Civil Aviation Organization
INAC	Instituto Nacional da Aviação Civil (Portuguese aviation authority)
LAE	Licensed Aircraft Engineer
LOSA	Line Operations Safety Audit
M&E	Maintenance and Engineering Department
MEL	Minimum Equipment List
MIT	Massachusetts Institute of Technology
MMEL	Master Minimum Equipment List
MRM	Maintenance Risk Management
ORM	Operation Risk Management
PSAS	Partnership for a Systems Approach to Safety
RPN	Risk Priority Number
SARPS	Standards and Recommended Practices
SMS	Safety Management System
SMM	Safety Management Manual
STAMP	System-Theoretical Accident Model and Processes
STPA	System-Theoretic Process Analysis
TEM	Threat and Error Management
UCA	Unsafe Control Actions
TCCA	Transport Canada Civil Aviation

Chapter 1. Introduction

1.1 Framework

This dissertation follows the crescent concerning with Air Safety nowadays. The huge expansion in air transportation verified in the past decades, brought together a rise in risk exposure and hence a major concerning in reduce those risks. In his main essence, air transportation is an economic mean and to reduce the negative out coming events it is not intended to cancel operations but prepare it to present an acceptable level of risk. To achieve this, all the operational areas work together being necessary a consensual approach in the way that some measures taken can affect other departments. In this study, we pretend to focus the case of Maintenance and Engineering, always having in mind the other departments of the same company, external companies and entities with direct involvement in pretended operation. This project was motivated by the difficulty of other departments, besides the flight safety, in implementing the Safety Management System as suggested by ICAO and now requested by authorities.

The aim is not only the use of SMS in human safety but also as a measure to improve the economic means of aviation services.

A partnership was established with Maintenance and Engineering Department (M&E) of a Company dedicated in aircraft operation allowing a study based on a real case scenario. The project will help this department accomplishing what is required for implementation of Safety Management System within operator internal structure, based on legislation and models already implemented in other programs.

The company participating in this study, is an aircraft operator approved under EASA Part M, Sub-part G. The fleet is composed by 10 long-range aircraft and is specialized in ACMI operations. All the aircraft are similar *Boeing*® models for long range. As a request of partnership, company must remain anonym so most of data collected will be hidden.

1.2 Objectives

Safety Management System, as purposed by ICAO and required by airworthiness authorities is a complex process to be implemented. Companies dedicate to one department, Flight Safety, that purpose however the other ones also have to accomplish several requirements and that's where our main target is found. To accomplish those requirements Maintenance and Engineering director needs to manage human resources to specific response for that, but in daily routine have been found difficulties to maintain those safety requirements updated. Besides all those programs created to manage safety, they all focus on the bigger picture and are more adequate for flight safety department daily activities'. Our program is intended to help maintenance engineers accomplishing their role in Safety Management System.

In the specific case of Maintenance and Engineering Department of Aircraft Operator, with whom a partnership was made in order to complete the study of this thesis, the main objectives are the ones described below:

- Prevent damages/delays/operational limitations due to technical issues and/or maintenance tasks;
- Analyze, previous and immediate, risks associated with the intended activities;
- Compliance with mandatory legislation in matters of Risk Management, in the scope of SMS implementation process;
- Analysis of data collected, evaluating safety events detected and justify the root cause of their happening.

With the program design to implement, the expected benefits are:

- Improve training plan;
- Assure / complement procedures suggested by Quality/ Flight Safety Departments in M&E procedures;
- Improve safety level in special operations, scheduled maintenance tasks, emergency response in case of unexpected failure/damage, as well as other unexpected situations;
- Identify errors and hazards in operation (not punitive culture);
- Present conclusions to administration about the analysis performed.

1.3 Dissertation Structure

This dissertation will be composed by five chapters. The present and first is were study is introduced, presenting investigation framework, main targets and structure.

The second chapter will resume the investigation that was made in order to respond to the raised problem. The focus will be on the state-of-the-art in matters of safety culture. Chapter starts with a brief resume on relevant concepts that will help to understand the scope of this dissertation. A brief review of regulatory documentation is done, promoting the understanding of most of legislation applicable of the program we intend to design and introduce in M&E department as explained before. Will also describe a few of Safety Management System, mainly the concepts to be implemented during the study. Analyses few programs and theory already implemented, yet, in different context. For the last, resumes some of the risks already known for this area in particular.

In chapter three the preparation of the case of study will be done. All the processes to be implemented will be reviewed and explained. This chapter includes the description of all the forms to be used and the application of a safety database when managing the hazards. Will also be presented the methodology used when assessing the performance of the program after one year of implementation.

Chapter four will be dedicated to present the data collected during the implementation of the program within M&E department internal structure. Will be shown one case application of each process, a report made, a safety note, the preparation of a new operation by M&E department, a form to follow the aircraft when visiting the hangar for maintenance, a case of a technical failure that lead to an operational interruption and the use of reliability for detection of negative trends. Also in chapter four, conclusions about the information collected in the company will be analyzed and presented what was found as an hazard in department scope.

Last chapter will be dedicated to the conclusions made about all the process, since the beginning of problem formulation, passing through investigation until the analysis of information obtained when applying the designed program to the case of study. It will express what could be improved, the difficulties found and the job that is still to be done.

Figure 1.1 helps understanding the scope of the study and the main targets for this implementation.

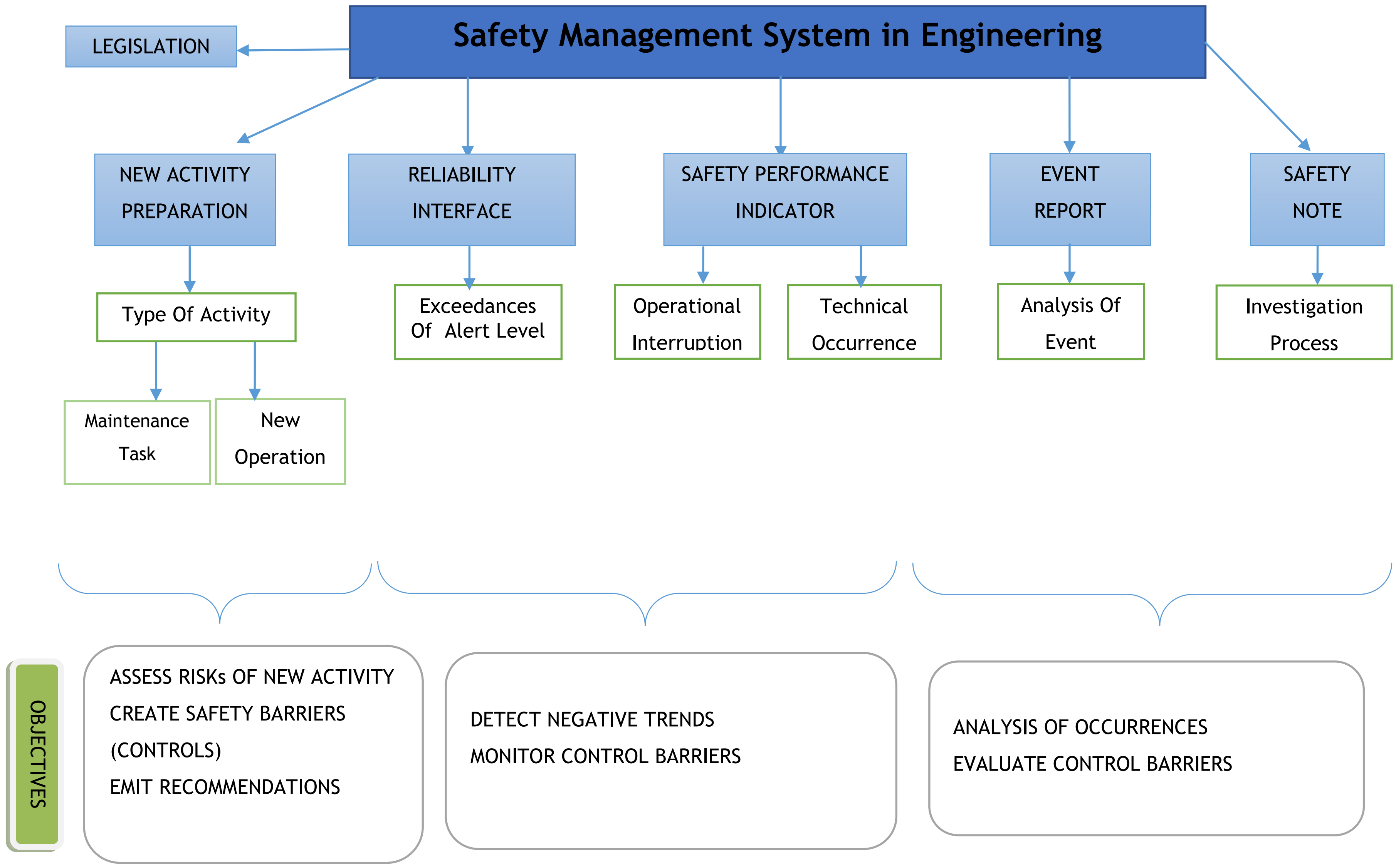


Figure 1.1 Program Main Structure

Chapter 2. Literature Survey

2.1 Chapter Summary

The second chapter presents a theoretical approach. Starting with a general review of specific contents to better understand the problems faced by M&E and contextualization of events presented in study case (see Chapter 4). One target for this review is a revision of legislation already implemented and yet to come in Safety Assessment procedures for airline companies. Starting with a perspective at Portugal case, origin country of this dissertation, then an European view, giving special attention to EASA regulation documentation, as well as other focal points where interesting programs were identified, and for the last an overview at ICAO recommended practices giving a global revision of aviation law (ICAO will act as fundamental base for this study). For the next, will be presented the main subjects regarding Risk Management, as fundamental part of Safety Management System. Will also be examined the state-of-the-art in matters of safety management models already implemented. Some existent threats of aircraft operation will be studied to minimize the possible negative outcomes from adverse maintenance conditions.

2.2 Definitions and Relevant Concepts

Accident -"(…) *an unplanned event or series of events that results in death, injury, occupational illness, damage to or loss of equipment or property, or damage to the environment* (...)" [1:93].

Accountable Manager - "(...) *single individual who is designated as the person responsible to a Regulatory Authority in respect of the functions which are subject to regulation, and carried out by an aircraft operator, an air navigation service provider, an aircraft maintenance and repair organization or an airport operator. That person is normally expected to be the person who has corporate authority for ensuring that all operations activities can be financed and carried out to the standard required by the Regulator* (...)" [2:1].

Airside - place planned and managed to accommodate the movement of aircraft around the airport as well as to and from the air. The airport's airfield component includes all the facilities located on the physical property of the airport to ease aircraft operations [3].

ATA-Chapter - referencing standard for commercial aviation. The standard divides aircraft in zones, following numeration from 05 to 100. As an example, 21 is dedicated to Air Conditioning. Sub-Zoning numeration depends on aircraft model.

Bird-Strike - a collision between a bird or birds and an aircraft that is flying [4].

Deferred Item - defect detected in the aircraft and not possible to repair but that can be dispatched to be solved in a convenient opportunity, however within a limited period of time.

Lightning-Strike - the hitting of something in aircraft by discharge of lightning [4].

Flight Cycle - one flight cycle is considered since aircraft lift off ground until it touch the ground again.

Flight Time - duration (in hours and minutes) of a flight cycle.

Hangar - building dedicated to host an aircraft, to perform maintenance tasks or only to be guarded. In the case of maintenance hangar, several tools, equipment's, spare parts and consumables are also kept. Can be located either on land-side as in air-side of the airport.

Hazard - "(...) *an hazard is a present condition, event, object, or circumstance that could lead to or contribute to an unplanned or undesired event such as an accident* (...)" [5:1].

Incident - "(…) *a near-miss episode with minor consequences that could have resulted in greater loss. An unplanned event that could have resulted in an accident or did result in minor damage. An incident indicates that a hazard or hazardous condition exists, though it may not identify what that hazard or hazardous condition is*" [1:94].

Land-side - components of airport planned and managed to accommodate the movement of ground-based vehicles, passengers and cargo. These components are further categorized to reflect the specific users being served.

Maintenance Error - The unintended failure to carry out a maintenance task in accordance with the requirements of that task and/or not working in accordance with the principles of good maintenance practice [6].

Master Minimum Equipment List (MMEL) - A list established for a particular aircraft type by the organization responsible for the type design with the approval of the State of Design containing items, one or more of which is permitted to be unserviceable at the commencement of a flight. The MMEL may be associated with special operating conditions, limitations or procedures [7].

Minimum Equipment List (MEL) - A list which provides for the operation of aircraft, subject to specified conditions, with particular equipment inoperative, prepared by an operator in conformity with, or more restrictive than, the MMEL established for the aircraft type [7].

Operational Interruptions - when the normal course of the operation of an aircraft is interrupted. The interruption can be a delay in departure time or release from maintenance or the cancellation of flights (Aircraft On Ground condition).

Threat - existent condition in certain environment or procedure possible to become an hazard.

Work package - set of tasks to be performed by a licensed aircraft engineer (LAE) in order to accomplish scheduled maintenance program.

2.3 Legislation Analysis

2.3.1 Local (*Portugal*)

Related with safety management system, Portuguese aviation authority create a guidance for company implementation. This guidance follow ICAO, namely Doc 9859 (key-document for the present thesis) and also EASA implementing rules, as stated bellow: "*...development of management policies and processes to implement and maintain an SMS that meets ICAO requirements and future EASA implementing rules. Therefore, organizations are encourage to refer to this document and ICAO Doc 9859 as their principal source of guidance in SMS*" [8:3].

Safety is a responsibility for everyone, but some distinct roles are played when talking about SMS implementation. Starting with Accountable Manager, the implementation and continuing compliance is under the responsibility of the person in this charge. Right below, a Safety Manager must be nominated to represent the necessary authority when managing safety matters and communicate then directly to Accountable Manager. The information must reach safety manager by the hands of safety advisors from each department of the company.

SMS must be part of management system as well as integrated into the daily activities of the organization, creating a structural culture based in safety policy and objectives [8].

As an important core in SMS is Risk Management, being the main target for this thesis, the identification, assessment and mitigation of risks. Since in commercial aviation, rare are the operations not involving contract parts, risks generated by those companies must also be part of risk management system.

INAC guidance in implementation of SMS is new at the time of present document, however many regulations were already implemented by this authority in order to improve aviation safety. Important in the scope of the present study is occurrence reporting system. It's mandatory to report within a period of time, which fluctuates depending on the event, technical occurrences relative to the aircraft while operations as well as events occurring during maintenance procedures. The mandatory events to be reported can be found in national legislation [20]. Besides the occurrence reported to authority, internal safety investigations should include events that are not required to be reported to INAC.

2.3.2 Europe

EASA, fulfilling implementation of safety legislation, is also dedicated to create programs for that purpose. One example of that effort is ECAST, created by EASA in a partnership with other European regulators and aviation industry members. This program was launched in October 2006 and is based on the fundament that industry can complement legislation with their own experience and committing to cost effective safety enhancements [9]. ECAST addresses large fixed wing aircraft operations, aims to further enhance commercial aviation safety in Europe, and for European citizen worldwide. It was launched in October 2006. ECAST is a partnership between EASA, other European regulators and the aviation industry. ECAST is based on the principle that industry can complement regulatory action by voluntary committing to cost effective safety enhancements.

2.3.3 Other states

A joint venture between some regulatory authorities (FAA, EASA, TCCA, etc.) was created with the purpose of a better understanding of safety management principles and requirements, facilitating the implementation of SMS in international aviation community [10]. This group is known as “Safety Management International Collaboration Group” and in the last years, many others regulatory authorities joint this group, sharing experience and keeping SMS implementation methodology uniform in global aviation.

2.3.3.1 Canada

Regulatory documentation concerning Canada authorities follows the global recommendations made by ICAO. Next citation, describes briefly, Canada's authority main targets for a safety management system:

“*A safety management system shall include (a) a safety policy on which the system is based; (b) a process for setting goals for the improvement of aviation safety and for* *measuring the attainment of those goals; (c) a process for identifying hazards to aviation safety and for evaluating and managing the associated risks; (d) a process for ensuring that personnel are trained and competent to perform their duties; (e) a process for the internal reporting and analyzing of hazards, incidents and accidents and for taking corrective actions to prevent their recurrence; (f) a document containing all safety management system processes and a process for making personnel aware of their responsibilities with respect to them; (g) a quality assurance program; (h) a process for conducting periodic reviews or audits of the safety management system and reviews or audits, for cause, of the safety management system; (...)*" [11:1].

After checking most of legislation this case turns up to be one of the most complete and simple. We can see, in the brief review of Canada authorities safety recommendations, the most important steps when planning a safety program. It includes targets and measuring of those targets, hazards identification and management until safety level becomes acceptable, training is seen as a component of the program and not only as a requirement, responsibilities are attributed, the program must be monitored by quality system in order to accomplish regulation requirements, and also the program is not seen as finished but in constant growth. All the described above resumes the main targets for our study.

2.3.4 ICAO Recommended Practices

ICAO differentiates between state safety program (SSP) and safety management systems (SMS) for organizations. A state safety program consists in legislation created to improve safety, while safety management system is a methodology to manage safety within an organization, including internal structure, accountability, policies and procedures [12].

The member-state, national authority taking here an important role, must accomplish a safety management program. As was seen before (see 2.3.1), Portugal started already accomplishing ICAO recommendations in matters of Safety Management system implementation. The recommendations emitted by member state for safety management must provide specifications for performance, human resources and internal procedures required for the safety of air transport. In the text below, are transcribed ICAO demands for State Safety Program:

"*An SSP requires specific functions performed by States, including the enactment of legislation, regulations, policies and directives to support the safe and efficient delivery of aviation products and services under its authority*(...)" [12:3-1].

To ensure the correct implementation within a company, audits are performed and if all the requirements were accomplished it will be able to operate as desired.

The next section will describe the components of Safety Management System as proposed by ICAO that are directly related with our study.

2.4 Safety Management System

In the last years, ICAO has been promoting several recommendations in order to harmonize and improve safety management in aviation industry, not only for aircraft operators but for all aviation service providers. As the most complete and abroad organization, most of regulators and aviation industry started to see Safety Management as a need. Regarding this, implementation of a system that manage safety through internal structure of operator/service provider had become a requirement. As suggested by ICAO, implementation of such system includes four main components [12]:

- Safety Policy and Objectives;
- Safety Risk Management;
- Safety Assurance;
- Safety Promotion.

Assembling all the recommendations to implement Safety Management, ICAO created a manual SMM (Safety Management Manual), also known as Document 9859. That manual is commonly used not only by operators and service providers, but also by airworthiness authorities to introduce regulations.

In the scope of Safety Management Manual, there are plenty of contents used in structure of operators, however, the scope of this thesis is provide guidance in risk management for only one department of an operator, Maintenance and Engineering. Having this in mind, would be excessive the introduction of information not to be used directly. From all the contents we have seen, will be highlighted in the scope of this thesis, risk management, hazard identification process and classification of risks.

2.4.1 Risk Management

Risk management, as defined by ICAO is transcribed below [12]:

"*The identification, analysis and elimination (and/or mitigation to an acceptable or tolerable level) of those hazards, as well as the subsequent risks, that threaten the viability of an organization*" [12:5-3].

The main objective is then: "(...) *ensure that the risks associated with hazards to flight operations are systematically and formally identified, assessed, and managed within acceptable safety levels* (...)" [12:5-4].

The complete elimination of risk in aviation operations is an unachievable and impractical goal (being perfectly safe means to stop all aviation activities and to ground all aircraft). Risks cannot be completely removed, as well as possible risk mitigation measures are economically unpractical. Therefore, Risk Management is a demand for a balance in safety "cost-index" meaning that besides the cost of applying safety barriers operation remains profitable at an acceptable level.

When decided to act for limiting the exposure to the identified risks each risk control measure needs to be evaluated to reveal possible latent hazards and latent risks that may arise from activating that measure. As a component of the SMS, the process of manage risks has a vital role in addressing the risk in practical terms requiring a coherent and consistent process of objective analysis. Risk Management is a structured approach regarding systematic actions that aimed to achieve the balance between the identified and assessed risk and practicable risk mitigation. In the process of Risk Management there are three steps, considered as essential [13]:

- Hazard Identification - Identification of undesired or adverse events that can lead to the occurrence of an hazard and the analysis of mechanisms by which these events may occur and cause harm. Both reactive and proactive methods should be used for hazard identification;
- Risk Assessment - Identified hazards are assessed in terms of criticality of their harmful effect and ranked in order of their risk-bearing potential. They are assessed often by experienced personnel, or by utilizing more formal techniques and through analytical expertise. The severity of consequences and the likelihood (frequency) of occurrence of hazards are determined. If the risk is considered acceptable, operation continues without any intervention, if it is not acceptable, risk mitigation process is engaged;
- Risk Mitigation - If the risk is not considered to be acceptable then control measures are taken to fortify and increase the level of defenses against that risk or to avoid or remove the risk if this is economically reasonable.

The flow chart present in figure 2.1 illustrates the sequence followed in Risk Management process:

Figure 2.1 Risk Management Flowchart

2.4.2 Hazard Identification Methods

As ICAO states, three methods must be considered when accomplishing the identification of hazards [12]:

- Predictive - Analyzing procedures and preparing new activities having others or studies as reference lead to a prediction of negative outcomes that can happen in the future. Creating defenses for inhibit these outcomes or to be prepared in the case they happen will improve the safety standard of a company;
- Proactive - While performing operations / tasks identify hazards and respond in order to avoid the worst outcome. Requires some experience and capacity to respond quickly;
- Reactive - The hazards are identified with investigation of past outcomes or occurrences. Accidents and incidents are used as a base to identify the hazards affecting procedures.

2.4.3 Risk Classification

Identified risk must then be classified accordingly to their probability to occur (based on experience or knowledge of other companies) and severity in the case the worst potential outcome takes place. For simplify, let's see it through two simple "How" questions: How bad?, How often?

For both, it's attributed a level (descriptive) and an index (quantitative), from 1 to 5 in the case of likelihood and A to E in the case of severity. After classify the hazard accordingly to his severity and probability, indexes are combined and the result is analyzed following the risk matrix (see table 2.3). The classification will be a combination of a number and a letter, as will be explained ahead when describing risk matrix.

2.4.3.1 Severity

Assessing hazards involves determining the consequences suffered when predicted scenario happens. Based on ICAO recommendations [12], in Table 2.1 it's represented a scale from (A) to (E), and respective definition of hazard classification. When considering the severity of risk as Acceptable, it's attributed the index (A), meaning minor injuries to people and/or small impact in aircraft. Furthermore, when level is considered Extreme, index will be (E), and if event is achieved, results will be people's death and/or fully loss of the aircraft. It was used the initials of risk level for better intuition when performing identification. Table 2.1 resumes the risk levels and respective index with the description of associated consequences.

Table 2.1 Severity Scale

Severity		
	Personnel	**Material**
(A) Acceptable	No injury	Minor or inexistent damage
(B) Barely	Minor injury (first air treatment on site)	Minor damage requiring repair
(C) Considerable	Minor injury - personnel unable to continue on duty	Damage requiring repair and/or loss of function
(D) Dangerous	Severe injury	Severe damage requiring expensive repair and/or loss of function
(E) Extreme	Involving death	Full loss

2.4.3.2 Likelihood

The likelihood represents the probability of certain undesired state arises from the identified hazard. Table 2.2 describes the risk level and index accordingly to the probability of risks identified become undesired states. When attributing index (1), it's consider that events are really improbable to happen, in the other hand, index (5), associated with risk level "Common" is attributed to events reported with some frequency.

Table 2.2 Likelihood Scale

Likelihood	
(1) Improbable	Not credible or almost improbable, not heard or seen before and can be assumed that it never happens.
(2) Rare	Low probability and would require multiple failures but can eventually happen.
(3) Remote	Probably that it happens sometimes and can lead to an accident.
(4) Occasional	Could lead to an accident and similar incident have occurred before.
(5) Common	Probably that it happens and likely to lead to an incident.

2.4.3.3 Risk Matrix

Risk matrix serves to evaluate each hazard and decide if safety barriers have to be planned to avoid undesired states that can arise from those hazards. Table 2.3 assembles all the possible combinations of Likelihood/Severity. The diagonal of the table (E5, D4, C3, B2 and A1) work as a limit line, when safety level is situated on or below this line, safety barriers should be implemented or operation considered.

Table 2.3 Risk Matrix

	Extreme	Dangerous	Considerable	Barely	Acceptable
Common	E5	D5	C5	B5	A5
Occasional	E4	D4	C4	B4	A4
Remote	E3	D3	C3	B3	A3
Rare	E2	D2	C2	B2	A2
Improbable	E1	D1	C1	B1	A1

2.5 Risk Management Programs

While an accident may be caused by external factors which are outside of control, there are several ways to prevent it from happening. Identify and manage hazards can reduce the exposure to a critical situation. Several programs exist in aviation industry to serve that purpose. Some of them will be analyzed below being the base for achieve the target of this thesis mean the implementation of Risk Management in M&E department of an aircraft operator.

2.5.1 Partnership for a Systems Approach to Safety (PSAS)

Behind the increasing need for Air Safety improvement, MIT created Partnership for a Systems Approach to Safety (PSAS). This organized team is focused in analyze regulation concerning safety-critical systems, also studying new approaches and improvements in industry/companies safety system as well as many other activities as we can see in PSAS official website [14].

PSAS group created a model, STAMP, which approaches accidents as a chain of events, being the result of several dynamic procedures. Accident is seen as a control defect instead of a failure itself. In fact, STAMP can be considered a predictive safety measure, acting to keep hazards controlled before they can be felt as affecting systems. The main idea is to apply controllers to continuous monitor safety barriers, keeping an all-time update for new conditions, allowing a continued improvement in system safety. With this methodology is confirmed more hazards than similar programs once it defines hazard as a system state or set of conditions which along with worst-case scenario will lead to an accident, being the accident the undesired event resulting in loss (human life or injury, material damage, environmental impact...) [14].

Controllers use a process model to determine control actions to apply and are continuously receiving feedback of controlled processes so that applied measures were well introduced, suitable and remain appropriate. There are two fundamental factors in this approach, the actuator which implement the control and a sensor to give feedback about control influence [15]. Thus we can summarize some concepts, as follows:

- STPA - method of analyze, based in STAMP, for detection of threats and creation of measures to implement through system control theory. The target is accomplished with identification of unsafe behaviors and scenarios;
- CAST - method for understand the causes for an accident, based in system theory.

STPA basic steps:

- Identify past events and hazards;
- Implement a structure of control;
- Monitor unsafe control actions;
- Identify causal factors and control flaws.

Unsafe control actions (UCA's) are identified in this method as the controllers that weren't adequate for the identified risks. The most common are:

- Command not implemented or implemented out of time (sooner or later than required);
- Control applied not adequate;
- Control applied for wrong period of time (too long or too short).

2.5.2 Basic Aviation Risk Standard (BARS)

Created by Flight Safety Foundation, BARS program was a result of airliners need in establishing a standard safety audit complying all mandatory legislation from worldwide authorities. BARS was structured regarding mandatory legislation and means of compliance but also having in consideration the threats in aircraft normal operation [16].

BARS is based in legislation and suggests measures of control and defense of already know risks in aerial operations. The document edited by this program works as a reference document for companies, aircraft operators and for external entities certified to audit the program implementation and accomplishment. These audits can be performed by certified auditors auto-proposed for the effect. During the audit is verified the correct implementation and accomplishment by the operator of recommended procedures [17].

2.5.3 Threat and Error Management (TEM)

Another approach in matters of safety management is brought to us as Threat and Error Management (TEM). Accordingly to Maurino "(...) *TEM is an overarching safety concept regarding aviation operations and human performance(...) a conceptual framework that assists in understanding, from an operational perspective, the inter-relationship between safety and human performance in dynamic and challenging operational contexts*" [18:1]. This model is considered as descriptive and intended to evaluate human and system performance. Some of the purposes of this approach are resumed to:

- Safety analysis tool - used for analyzing unique events, as accidents or incidents;
- Monitor systemic patterns - detection of negative trends as from sequences of events;
- Licensing tool - as a help for legislation, define human performance and vulnerabilities, improvement of training requirements and management of change process.

The origin of TEM can be traced to the Line Operations Safety Audit (LOSA) concept. TEM was modelled in a joint venture between the University of Texas Human Factors

Research Project and Delta Airlines that in 1994 developed a line audit methodology utilizing jump-seat observations on scheduled flights. Both parties agreed that in order for the audit to be productive and show realistic results confidentiality of the findings with no regulatory or organizational jeopardy to the flight crews should be guaranteed. The initial observation forms of the audit were designed by the University of Texas researchers to evaluate Crew Resource Management (CRM) behavior on the flight deck. The process was then extended to include error and its management as well as the type of error observed. This enabled trained observers to categorize the origin, detection and response to (if any) outcome of each recorded error. The first full scale TEM-based LOSA was conducted at Continental Airlines in 1996. Together with the original CRM indicators (leadership, communication and monitoring/cross-checking) the extended concept of TEM was used to identify most frequent threats. This method provided a picture of the most common errors and threats both that are well managed and the more problematic and mismanaged.

The recognition of the influence of the operational context in human performance led to the conclusion that the study and consideration of human performance in aviation operations should not be an end in itself. TEM has developed therefore aims to enable broad examination of the dynamic and challenging complexities of the operational context in human performance.

In this theory threats are defined as "*events or errors that occur beyond the influence of the flight crew, increase operational complexity and which must be managed to maintain the margins of safety*" [18:2]. On the other hand errors are defined as "*actions or inactions by the flight crew that lead to deviations from organizational or flight crew intentions or expectations*" [18:2]. Besides the statement referring to flight crew, this definition applies to other individuals whose work impacts aircraft operation, as for the case of maintenance and engineering teams, the base of this study.

Threats are always present but when combined with human errors they can lead to undesired states with negative consequences. This study will focus in prepare for threats and mitigate human errors in order to avoid undesired states.

2.5.4 Failure Mode Effects Analysis (FMEA)

FMEA is known to be a method of systematic identification and assessment of potential failure modes, studying the root causes of those failures and creating the necessary actions to eliminate potential negative outcomes [19].

Just like SMS risk matrix, FMEA uses likelihood and severity to determine safety levels, however add a new element in calculation. Probability of controls detecting the failure is also taken in account. As in risk assessment proposed in SMM (ICAO) where the measurement is done by multiplication of all the elements considered. In this methodology, this value is known as RPN, meaning risk priority number. This method is applicable to hazards for which safety barriers were already implemented.

2.6 Risks in Maintenance & Engineering

Airline companies, highly motivated with market, find risks every day and are continuously searching for defenses which minimize the negative outcomes that may arise from those risks. There will always be new safety events and unexpected situations, so the best way to be prepared is to assume the worst situation and prepare a contingency plan to quickly respond in those situations. As said by Stolzer et. al.:

"*Today we realize that it is much more productive to engineer a system in which, to the extent possible, causes of failure have been designed out. As one might imagine, there are many elements to this engineering effort (...). The modern, well-informed aviation safety practitioner must have a working understanding of hazard identification, risk management, system theory, human factors engineering, organizational culture, quality engineering and management, quantitative methods, and decision theory* (...)" [13:13].

Having this in mind, it's intended to perform a brief review of civil aviation world and identify some of the risks already detected. With this start, we are able to prepare a program for recognition, analysis and continuous improvements in matters of Operations Safety Performance.

2.6.1 Atmospheric Conditions

Most of scheduled maintenance tasks are performed outside of the hangar. With this, aircraft, equipment and personnel are exposed to external environment conditions. One example is pre/post flight inspections performed not only by LAE but also by one member of flight crew.

With extreme atmospheric conditions, risks increase significantly. Damages in the aircraft are more difficult to detect in raining/snowing conditions. Also, replacement of small components can become a nightmare for engineers. Higher temperatures are also seen as a root cause for avionics break down.

Regarding this, average weather at locals is also taken into in consideration when preparing an operation. It's really important that maintenance tasks won't be performed if tolerable workplace conditions aren't met.

2.6.2 Operational Conditions and Equipment's

Flying to remote places, sometimes, lead to works being carried out in locals without maintenance dedicated stands or hangars and so works had to be performed in ramp with all the operations happening around. Off course, we are talking about airports with less traffic and places without huge air transportation system. These are the kind of places where nobody wants to fly and companies specialized in ACMI operations found their bigger business opportunities. Risk Management of this kind of operations has a great role, once operation must be performed but has to be profitable. In the case of M&E department, safety advisor must have in consideration place conditions in case of works that have to be carried out (mainly the unscheduled ones!) and also information regarding equipment and tools (e.g. stairs, ground power units for the case of inoperative APU ...).

2.6.3 Maintenance and Engineering

ICAO defines maintenance as "*The performance of tasks required to ensure the continuing airworthiness of an aircraft, including any one or combination of overhaul, inspection, replacement, defect rectification, and the embodiment of a modification or repair*" [7:1-3]. Following this definition, this thesis will divide maintenance activities in scheduled, when the task it's programmed and unscheduled if A/C is affected by a defect that wasn't expected to happen.

Ramp is a high risk place, both for A/C and human being, since the frequent movement of aircraft and support. In order to contribute for ramp safety, operator must keep ramp procedures well documented and available for each A/C. One example is the pre-flight check, performed in the ramp before the flight, where several different situations take place at same time (maintenance, fuelling, boarding, catering, name just a few). For this reason is important to maintain a culture of safety so that risks are identified and managed until an acceptable level of safety is achieved.

2.6.3.1 Scheduled Maintenance

Since no machines are free from damage and breaking down, authorities require several checks and inspections to be performed in the A/C in order to maintain its airworthy and capacity to accomplish the pretended operations for which they were projected. To complete these technical procedures, operators must follow approved documentation from aircraft manufacturer and prepare the required maintenance activities. The list below resumes the most important scheduled inspections required by authorities to keep an aircraft airworthy:

- Daily-check
- Weekly-check

- A-check (500 - 800 flight hours or 200 - 400 cycles)
- 18-months
- 6-years
- Pre-flight
- Post-flight

During the accomplishment of the previous inspections several safety measures are neglect, putting aircraft and maintenance personal in danger. In a first instance, the major risk are injuries or deaths to people working around the A/C and for this issue several courses and certifications are required by the companies who sign the contract for the work. However, many others risks are faced when A/C is at maintenance. During those tasks some threats are present, components may be wrongly installed or hidden damages caused during installation. When not detected the safety of flight is compromised and can even cause an accident. In chapter 3 will also be presented a guide with check-list to follow A/C inspections.

2.6.3.2 Unscheduled Maintenance

Even when all the recommended practices are accomplished the aircrafts, like many other machines, break down. Either with a system failure or an external condition, it's impossible to keep them working all the time. Besides this, the interest of the operator is the quick response in manners of contingency plan and reduce the AOG time to as few as reasonable possible. One of the biggest causes of financial problems are operational interruptions. Not only the evident costs related with components and extra maintenance providers, is the hidden cost of have an aircraft unable to fly. Some examples are the accommodations for passengers and crew, extra taxes of airports, tickets refund. So, it's of great concerning for a company to reduce the amount of unexpected events and improve the capacity to respond in the case of an extra maintenance tasks have to be performed.

2.6.4 Human Factors

Not only contracted part but also A/C operator must ensure that workers have the correct training and certification in accordance with aircraft type and authority requirement. Must also keep a file with documents certifying individual training and ensure the correct distribution of tasks and responsibilities. Training plan must include refreshing, introduce of new procedures/equipment and also human factors and changes in legislation. Work-time must be managed having in consideration human fatigue.

Besides occurrences during maintenance tasks usually involve errors made by LAE, investigation of events identified at organizational-level such as: the training and qualification systems, the allocation of resources and the cultural or value systems that permeate the organization. One example, is using an incorrect tool that may occur because the correct tool was not available, which in turn may reflect equipment acquisition policies or financial constraints. Other example, common in line maintenance, is time pressure, as aircraft release has to be immediate and pressure can affect the work performed by maintenance teams [6].

2.7 Chapter Conclusion

In this chapter, we intended to demonstrate theoretical information for understanding the concepts to be used in study-case. Legislation was briefly review, presenting the guidelines considered determinants for the implementation of this program in a real operator internal structure. In the present thesis, only some of the legislation in use is presented, as to explain all the regulation we may fall into the risk of information overload in the scope of our study. We have also studied the principles of safety management, namely risk management process. State of the art helped us to understand some known techniques for risk culture and programs already used in real scenarios. With PSAS we understand the importance of controllers in processes, how they can implement safety barriers and permanently monitor them. BARS present an audit that will help to complying and understanding most of regulation. With TEM, we learnt to manage threats within operation course. And yet in existent programs, FMEA will be used to complement measurement of safety levels. Some of their recommendations will be used while designing our own program. For the last, it was presented what affects more maintenance and engineering department of aircraft operator's. Special incidence was given to non-routine operations, since company participating in our study distinguishes itself in that kind of operation.

Chapter 3. Model of Safety Management

3.1 Chapter Summary

The third chapter will be dedicated to explain how risk management methodology is introduced in M&E (Maintenance and Engineering) department of an Aircraft Operator. It will be studied a process for identification and mitigation of root causes that have potential to lead to negative outcomes. A database will be prepared to keep the process in a simple way to identify, monitor and manage risks associated with maintenance and engineering tasks. With this databased is also intended to evaluate the efficiency of safety measures and yet a simple way to prepare execution of a new task, namely hazard identification and risk level measurement. It will also be studied a cross-line with reliability program for detection of negative trends in matters of technical failures. As already said, the target is not the all process of implementation SMS program in Aircraft Operator, but help M&E managing the risks faced in their field of action.

The figure 3.1 resumes the main targets and respective sequence of fulfilment in internal structure of referred department.

1 -Hazards Identification

- Occurrence reporting
- New operation preparation
- Internal/ external safety note
- Internal information collecting (ex. Reliability, Operational Interruptions, Deferred Itens)

2 - Risk Assessment Process

- Database system (file number with associated information)
- DME safety advisor who accomplish the investigation
- Inform flight safety department about process opening

3 - Investigation and Risk Analysis

- Identify threats / causal / potential outcomes
- Define safety barriers
- Discuss feasibility of control barriers with other departments

4 - Meeting Flight Safety Department

- Present conclusions and control barriers
- Final decisions about barriers to be implemented

5 - Implement Control Barriers

- Implement new procedures / review existing procedures
- Training about new procedures
- Disclose information collected within the company

6 - Process File

- Keep a file with collected data and procedures applied

7 - Control Barriers Evaluation

- Evaluate eficiency of applied barriers
- Identify new risks(raised by new procedures applied or not yet detected)

8 - Conclusions

- Assess if risk was reduced
- Review all the process

Figure 3.1 Implementation Guidelines

3.2 Safety Management System in Engineering Department

Following the exposed in chapter 2 of this thesis, SMS will be introduced in M&E following the schematic present in figure 3.2, having as base, not only ICAO recommended practices but thoughts from safety programs presented (TEM, BARS, STAMP).

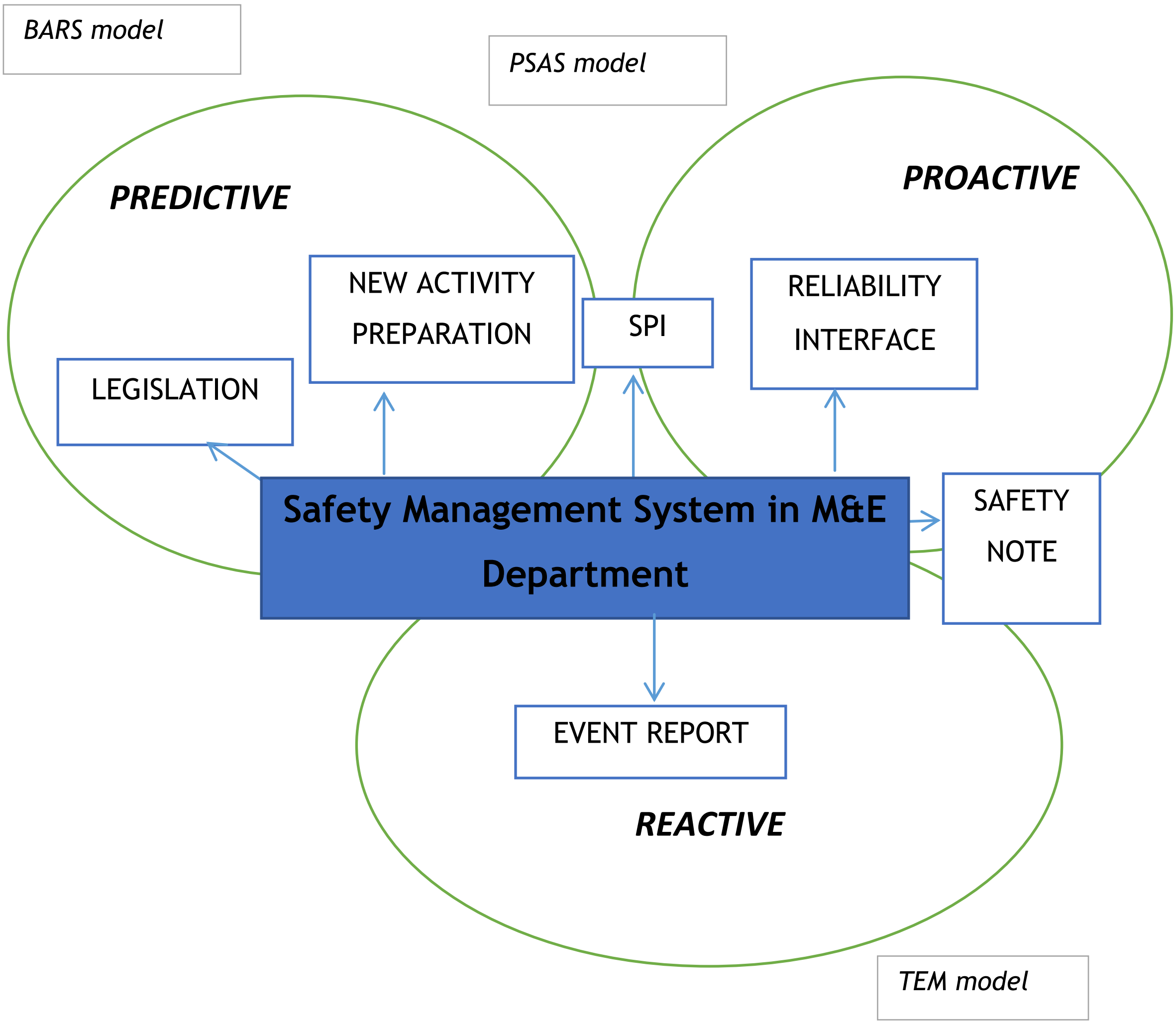


Figure 3.2 Safety Management System in Engineering Department

It was seen in previous chapters, three methods possible to be used in order to identify an hazard. The scheme shown in Figure 3.2 was constructed to understand how the components of our system are used in risk assessment. While preparing a future operation and analyzing legislation, hazards are identified in a predictive way, since it's intended to identify what can go wrong in order to create the control barriers which will avoid/ minimize negative outcomes. With SPI's and interfacing reliability, hazards are detected in real-time, meaning besides no major event had taken place yet, a negative pattern of failure was already been detected. Within this a quick reply is necessary to avoid the raise of a negative trend. Safety Notes can be used to report a repetitive pattern of failure or deficiency in a process but we are not considering them completely proactive since some events may had already questioned operation safety, however they can't be seen completely as reactive, since the intention is to identify negative trends before they can affect any system. For the last, an event report is completely a reactive method since the experience of an occurrence is used to identify hazards.

3.3 Safety Management Database

The main goal of a safety program is to identify hazards that can result in negative consequences. After reporting and analyzing safety events, they must be stored for further consult and inserted in a system capable to emit trend information. Safety analyst must monitor this trends and the system database issued in a way of automatic association of events. The target is a simple way to control the hazards and safety information for an airline company technical events.

It will be used a current data-base software, being the structure adjusted for the department needs. To remember, safety is a very important component of the internal structure of any company, however must be intuitive avoiding excessive workload and unnecessary expenses. For this the components helping maintenance department safety management, namely hazard identification, safety notes, event reports, operational interruptions, safety performance indicators and new activity preparation will be assembled in this unique database system, allowing a quick overview of all them and also an organized store for quick consulting and better daily monitoring.

A database will be used as a controller, following the methodology described by STPA [15]. Being a controller, all the assessment and implementation of defenses is stored and easy to be accessed. Daily monitoring would be improved since the database itself can present data in several formats for a quick overview of outstanding items and negative trend detection.

3.4 Safety Event Report

In accordance with the exposed in chapter 2 concerning mandatory occurrence report (see 2.3.1), whenever happened an event related with technical state of the aircraft, a participation to authorities should be made by at least one person involved. In the case of technical failure it's mandatory that LAE who performed the maintenance action for occurrence reports it to the authorities. To keep the reporting system quick and dynamic, it's important to have a form on board the A/C and accessible for the people working with it. This way, who reports knows the information that has to share and who receive it can easily analyze and classify it. For the purpose of internal investigation it's helpful to receive more than one report for the same event in order to have a more complete view of all the situation. Even when the report is not mandatory, it is still very important investigate the causes for the event.

Having this in mind will be created a form to be filled with information regarding technical occurrences. When an internal investigation is opened more information will be necessary but in that case Safety Advisor decides where and how will get that information. In a first approach the information consider essential is:

- Reporter info (name/position in the company);
- Local where event takes place (station);
- Dates (occurrence and report);
- A/C identification (registration);
- Occurrence classification ;
  - Minor;
  - Small impact in operation;
  - Operation affected;
  - Significant impact;
  - Critical safety event;
- Type of occurrence;
  - Misused tools/ parts/ fluids;
  - Unserviceable upon installation;
  - Component damage;
  - Material deterioration;
  - System failure;
  - In-flight faults (engine shut-downs, air impact, parts missing in flight);
  - A/C documents out of compliance;
- Description;
- Response to event;

- Corrective actions taken.

The form structure can be organized in several ways, in the annex A.1 it will be presented a form created in this study case to be used when an occurrence has to be reported.

All the reports must be stored, creating a file where all the events can be accessed by authorized people, in order to detect trends, keeping an attitude of monitoring fleet technical failures and investigation accomplishment. All the reports must contain an unique number for identification.

3.5 Reliability Interface

Monitoring the technical events in reliability gives the chance to identify repetitive pattern of failures, allowing previous detection of latent defects and react before they become hazards and threats aircraft airworthiness. For this, after analyzing the reliability reports, the ATA chapters kept under monitoring are assembled in a document, known as Alert Notification Status Report. Safety Advisor together with Reliability Engineers will detect which defects can be seen as hazards and after identify them, a safety note must be open in order to keep the subject under investigation. With this, we can help solving the defect before it becomes a worst undesired state and also, if a new activity has to be prepare, the safety note is included in risk management file and a better safety assessment can be done if A/C limitations are well documented.

3.6 Safety Note Report

A safety note must be filled by any person in contact with the aircraft considering any latent defect of a deficiency in procedures. To do so, it will be created a form to simplify the acquisition of information by safety advisor. This form distinguishes from the event report in the way that an event report is a participation of a technical failure mandatory to be sent by national authority. Also the event report, can only be filled by the LAE who performed the maintenance action in response of the safety event occurred. Safety note is intend to communicate hazards threatening the correct function of any component or procedure regarding technical aspects of aircraft operation. It's an act of voluntary report unlike the technical event report, mandatory to report to the authorities.

An example of the form for a Safety Note is found in Annex A.2.

3.7 Risk Management Process

The most common predictive method in risk management is to prepare the operation with previous identification of Hazards, followed by the evaluation of existent defenses and attribute for each a risk level. As said before, Risk level is find by the division in two different qualifications: Severity and Likelihood, attributing the values as shown in table 2.3. The value found is then analyzed and if above the acceptable new barriers must be created. A responsible person must be nominated to manage and ensure the correct application of each control barrier before or during scheduled activity. In database is monitored the evolution of safety barriers, and further explanation is asked to the person in charge of accomplishing it. In our specific case, will be focused on two different processes of risk management. The preparation of a new operation and of a scheduled maintenance task. Those processes intent to minimize risk exposure while operating or in maintenance and prepare safety barriers for the case of undesired states.

3.7.1 Operation Risk Management

When a client require a special kind of operation, all the departments of the company join efforts in order to provide the better service and the accomplishment of contracted service. To do so, analysis must be made in order to define the feasibility of the mission in first place. Sometimes, operations required are far from what is considered as normal in aviation. Every mission must be prepared and evaluated considering all the details. Risk Management is crucial in this process. As service provider, the company wants the best profit, so the process of Risk Management has the objective to keep the level of safety acceptable and yet keeping operation profitable. For the case of M&E, when preparing operations, the next items are considered of great influence and require a process of risk management:

- Maintenance contracted parts to accomplish scheduled tasks and also available teams at operated airports in the case of unpredictable events than can occur during operation;
- Spare parts available at local and also country customs in matters of tools/parts clearance in case of AOG (parts required immediately);
- Hangar and/or tools to perform maintenance activities and capacity to store A/C spare parts;
- Consider the limitations of the A/C selected for operation;
- Regulation applicable to local;
- Other Hazards must be evaluated for each particular case (environment, airport conditions, security...).

In the form suggested by this program, the process is simplified and quickly an operation can be prepared giving a global vision if existing defenses are adequate or if new control action has to be implemented. These forms must be reviewed during operation, in the case of duration allows it, in order to ensure that applied barriers remain adequate and if there be the case, any time a change is verified in operation conditions.

3.7.2 Maintenance Risk Management

Aircraft maintenance assembles several risks not only for people working around, but all what can cause damages to the aircraft. As was already said, an hidden damage can cause a catastrophic event later on. Also, operational impact caused by a late release from maintenance can mean a financial impact. In order to prevent all of negative events above, it is important to have safety barriers. To achieve that, one big step is to perform a process of risk management before each maintenance scheduled task. In this study, maintenance risk assessment was one of the concerns, once one of the biggest problems of M&E department is about occurrences during the accomplishment of scheduled tasks that compromise aircraft release on-time. Once again, the process for implementing risk management has to be simple and easy to accomplish. Having a form in safety database, who is in charge to prepare the work package will enter the information and a safety level is attributed. Safety Advisor must analyze it and decide if it's acceptable or if defenses have to be applied before/during task accomplishment. Most of the tasks are repetitive, so the process is not created from the beginning but only evaluate if safety level remains acceptable.

3.8 Safety Performance Indicators

It's not enough to start a safety program if continuous monitoring isn't performed. As seen in ICAO recommendations and also in STPA methodology it's important to review control barriers. Safety Performance Indicators are used as a controller to monitor known risks, detect any new trend and determine if any necessary corrective actions are necessary to apply.

Regulators can also use SPI as an evidence of effectiveness of the operator SMS and monitor achievement of its safety objectives. These must be accepted by the state responsible for the operator authorization, certification or designation. SPI's are supplementary to any legal or regulatory requirements and do not relieve operator from regulatory obligations [12].

Safety performance is measured by target values and alerts raised when those targets are exceeded. Targets are established in recent historical performance. In our case, it's used the information of one year (last twelve months of operation). Targets must be realistic and achievable.

The method used to define target levels is standard deviation principle, as suggested by ICAO [12].

3.8.1 Standard Deviation Principle

Standard deviation principle is a measure of uncertainty of a distribution. Having a distribution of data with mean μ and standard deviation σ. The risk measure will be given by $\mu + k*\sigma$. The value k is used to ensure that losses will exceed the risk measure for some distribution [19]. In our case, the values used for k are 1 to define the first alert level, 2 for the second one, and last the 3 for the third alert level.

$$\sigma = \sqrt{\frac{\Sigma(x-\mu)^2}{N}}$$

The alerts are raised when at least one of the following conditions are met:

- One single point is above the 3º alert level limit;
- Two consecutive points are above the 2º alert level limit;
- Three consecutive points are above the 1º alert level limit.

Of course, every program has its start. So in the beginning no data is available to define the limits. We suggest to search in company's history if any similarity can be found. If not the following must be done:

- In the first 6 months must be done a qualitative analyze of events;
- In the seventh month, alert levels can be calculate as the average of the last 6 months;
- After one year of collected data, new alerts are calculated with values of the last 12 months. These alerts remain for one year. After completing another period of one year new values are then calculated.

3.8.2 Technical Events

One of the indicators selected in the present study is the amount of technical events taking place every month. Is made a ratio of events quantity by the total flight hours and flight cycles performed during that month. The intention for this ratio is to evaluate how the utilization of an aircraft affects it technical degradation. Counting the technical events in relation with flight hours or cycles allows a better understanding if major utilization leads to an increase in technical events.

With this analysis we also evaluate the technical status of the fleet and the trend of defects. This will help to assess the efficiency of maintenance program for the fleet. Meaning that a major rate of technical failure is associated with the increase of aircraft defects and that can be caused by a deficiency in scheduled maintenance. Other conclusion that can be made is relative to reliability control program. If a negative trend is noticed in technical events reliability is advised to investigate what could have been causing the events.

Data to be used in this SPI is given by a technical event report, stored in the created database.

3.8.3 Operational Interruptions

Operational Interruptions due to technical events also represent a measure of safety. These events are related with unexpected defects and as a complement of Technical Events in SPI measurement, their rate is used to detected negative trends of mechanical failures and procedures that were wrongly implemented. Sometimes procedures are well defined but when implemented can reveal to be not appropriate or misunderstood causing impact in operational dispatch or leading to defects in aircraft itself. The measure of operational interruptions will also be divided by the leading causes. Evaluation made will help to create new barriers and improve procedures to avoid new events in the future.

The information about operational interruptions is collected on daily basis by safety advisor with fulfilment of a form (to be presented in Annex A.3) when a technical interruption is verified. This data is introduced in a databased creating monthly trend analysis.

3.9 Internal Procedure

For the implementation of this program, an internal procedure was written and is being analyzed in order to be approved. This document has great importance in internal structure, since it’s used as a guide and also allows everyone to follow the same methodology. Since partnership with company includes the confidentiality of identity, information that can jeopardize anonymity will not be published. Being only made a reference to better understanding the course of the implementation process.

3.10 Chapter Conclusion

The third chapter of our study was the modelling of a program to manage risks in daily activities of Maintenance and Engineering department of an aircraft operator. We introduced all the components included in safety database created for managing safety issues in daily base by Safety Advisor: reporting an event works or the raise of a safety note, how reliability will share information with safety management, the guidelines to start an operation and for the last the introduction of safety performance indicators for measurement of trends and control of safety barriers. After determining the components of our program, we will pass to next step, the introducing of this method in a real case scenario. All the forms referred above can be found in annex of this document (see Annex A).

Chapter 4. Case of Study - Implementation Process

4.1 Chapter Summary

The objective of the fourth chapter is the implementation process in M&E department. With this, is our intent to measure the improvement in procedures and safety of operations that Risk Assessment and Management can provide, not only for M&E, but for all the company. Ahead, will be presented the application of what was described in previous chapter, in the real context of the company participating in this study. In order to protect company identity, some fields will be hidden with description “COMPANY CLASSIFIED”.

All the information is saved in a database, being complemented with forms in the paper format stored in appropriate file. This is a double safeguard to avoid information loss.

The implementation process included the introduction of the model presented in previous chapter. The presentation of the study will start with Risk Management when starting an operation, namely will be shown an example of a new operation and also assessment of hangar entrance (as an example of maintenance risk management). Then, will be shown how reliability is used for risk assessment. It will also be shown a case of safety note emitted, with investigation records and conclusions. Hereinafter, as example, will be analyzed a report of an event from all collected. For the last, SPI's will be used to evidence some conclusions of this thesis and measure the efficiency of the implemented safety system.

Information is presented using figures of the forms created and an explanation is added for better understanding.

4.2 Sample Data

Sampling for the study case is a 10 aircraft fleet, operating worldwide and without a schedule of routine flights. The implementation process started July 2013 and data was collected for a period of one year, starting August 2013 until July 2014. With this, we can analyze whole seasonal activities (peaks and low season time).

Table 4.1 resumes the total flight hours and cycles used in this study and also an average of flight time (flight hours performed during one cycle).

Table 4.1 Flight Hours and Cycles Performed

	Flight Hours [FH]	Flight Cycles [FC]	Average FH per FC [1]
August 2013	2898,70	458	6,33
September	1962,93	370	5,31
October	1821,06	296	6,15
November	1323,13	222	5,96
December	1486,62	261	5,70
January	1119,23	237	4,72
February	962,35	212	4,54
March	1033,45	228	4,53
April	1568,00	325	4,82
May	1854,80	374	4,96
June	1747,70	370	4,72
July 2014	1762,85	438	4,02

The graphic in figure 4.1 shows the distribution of flight time during the analyzed period.

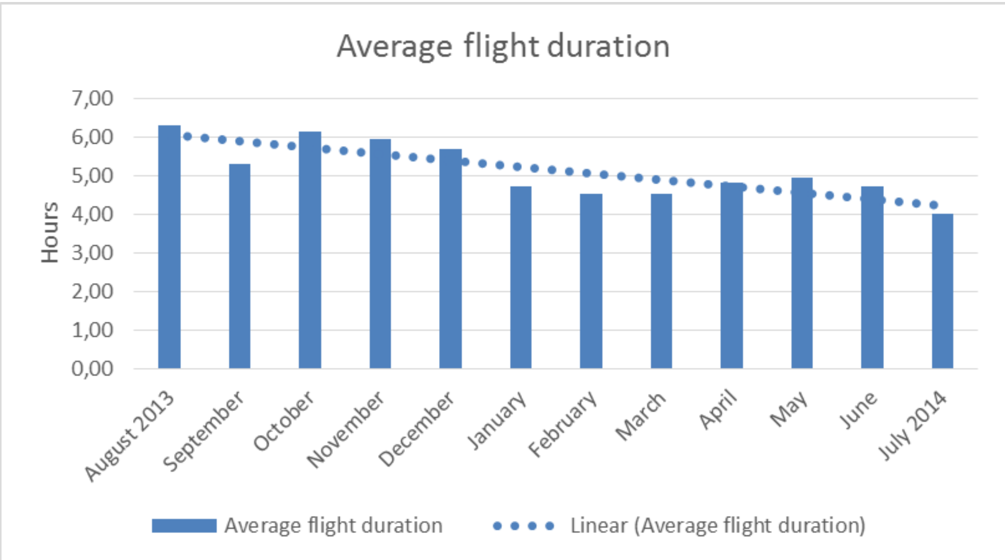


Figure 4.1 Average Flight Duration

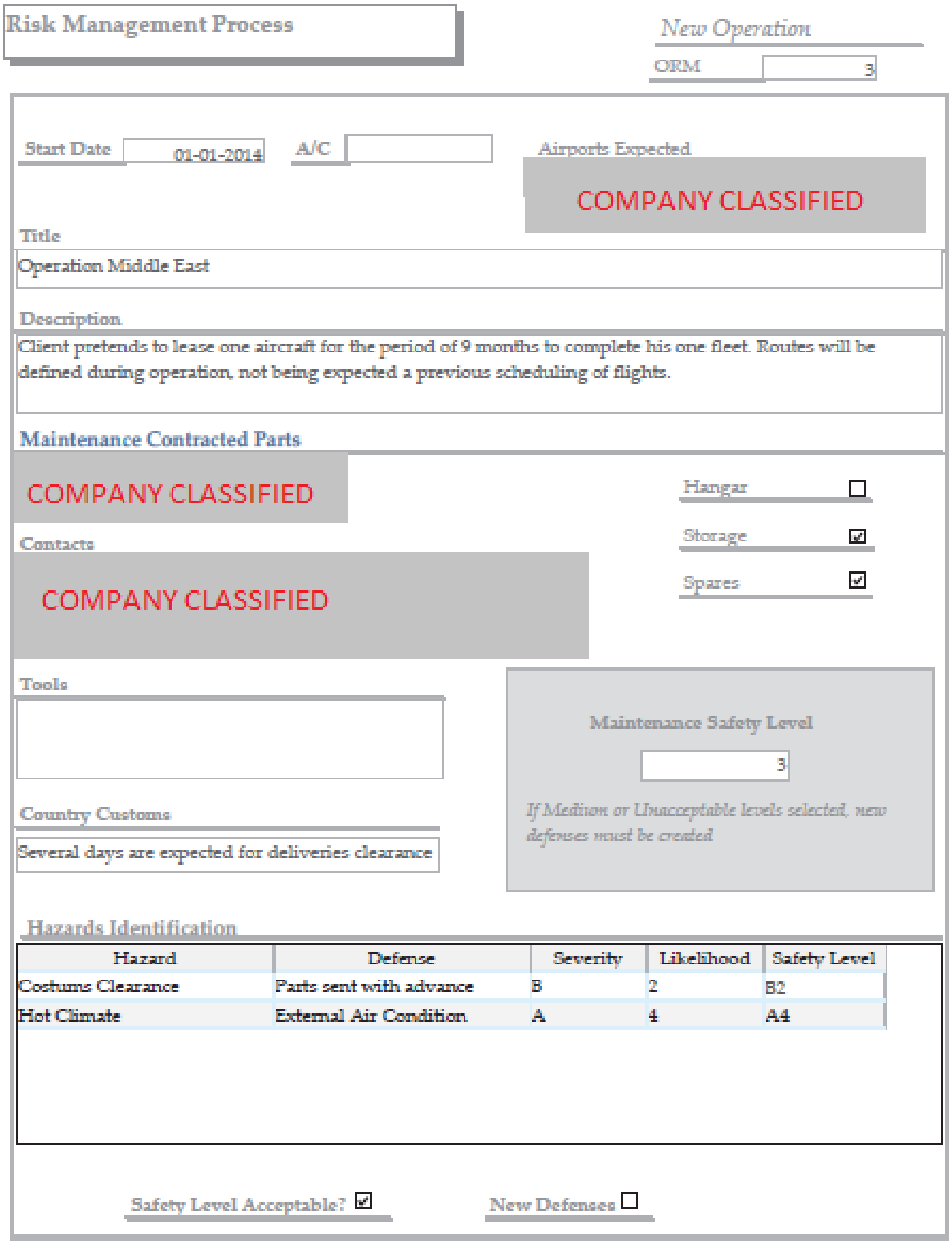
[1] Average of flight duration (in hours) per each cycle performed.

4.3 Activity Risk Management

Hereafter, will be described the application of the models studied for assessing the risks when a new activity is contracted and for accomplishing the required maintenance procedures.

4.3.1 Operation Risk Management

As described in section 3.7, when a new operation is prepared a process is initiated in the safety database and a final report is emitted to be presented to Maintenance and Engineering director for appreciation. In that form are analyzed subjects directly related with maintenance, as external companies contracted, storage capacity at base airport, equipment available, time frame to get deliveries from customs, etc. There are also described the hazards identified for the operation course and existent defenses that could minimize the effects of those hazards. Safety level is then attributed accordingly to severity and likelihood of the risk, using risk matrix (figure 2.3) to evaluate if safety levels are accepted. From the list of hazards, if at least one of them is situated in "alarm zone" of the matrix, new defenses have to be created being nominated a responsive person to ensure correct implementation. One of the examples collected from implemented process is presented in figures 4.2 and 4.3.



Risk Management Process

New Operation

ORM 3

Start Date 01-01-2014 A/C

Airports Expected

COMPANY CLASSIFIED

Title

Operation Middle East

Description

Client pretends to lease one aircraft for the period of 9 months to complete his one fleet. Routes will be defined during operation, not being expected a previous scheduling of flights.

Maintenance Contracted Parts

COMPANY CLASSIFIED

Hangar ☐

Storage ☑

Spares ☑

Contacts

COMPANY CLASSIFIED

Tools

Maintenance Safety Level

3

If Medium or Unacceptable levels selected, new defenses must be created

Country Customs

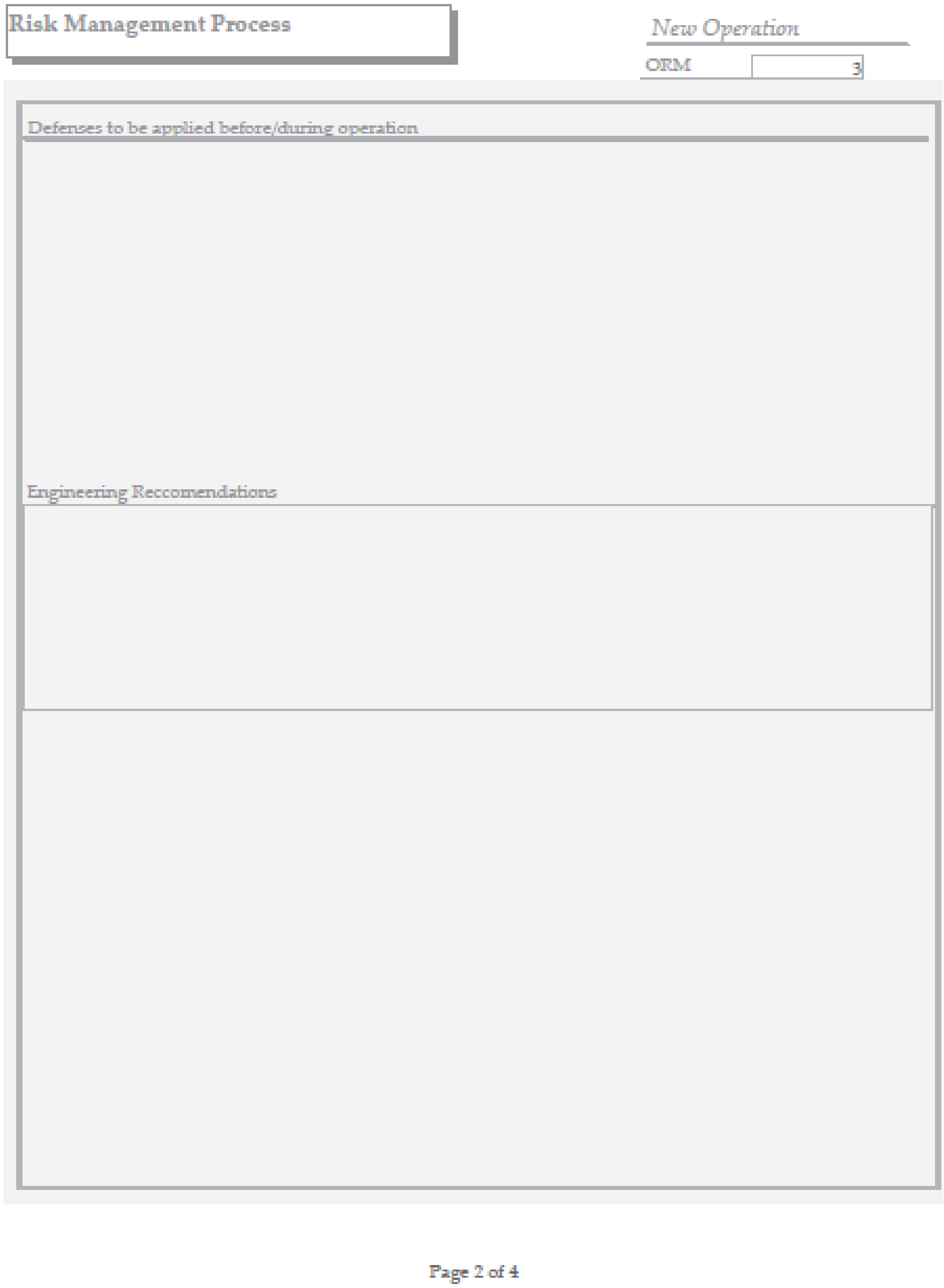
Several days are expected for deliveries clearance

Hazards Identification

Hazard	Defense	Severity	Likelihood	Safety Level
Costums Clearance	Parts sent with advance	B	2	B2
Hot Climate	External Air Condition	A	4	A4

Safety Level Acceptable? ☑ New Defenses ☐

Figure 4.2 Operation Risk Management - Page 1


Risk Management Process

New Operation

ORM 3

Defenses to be applied before/during operation

Engineering Reccomendations

Page 2 of 4

Figure 4.3 Operation Risk Management - Page 2

4.3.2 Maintenance Risk Management

For the case of Risk Management of maintenance duties, we select one case where the assessment made was concerning the entrance / exit of the hangar. This procedure although seems simple can lead to major damages in A/C. Sizes of the A/C and facilities must always be taken in consideration, tools and equipment should be in safety position and collected when not required and also work conditions must remain adequate to the accomplishment of planned tasks. The figures 4.4 and 4.5 illustrate the process that was prepared in order to reduce the risk in movements of A/C to the hangar for maintenance tasks.

New Maintenance Task

MRM number: 3

A/C: COMPANY CLASSIFIED

Task Description: Hangar entrance due to scheduled maintenance work.

Contracted Part: COMPANY CLASSIFIED

Expected Time: 1 hour

Hangar ☑

Representative: COMPANY CLASSIFIED

Hazards Identification

Hazard	Defense	Risk Index	Risk Level	Safety Level
Push the aircraft into the facilities	Inspect if towbar is adequated; existence of FOD in way to stand.	B	4	B4
A/C sizing/dimensions	Verify the A/C dimensions; check hangar dimensions.	C	3	C3
Access tools/equipment's during work accomplishment	Avoid unnecessary equipmets nearby the A/C; lock all movable devices; check correct ilumination.	B	4	B4
Facilities capability	Require safety margin around A/C; check circulation way clearance.	C	2	C2

Safety Level Accepted ☑ New Defenses? ☐

Figure 4.4 Maintenance Risk Management - Page 1

Figure 4.5 Maintenance Risk Management - Page 2

4.4 Alert Notification Status

In the field of reliability "cross-check" with safety management, analysis is made directly with reliability engineer. When negative trend is detected in reliability analysis, safety advisor must be informed and after meeting it's decided about the need to raise a safety note. Other case, is when safety advisor detects a negative trend (for example through SPI) and alert reliability. This partnership can provide in global terms a wide review in technical defects of the fleet, avoiding unexpected failures. As far as we are authorized, Figure 4.6 represents the table used to monitor alert notifications and respective safety notes. Cases were hidden to protect company's data.

ITEM	AN REFERENCE	ATA	A/C REG	SUBJECT	ISSUE DATE	SUMMARY	NOTES	STATUS	SAFETY NOTE
1	AN_14_001	32	COMPANY CLASSIFIED	BRAKE #5 OVERHEAT	COMPANY CLASSIFIED	TEMPERATURE OF BRAKE IN POSITION #5 ABOVE OPERATIONAL LIMITS	- NO EXCESSIVE WEAR OF CARBON DISCS WAS VERIFIED - PLUG FROM TEMPERATURE CONTROL WAS FOUND WITH SIGNS OF BURNT AND IDENTIFED AS THE ROOT CAUSE FOR FAILURE	CLOSED	ID_01

Figure 4.6 Alert Notification Status

4.5 Safety Note

From all the safety notes collected and analyzed in the scope of this study, one will be presented as an example of how this part is a complement of safety management program. The case reported was an indication of excessive temperature in one brake for more than once. As reported by flight crew, during pre-flight taxi one of the brakes was showing higher temperature than the others, reaching values above operational limit. When inspected by maintenance team, brake didn't present any signs of overheat and according to maintenance manual, values of temperature reached weren't over value considered as overheat temperature (in that case, brake deactivation and consequent replacement had to be performed). Safety advisor performed a deeper investigation involving manufacturer and was found that a plug in temperature monitoring system of that specific brake presented signs of burnt. That plug was replaced and no further events were reported. Figures 4.7 and 4.8 represent the form used to follow this case.

Risk Management Process

Safety Note

ID COMPANY CLASSIFIED

Reported

A/C	Date Open	Due Date	Reported By (Name/Position)
COMPANY CLASSIFIED	04-02-2014	29-06-2014	COMPANY CLASSIFIED

Title	Risk Level
Brake #5 hotter (~200ºC) than others	C4

Description

For more then one time (not consecutive), brake #5 found to be hotter than the other ones. For a couple times, value was above operational limits causing a return to gate (when event took place during take-off taxi).

Investigation Process

Investigation Steps

- Brake removed and inspected in accordance with maintenance manual from manufacturer - found ok;
- Carbon disks from brake oxidation causing rising in temperature of assembly - after brake replacement, new events were reported;
- Inspected plug from brake temperature monitoring - found signs of short-circuit and burnt - confirmed as root cause.

Potential Outcomes

Wheel/brake fire.

Corrective Action

Plug affected was replaced and remaining ones inspected. Another one in a different position was found with small signs of burnt, and was also replaced.
As suggestion of manufacturer, procedure for landing gear lubrification review.

Attributted Risk Level	C3	Closed? ☑

terça-feira, 30 de setembro de 2014 Page 1 c

Figure 4.7 Safety Note File - Page 1

Barriers Evaluation

After one month no further events were reported.

Close Date	31-07-2014

Safety Advisor	COMPANY CLASSIFIED
Approver	

Flight Safety Sight

domingo, 7 de setembro de 2014 Page 2 of 2

Figure 4.8 Safety Note File - Page 2

This is an example of advantages of safety management. With a reporting system, defects can be detected sooner, avoiding it to make part of an undesired state.

4.6 Event Report

The graphic in Figure 4.9 shows the amount of occurrences reported during the period of implementation of our program.

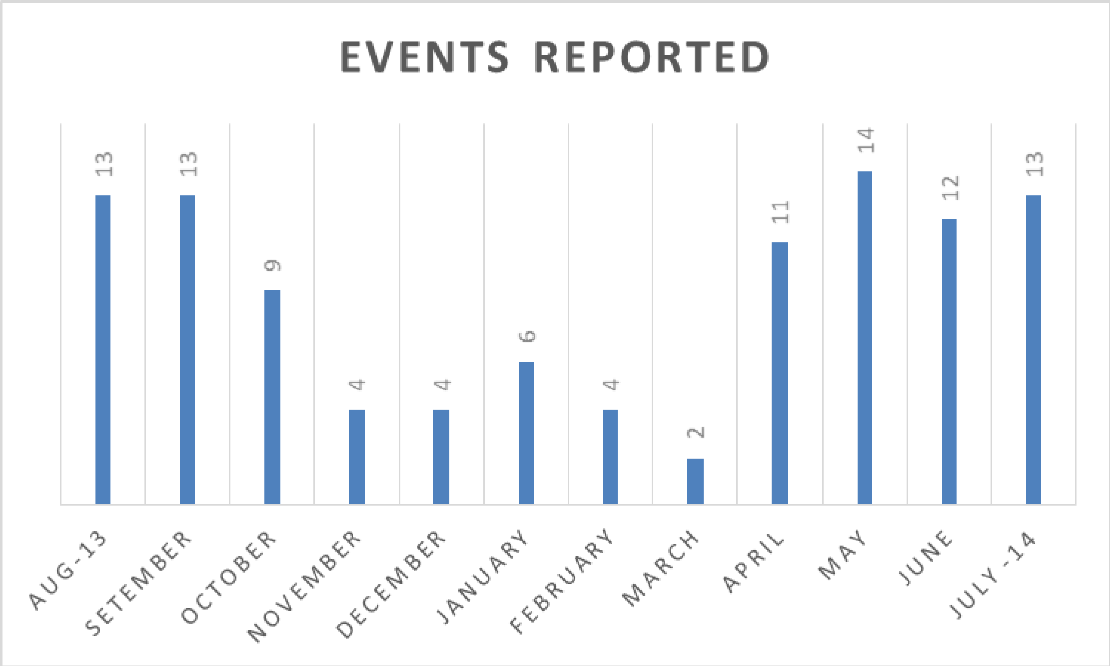


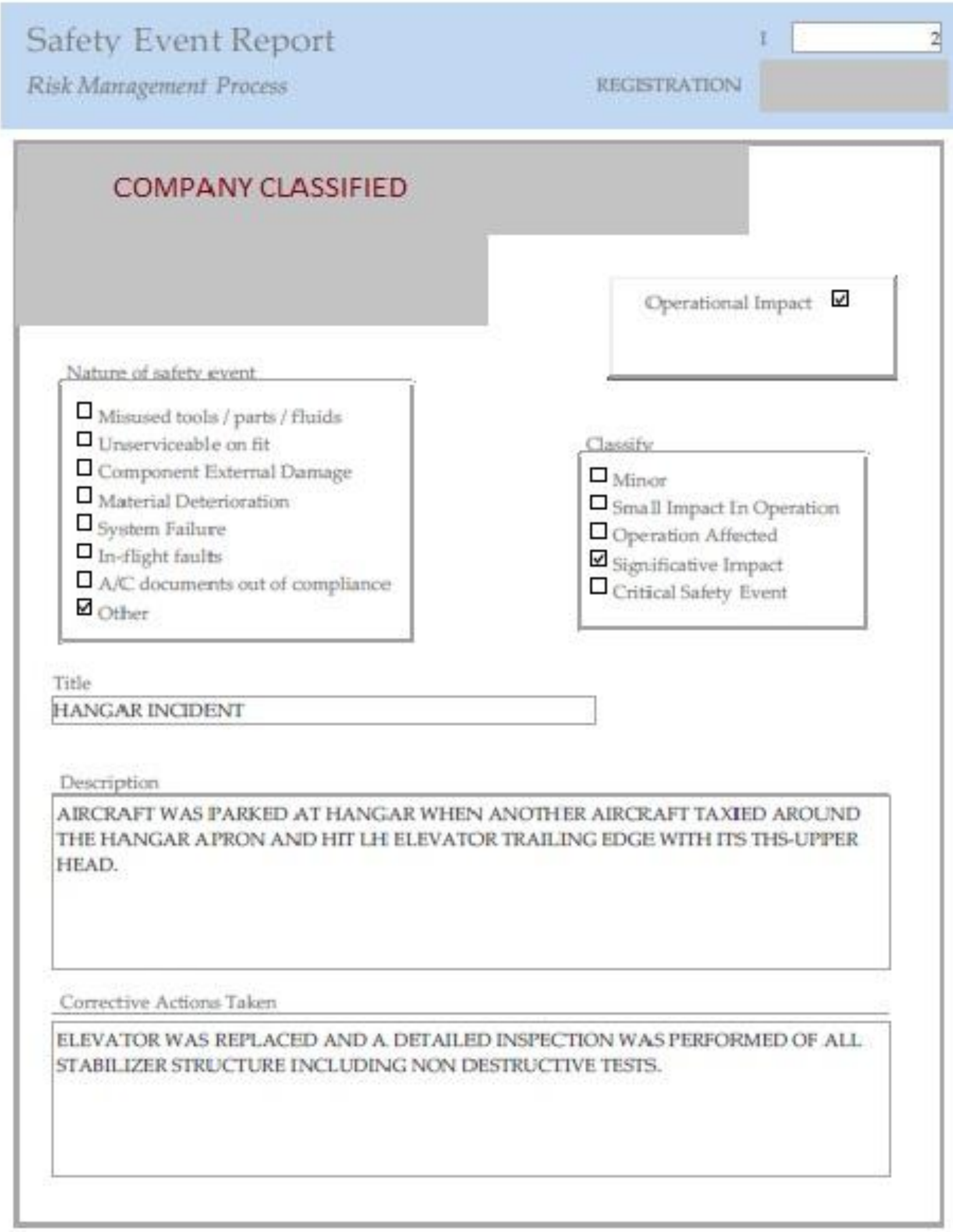
Figure 4.9 Events Reported

As we can see, during low season (November until March), a low number of events were reported, this follows the expected, since this time less flights were performed.

As we will present ahead, several events were reported during implementation time. From all of them, one was selected to be presented and analyzed. This event was considered interesting since it follows a human error and is directly related with risk management of maintenance tasks, another target of this study. The event took place in hangar entrance when the aircraft was parked waiting for spare parts to be installed and while taxing a smaller aircraft, the vertical empennage of this one impact stabilizers of the first aircraft.

Investigations concluded that besides darkness and few manpower guiding taxi, the man who was maneuvering tractor was reaching his work time limit. It was also reported poor conditions for rest time. Those conditions are seen as the biggest hazards in human factors and is proved by several studies the increase of risk exposure when work is performed by tired people. Fortunately, no injuries were verified in this incident however it caused operational and financial impact, components had to be replaced and heavy inspections were carried out. Also, aircraft was unserviceable during the next 15 days. In Figure 4.10 it's presented the report generated for the referred event.

As a response to this event, conditions of workers of that company were improved and training was updated.


Safety Event Report

Risk Management Process

1 2

REGISTRATION

COMPANY CLASSIFIED

Operational Impact ☑

Nature of safety event

- ☐ Misused tools / parts / fluids
- ☐ Unserviceable on fit
- ☐ Component External Damage
- ☐ Material Deterioration
- ☐ System Failure
- ☐ In-flight faults
- ☐ A/C documents out of compliance
- ☑ Other

Classify

- ☐ Minor
- ☐ Small Impact In Operation
- ☐ Operation Affected
- ☑ Significative Impact
- ☐ Critical Safety Event

Title

HANGAR INCIDENT

Description

AIRCRAFT WAS PARKED AT HANGAR WHEN ANOTHER AIRCRAFT TAXIED AROUND THE HANGAR APRON AND HIT LH ELEVATOR TRAILING EDGE WITH ITS THS-UPPER HEAD.

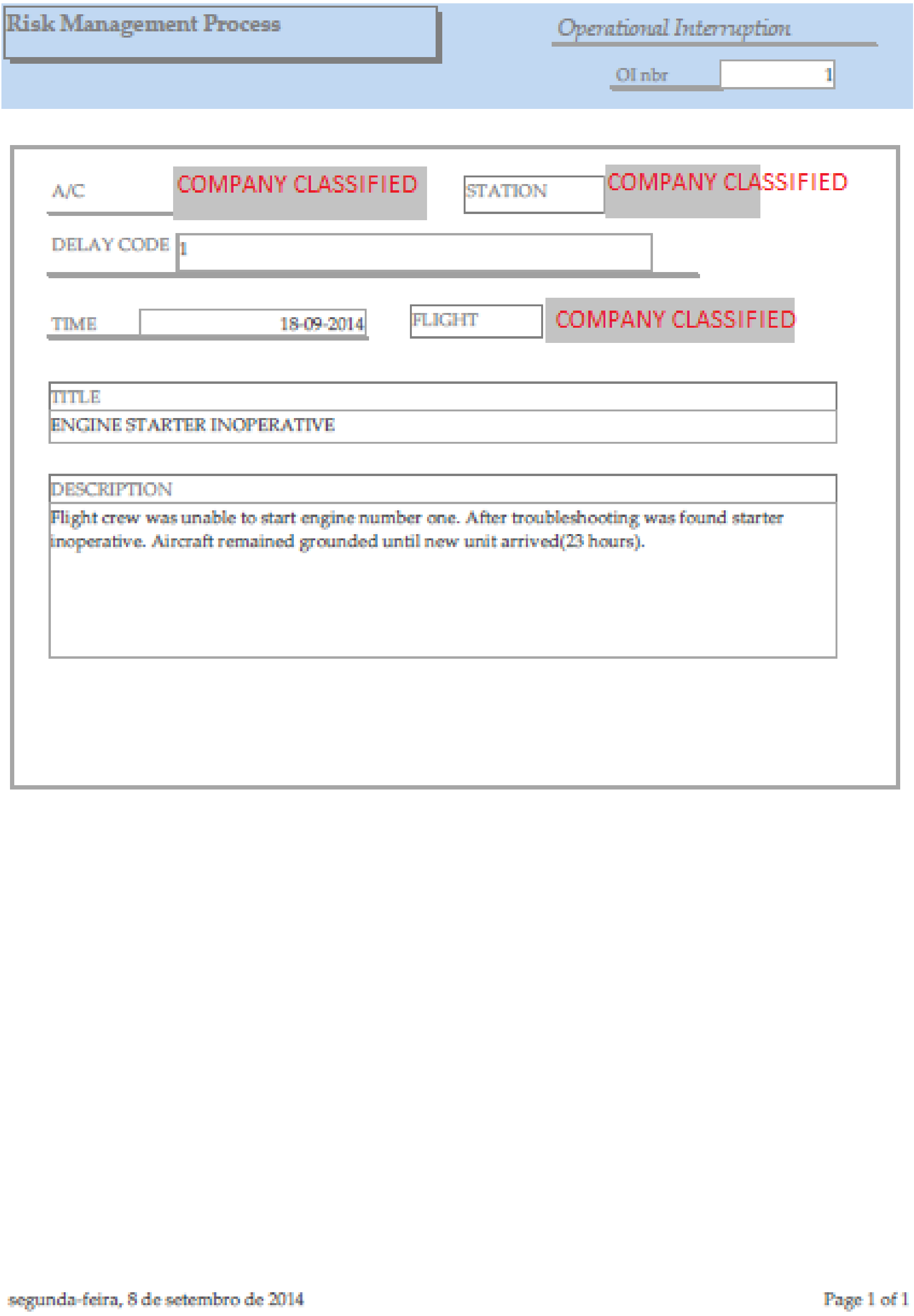
Corrective Actions Taken

ELEVATOR WAS REPLACED AND A DETAILED INSPECTION WAS PERFORMED OF ALL STABILIZER STRUCTURE INCLUDING NON DESTRUCTIVE TESTS.

Figure 4.10 Reported Event

4.7 *Operational Interruption Report*

Figure 4.11 shows an example of one operational interruption that took place during the implementation process of our program.



Risk Management Process

Operational Interruption

OI nbr 1

A/C COMPANY CLASSIFIED

STATION COMPANY CLASSIFIED

DELAY CODE 1

TIME 18-09-2014

FLIGHT COMPANY CLASSIFIED

TITLE
ENGINE STARTER INOPERATIVE

DESCRIPTION
Flight crew was unable to start engine number one. After troubleshooting was found starter inoperative. Aircraft remained grounded until new unit arrived(23 hours).

segunda-feira, 8 de setembro de 2014

Page 1 of 1

Figure 4.11 Operational Interruption Report

This case reflects a component failure causing cancellation of scheduled flight. Since no spare part was available at local, aircraft was unable to fly until a new unit arrived.

4.8 Safety Performance Indicators

As was already said in chapter 3 it will be used technical events and operational interruptions caused by technical failures as Safety Performance Indicators. With this, we intend to measure the amount of technical events experienced and also monitor the influence that technical defects have in operational dispatch.

Analysis will be performed per each 100 Flight Hours and 100 Flight Cycles, meaning, the amount of events reported for one month will be divided for the amount of hours or cycles performed that month and multiplied by 100. The intention is to standardize the sample at the most.

It's important to have the analysis done by flight hours and cycles in the way that average flight time can be different, meaning for example, that for the same flight cycles we can have more flight hours or the inverse.

The analysis is done per flight time or cycles in order to have an idea of the influence of aircraft utilization namely the failure of components regarding more usage and also as with more flights the exposure to risk is bigger.

4.8.1 Technical Safety Events Reported

With the graphics shown in Figures 4.12 and 4.13, we intended to analyze if incidence of events follow the bigger aircraft utilization (more hours or cycles) and also study the trend of reported events during the implementation year of risk management as a complement of SMS. Both graphics show the rate of events reported per month for each 100 hours of flight or for each 100 flights and the trend line for the period analyzed.

4.8.1.1 Analysis per 100FH

The Figure 4.12 presents the graphic with a rate of events reported for each 100 flight hours performed (columns). It’s shown a line with the amount of flight hours performed and a trend line of events reported *per* each 100 FH. With this graphic we intended to evidence the influence of aircraft utilization in technical failure.

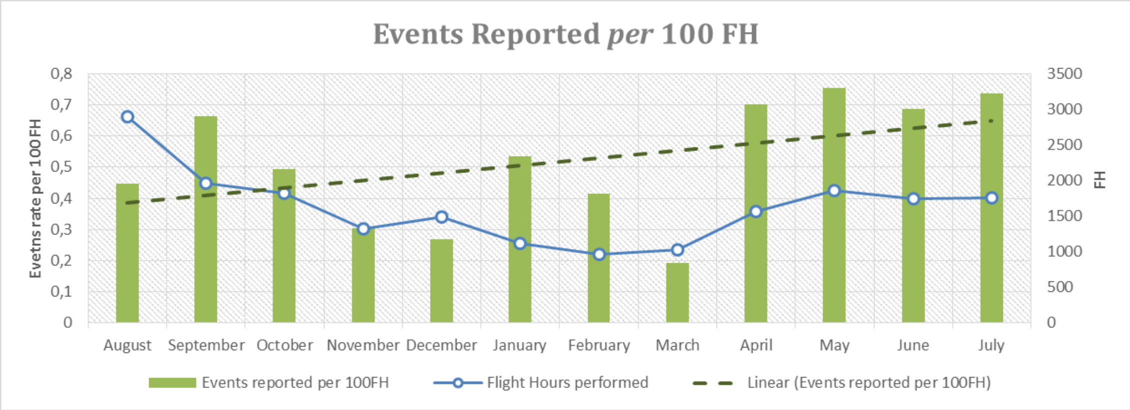


Figure 4.12 Technical Safety Events per 100FH

4.8.1.2 Analysis per 100FC

The graphic shown in Figure 4.13 it's similar to the presented in point 4.8.1.1, the difference is that in this one the analysis is made for flight cycles instead of flight hours.

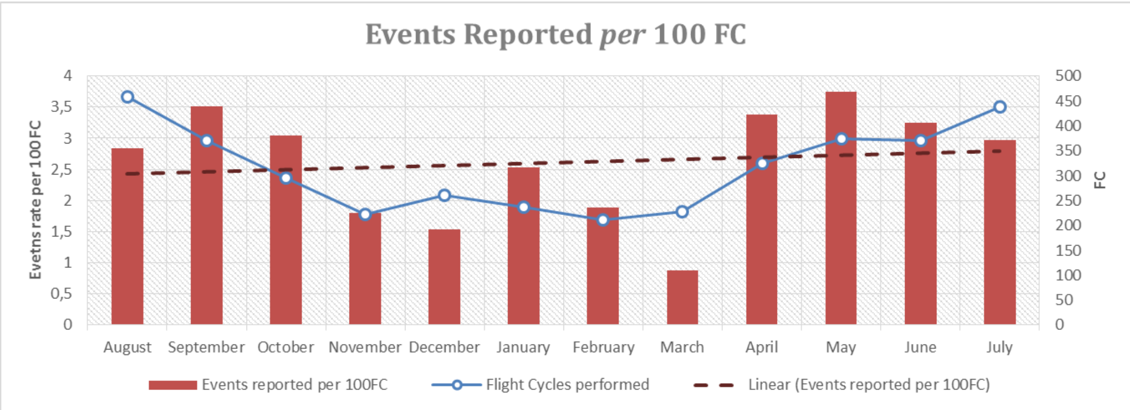


Figure 4.13 Technical Safety Events per 100FC

4.8.1.3 Conclusions

- Seasonal peaks are detected following the periods where aircraft are flying the most, namely IATA summer and New Year's Eve. This conclusion was expected since aircraft flying more, components suffer more deterioration and are more able to present failures. Exceptions of this are seen in December and further investigation was done in that specific cases. It was identified that besides the number of flights or amount of flight hour's aircraft didn't present an increase in technical failures. For this, we can see one possible reason. November was a month in which most of the aircraft were on scheduled heavy maintenance suffering replacement of several components for new ones, the failure rate is then expected to be minor. With this, we do not mean that safety of aircraft is lower in the months farthest from the last major maintenance but that the limit life of components are more near of its end and as considered by mainly of manufactures, failure probability increases with components life time. The components referred are failure safe, meaning it's a failure that won't compromise directly aircraft safety.

- The trend in reported events is increasing, this can be seen as an effect of improvement gave by risk management in reporting system. The reporting system, besides mandatory, sometimes it's difficult to accomplish and great efforts are made in daily basis for that every technical occurrence is reported. In this particular case, sometimes, the biggest obstacle is the fact that maintenance team can't meet the required conditions to perform participation. Namely, network conditions, external LAE's training and accomplishment of contracted tasks (in this case, the fulfilment of report form) and hesitation in utility of participation. During this time, we insist that it's always important the report of events and that this system is not punitive. Along with this, we can see visible improvements in safety culture and greater participation in reporting system.
- Comparing both graphics, we can see that the tendency line has greater slope in the case of analysis by flight hours rather than by flight cycles. This can be explained with the decrease in average flight time during referred period. Flight cycles present a tendency to be shorter, but the number of flights is near the same with less hours, in comparison, the rate will be bigger for the analysis by flight hours.

4.8.1.4 Analysis of Alert Level Exceedances

The next assay will be about comparing when rate of events reached levels of alert.

In Figure 4.14 it's shown a graphic with the rate of technical events per 100 flight hours being present the alert levels calculated for the last twelve months. With this graphic, it's analyzed the trend of events comparing to the levels considered for alert. The conditions to raise an alert were already described in 3.8.1 of this dissertation.

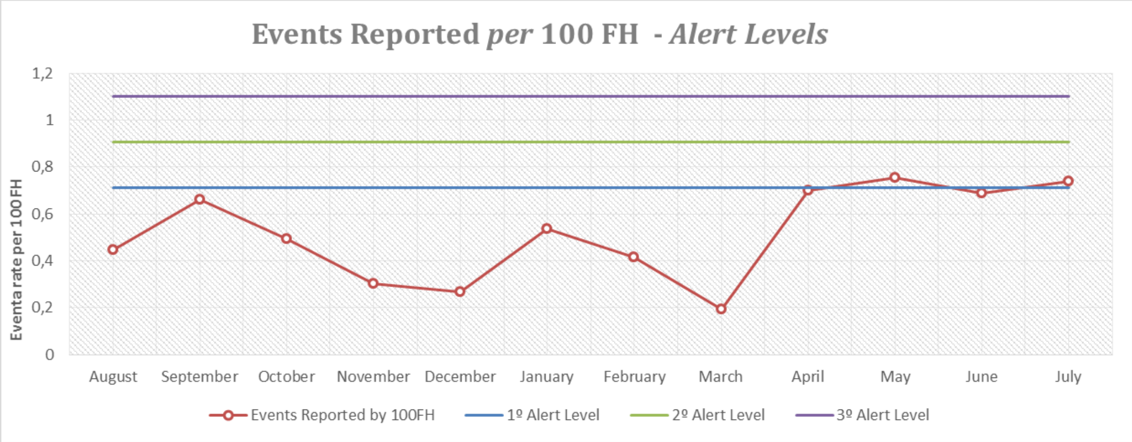


Figure 4.14 Technical Safety Events per 100FH - Alert Levels

In Figure 4.15 is done a similar analysis as described before, but for the technical events reported for each 100 flight cycles performed.

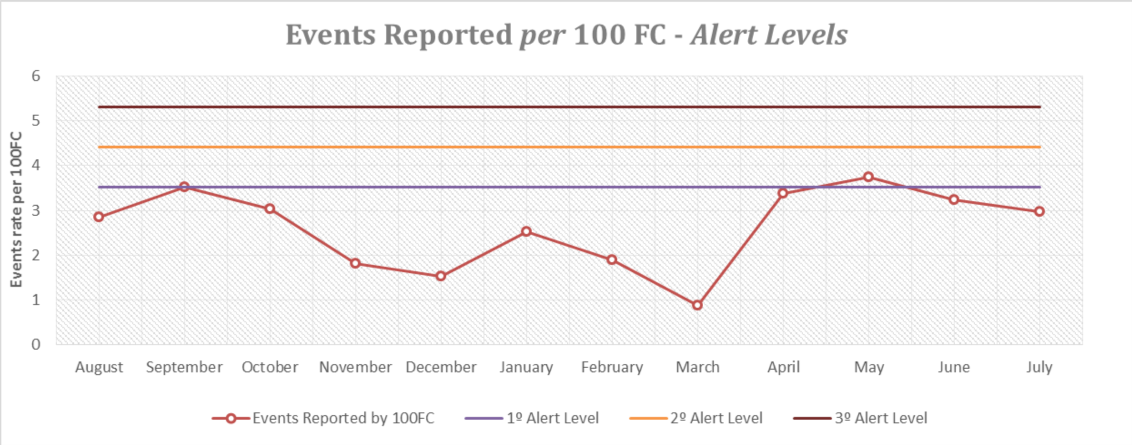


Figure 4.15 Technical Safety Events per 100FC - Alert Levels

As we can see since April the values of reported events are near the first alert level. Investigation was performed and the conclusions we obtained are described in the list below:

- Most of the fleet (7 of 10 aircraft) performed a huge amount of flights (several per day and/or long flights);
- Operation performed during that period was mainly in places with higher temperatures than desirable causing huge impact in aircraft components (being avionics, specially computers, particularly affected - computers failures are one case of mandatory events to be reported).

4.8.1.5 Technical Safety Events Leading Causes Distribution

From all the technical events collected for this study case was done a classification of what was the biggest leading cause. The causal factor, most of the times, is not isolated and other situations can had interfered in outcome event. For this analysis we separate events by the next leading causes:

- Technical Failure - of the aircraft itself, in the form of a component or a system;
- External Impact (e.g. birdstrike, lightning strike...) - meaning situations out of human control;
- Damage Found - that was found with no identified reason, this can be result of hidden/unnoticed impact or aircraft deterioration;
- Human Error - result of an human error committed by personal, not only maintenance error but from other service providers around the aircraft - (non-intentional acts);
- Others - out of any of the last expected causes.

The graphic presented in Figure 4.16 represents the distribution of events by the main cause that lead to their occurrence.

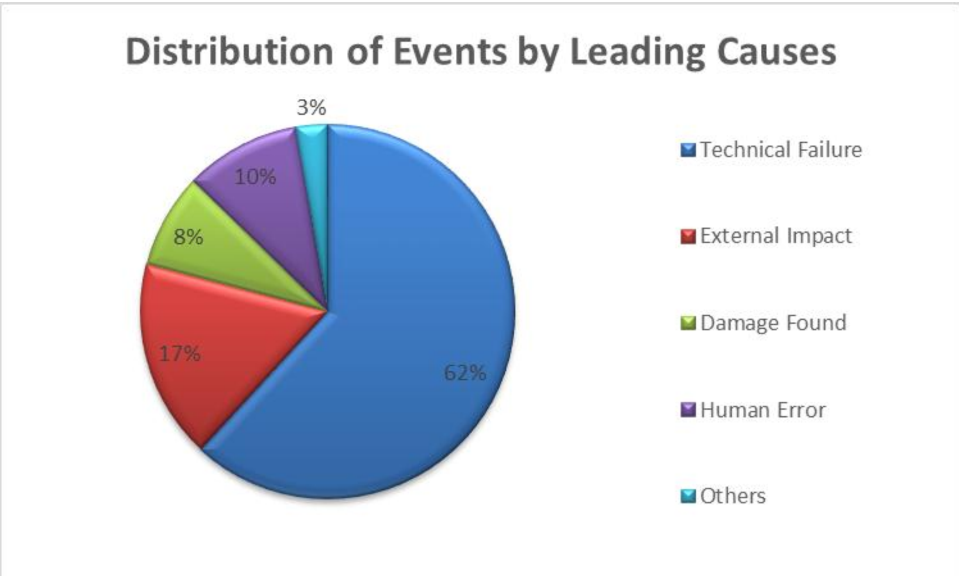


Figure 4.16 Leading Causes of Technical Events

Conclusions

- The major root cause identified in safety events was technical failure of the aircraft itself and its respective components. As a safety barrier of this event, reliability is making efforts to improve their program for better pattern of failure detection.

- External impacts are the second biggest cause for a safety event to happen. Unfortunately, these events are out of human control. It's not possible to avoid birds impact and lightning's are difficult to predict. The only control barrier we can take is to be prepared when this situation happens. For example, ensure that a LAE is available to perform required inspections when such event occurs and spare parts are available.
- The third cause detected, human error, can be minimized with training and continuous improvement of human factors.
- For the damages found, it's important that they are detected as soon as possible, in order to avoid worst effects and also investigate what had caused the damage.

4.8.2 Operational Interruptions due to Technical Failures

Another SPI used in our program is based in operational impact of technical failure. When aircraft has a technical defect and doesn't comply with all airworthiness requirements can't be used for profitable means. This cause financial impact in operation. The next analysis is done in matters of operational interruptions taking place due to technical events.

4.8.2.1 Analysis per 100FH

The Figure 4.17 presents the graphic with a rate of operational interruptions occurred for each 100 flight hours performed (columns). It's shown a line with the amount of flight hours performed and also a trend line with the rate of interruptions *per* each 100FH. With this graphic we intended to evidence the influence of aircraft utilization in operational interruptions occurred due to technical failures.

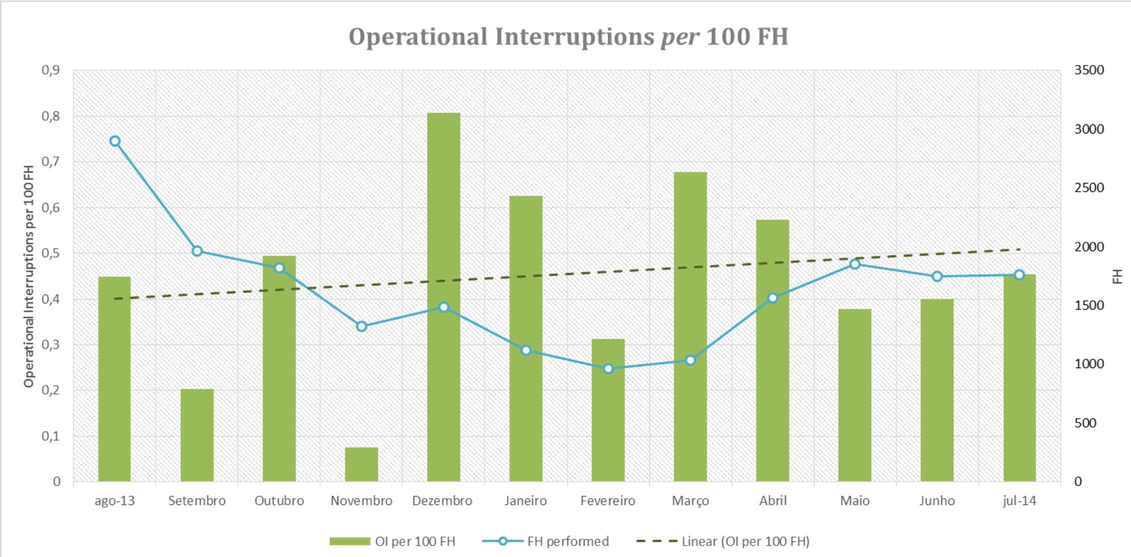


Figure 4.17 Operational Interruptions per 100FH

4.8.2.2 Analysis per 100FC

The graphic shown in Figure 4.18 it's similar to the presented in point 4.8.2.1, the difference is that in this one the analysis is for flight cycles instead of flight hours.

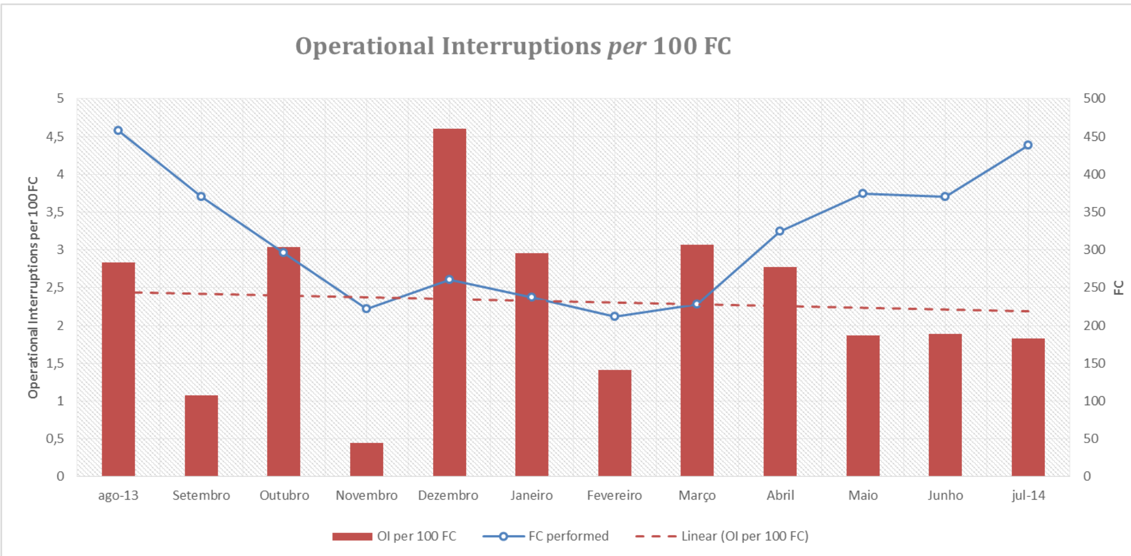


Figure 4.18 Operational Interruptions per 100FC

4.8.2.3 Conclusions

- We can see in such graphics, as for analysis per Flight Hours as for analysis per Flight Cycles, that operational interruptions follow aircraft utilization. With more flights, it's expected more degradation of components accompanying the increase of aircraft defects and also a major exposure of risks associated with operation around the A/C.

- Two situations were found not to be in accordance with tendency explain below. In this case, further investigation was made. In December and March/April was detected that for less aircraft utilization more events were registered (in comparison with other month), and also December was the month were more OI were reported. After investigation, it had been found several repetitive events in the same aircraft (8 cases of a total of 12), concerning air condition system. Even with all maintenance actions performed, this problem always come on during pre-flight, being present intermittently and without a predictable pattern of failure. Defect was corrected and aircraft released for flight. When, root cause was definitely found (ventilation controller faulty) and defect corrected, no more interruptions took place. In March/April period, were also detected repetitive faults in the same aircraft (this was different from December reported case). In this case, operational interruptions were being caused by brake defect already described in Safety Note (section 4.5) analysis above.
- Between the two graphs, we can see that trend slope is different, and this can be justified by the exposed before concerning the decreasing noticed in average flight time of analyzed period.

4.8.2.4 Analysis of Alert Level Exceedances

Figure 4.19 and Figure 4.20 show the graphics where rate of events is compared with alert levels, as defined in chapter 3 (using the annual average of reported events per 100FH or 100FC).

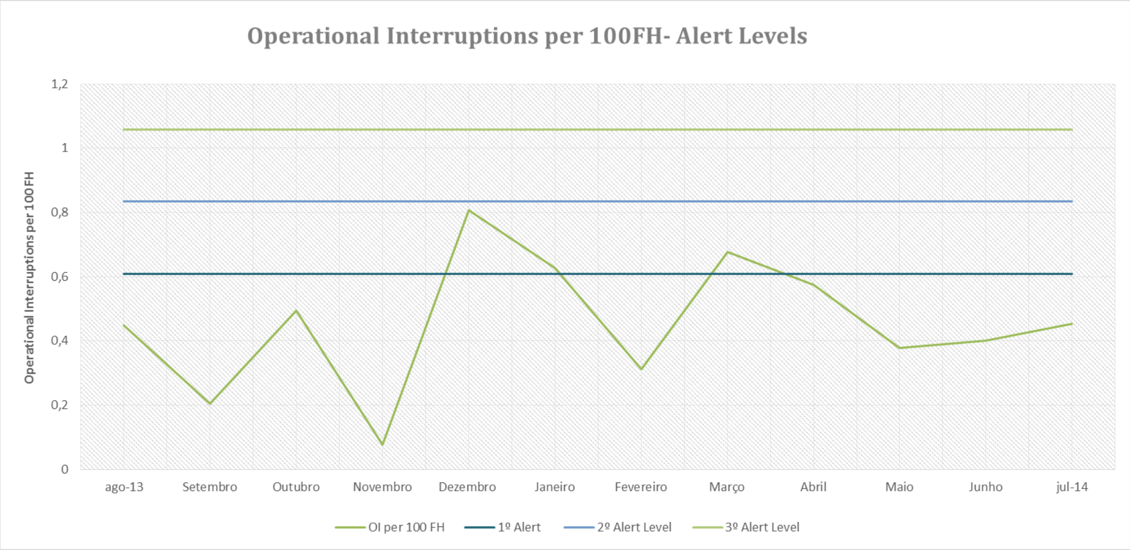


Figure 4.19 Operational Interruptions per 100FH - Alert Levels

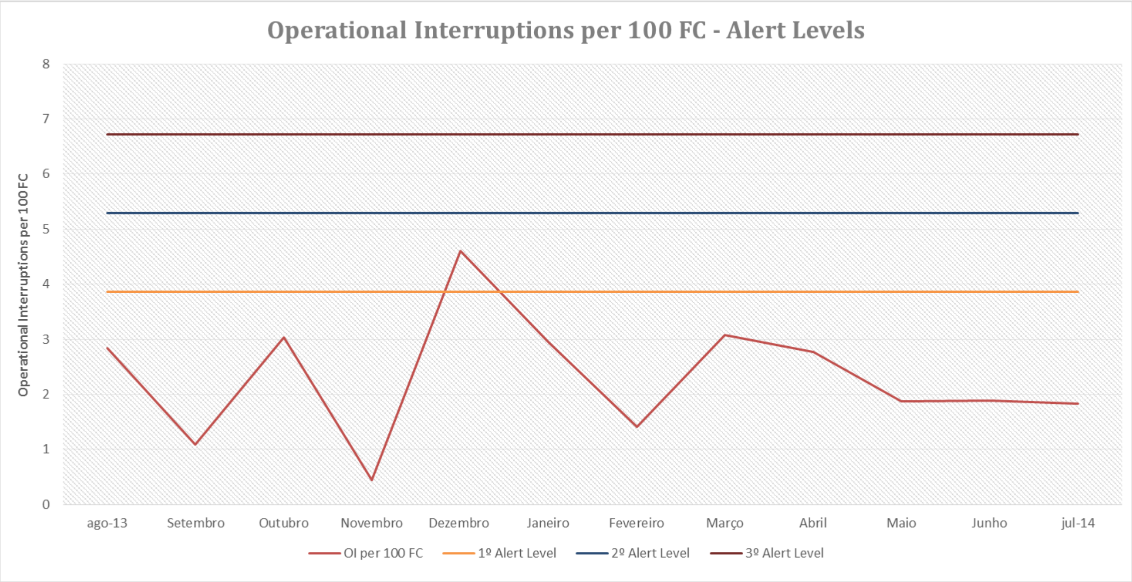


Figure 4.20 Operational Interruptions per 100FC - Alert Levels

As we can see in graphics of Figure 4.19 and Figure 4.20, none of the conditions to raise an alert was reached. However, must be noticed that a qualitative evaluation must be done by Safety Advisor in cases like December. This evaluation is done on monthly basis, so when a value reaches an alert level, is advised to understand the causes, even if an alert is not raised. In our case, the reason of this exceedance was already described and no further information will be added.

4.8.2.5 Operational Impact of Reported Technical Safety Events

Technical safety events, can have operational impact, leading to an effect in normal operation. Financial impact can be huge not only for the direct cost of failure itself but also for the indirect costs associated with loss of aircraft usage. From those indirect costs we underline delays, passenger's re-scheduled flights/accommodation, airport taxes as many others sometimes hidden in the bigger picture. Figure 4.21 shows the percentage of each technical safety event that lead to an operational interruption. Technical events were also divided by leading causes.

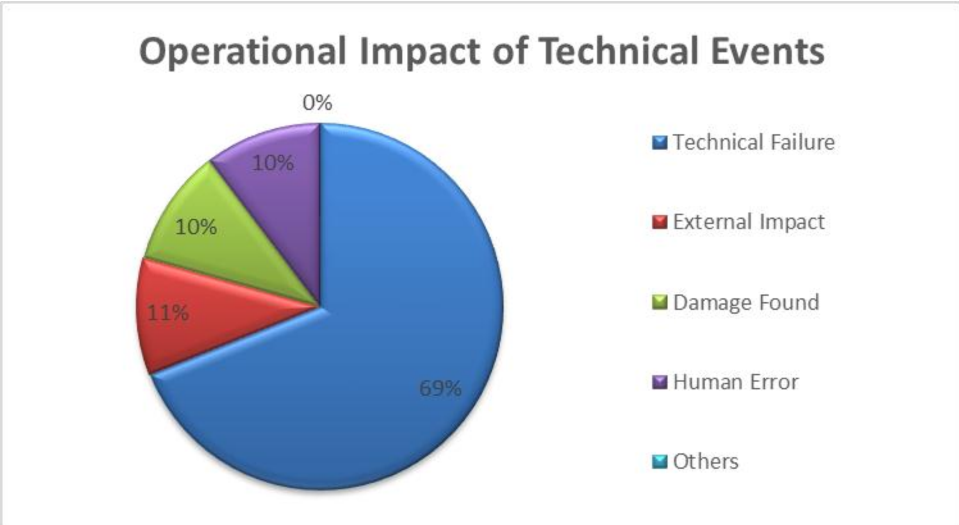


Figure 4.21 Operational Impact of Technical Safety Events

As in graphic of Figure 4.16, we can see in graphic represented in Figure 4.21 that failure of components/systems of the aircraft represents the biggest cause for an operational interruption. Again, reliability used in risk management can significantly improve the operational dispatch. In fact, components purchased in AOG basis are more expensive than when planned not mentioning maintenance costs for lack of tools and manpower (to be external contracted). The above events, external impacts, damages found and human errors represent near the same in terms of potential causes that lead to operational interruptions. Once again, external impacts are impossible to avoid and only a good preparation can reduce the effects of these situations. On the other hand, human errors can be significantly minimized with adequate training and management of human factors. As far as we are able to present in this study, some of the events that are here presented as caused by human errors were related with poor training of evolved human resources and also some disregard concerning the workplace conditions and work time.

4.9 Chapter Conclusion

This chapter was dedicated to a dissection of information collected during the implementation phase of our study. The first content was a presentation of sample data, meaning the flight hours and cycles performed by the 10 aircraft during the reported period. We also can see the rate of flight time during one year. The next was a demonstration of one of the processes to prepare a new operation and also one maintenance task, in this case we selected the entrance in the hangar. It was shown how safety advisor manage the alert notifications from reliability in order to detect hazards and negative trends. In the case of safety influence in reliability, safety notes are used to monitor the evolution of a certain pattern of failure. This element of the program was also shown where, giving a particular case of a safety note raised and respective corrective action. For the next, was given one of the events reported being made an analysis of the occurrence. We selected an occurrence related with a damage caused during the entrance of an A/C in the hangar as comparison of the maintenance tasks preparation also presented. With this, we intended to evidence the importance of risk assessment and justify the reason why that specific form was build. For the last, we interpreted SPI's for events reported and operational interruptions due to technical failures, with root causes for exceedances investigated and explained. This was presented to explain how SPI's work and also as an analysis tool in the whole information collected, allowing us to derive conclusions about the implementation of this program.

Chapter 5. Conclusion

5.1 Dissertation Summary

This study started with intention to help a department of maintenance and engineering from an aircraft operator (with uncommon operation) to implement a culture of Risk Management in their internal structure.

As we proposed, legislation was reviewed and study was based in regulation at global level making valid to operate worldwide. The necessary legislation was applied and recommended practices followed in the scope of department needs and targets. To improve our demand, was also consulted other programs with the same targets. With these programs, we were more aware of procedures that can smooth the work and also make the managing of risks a more comprehensive process. The partnership was helpful for our side, since many experience contributed to better know how aviation works and be able to detect what really threats aircraft operations.

All the forms are now part of an internal procedure within department structure. They are used on daily basis and when received, Safety Advisor add information in the database created. Get access to past files or emit a report of trends is now easier for engineers preparing new activities.

After one year implementing this program, many information was collected. As was being said, company want to remain unknown and some information was hidden from this document and have been only used conclusions that support our study. With this study, several situations were investigated, improving the knowledge of aviation industry, in particular technical information about aircraft. In the scope of this dissertation, we do not intend to analyze all of them, but only demonstrate how safety management is now working with direct application of the program. It was also possible to understand trends using performance indicators. This method was useful to compare the amount of events from one month with annual average, working as a level of alerts.

5.2 Objectives Evaluation

From what we intended to realize when starting the project:

- Prevent damages/delays/operational limitations due to technical issues and/or maintenance tasks:
  - A better analysis is now done about operational interruptions (causes, how would have been avoided);
  - Technical defects are monitored in a partnership with reliability, detecting negative trends with the help of safety notes and SPI's;
  - Maintenance tasks are assessed in matters of safety to prevent potential negative outcomes (like lack of equipment, disrespect with A/C dimensions and movements it).
- Analyze, previous and immediately, risks associated with intended operations;
  - When a new operation starts, risk management process identifies what could threat it and prepare necessary response;
  - Risk level is assessed with barriers implemented until becomes acceptable. Barriers have a controller (SPI's) to grant it's correct implementation.
- Accomplish with mandatory legislation in matters of Risk Management, in the scope of SMS implementation process:
  - At the time of implementation ends, most important legislation was accomplished with program implementation (note, only Maintenance & Engineering department is under analysis).
- Analysis of trends and exceedances of alert level:
  - SPI's were analyzed and reports were made concerning the root causes for exceedances.

On the other hand, from the intentions for the project, it is missing:

- The process for automatic trends being generated wasn't achieved. Some difficulties were found working with selected software, but it was decided to go on the project since it would not affect the final evaluation of the case of study.

5.3 Final Considerations

Data collection was not always easy, since, there is still some “fear” of consequences when reporting events. All the time, efforts were made to change that way of thinking and actually, along with time, we observed an increase of voluntary reports.

The amount of information available was also a difficulty, since we can fall into the risk of losing something important from the great collection of safety documents.

5.4 Future Perspectives

For the future, a good improvement would be a new software as support for database since the one used for this study presented several limitations. Namely, an easier way to calculate trends and generate automatically the reports.

Another improvement would be the design of an application, able to be installed in mobile devices (smart-phones, tablets...) to follow engineers in daily routines around the A/C, where information was included and promptly sent to safety advisor. With this we could have a quicker reaction when an hazard is detected, allowing a better responsive plan.

Bibliography

[1] Arendt, D., Brisbois, F., and Brisbois, S., Dupont,G., Komarniski, R.,

Heffernan, J. and Lugger, E., Uhlin, D., “Safety Management Systems Tool Kit”, Airborne Law Enforcement Association, 2009, chapter 1 and 2.

[2] Eurocontrol, “Accountable Manager”,

http://www.skybrary.aero/index.php/Accountable_Manager , [last access at 8-09-2014].

[3] Wells, A. T., Young, S. B., “Airport Planning and Management”, McGraw-Hill, 2004.

[4] Crocker, D., “Dictionary of Aviation”, A and C Black Publishers, 2007.

[5] Federal Aviation Administration, “Risk Management Handbook”, U.S. Department of Transportation, 2009.

[6] Hobbs, A., “An Overview of Human Factors in Aviation Maintenance”, Aviation Research and Analysis Report: AR-2008-055, Australian Transport Safety Bureau, December 2008.

[7] ICAO, “Annex 6 to the Convention on International Civil Aviation”, Montreal, 2001.

[8] INAC, “Safety Management Systems – Guidance to Organizations”, Instituto Nacional da Aviação Civil, Lisbon, 18 de Junho de 2014.

[9] Maragakis, I., Clark, S., Piers, M., Prior, Capt. D., Tripaldi, C., Masson, M., Audard, C., "Guidance on Hazards Identification", Safety Management System and Safety Culture Working Group, European Strategic Safety Group, March 2009.

[10] SM ICG, “Safety Management International Collaboration Group (SM ICG)”, http://www.skybrary.aero/index.php/Safety_Management_International_Collaboration_Group_(SM_ICG) , [last access at 25-08-2014].

[11] Government of Canada, “Justice Laws Website”, http://laws-lois.justice.gc.ca/eng/regulations/SOR-96-433/page-18.html#h-49 , [last access at 17-08-2014].

[12] ICAO, “Safety Management Manual”, Montreal, International Civil Aviation Organization, 2006, chapter 2,3 and 5.

[13] Stolzer, A. J., Halford, C. D., Goglia, J.J., “Safety Management Systems in Aviation”, Ashgate Publishing Limited, 2003.

[14] PSAS, “Partnership for a Systems Approach to Safety (PSAS)”, http://psas.scripts.mit.edu/home/ , [last access at 13-08-2014].

[15] Leveson, N., “Engineering a Safer World”, The MIT Press, Cambridge, 2011.

[16] Flight Safety Foundation, “Program Overview”, Basic Aviation Risk Standard, Flight Safety Foundation Inc., New York, 2013

[17] Flight Safety Foundation, “Implementation Guidelines”, Basic Aviation Risk Standard, Flight Safety Foundation Inc., New York, 2013

[18] Maurino, Capt. D., “Threat and Error Management”, Canadian Aviation Safety Seminar (CASS), Vancouver, BC, 18-20 April 2005.

[19] Panjer, H., “Operational Risk: Modeling Analytics”, John Willey & Sons Inc., 2006.

[20] DL, “Decreto-Lei n.º238/2005 de 14 de Dezembro”, Ministério das Obras Públicas, Transportes e Comunicações, Lisboa, Imprensa Nacional – Casa da Moeda, S.A., 2005, pp. 7051-7061.

Annex A Forms

A.1 Safety Event Report Form

A.2 Safety Note Form

A.3 Operational Interruption Form

A.4 Operation Risk Management Form

A.5 Maintenance Risk Management Form

Safety Event Report

I 4

Risk Management Process

REGISTRATION

Reporter

Statio

Associated TOR

Occurrence Date

Report Date

Operational Impact ☐

Nature of safety event

- ☐ Misused tools / parts / fluids
- ☐ Unserviceable on fit
- ☐ Component External Damage
- ☐ Material Deterioration
- ☐ System Failure
- ☐ In-flight faults
- ☐ A/C documents out of compliance
- ☐ Other

Classify

- ☐ Minor
- ☐ Small Impact In Operation
- ☐ Operation Affected
- ☐ Significative Impact
- ☐ Critical Safety Event

Title

Description

Corrective Actions Taken

Risk Management Process

Safety Note

ID	

Reported

A/C	Date Open	Due Date	Reported By (Name/Position)

Title	Risk Level

Description

Investigation Process

Investigation Steps

Potential Outcomes

Corrective Action

Attributted Risk Level

Closed? ☐

Barriers Evaluation

Close Date	

Safety Advisor	
Approver	

Flight Safety Sight

Risk Management Process

Operational Interruption

OI nbr

A/C

STATION

DELAY CODE

TIME

FLIGHT

TITLE

DESCRIPTION

Risk Management Process

New Operation

ORM

Start Date

A/C

Airports Expected

Title

Description

Maintenance Contracted Parts

Hangar ☐

Storage ☐

Spares ☐

Contacts

Tools

Maintenance Safety Level

If Medium or Unacceptable levels selected, new defenses must be created

Country Customs

Hazards Identification

Safety Level Acceptable? ☐

New Defenses ☐

Defenses to be applied before/during operation

Engineering Reccomendations

New Maintenance Task

MRM number

3

A/C

Task Description

Contracted Part

Expected Time

Hangar ☐

Representative

Hazards Identification

Safety Level Accepted ☐

New Defenses? ☐

New Defenses

Recommendation