CZECH TECHNICAL UNIVERSITY IN PRAGUE

Faculty of transportation sciences
Department of Air Transport

Provázání leteckých taxonomií a kontextuálních informací v modelu STAMP

Alignment of Aviation Safety Taxonomies and Contextual Information in STAMP

Bachelor's thesis

Study programme: Technology in Transportation and Telecommunications
Study field: Air Transport

Thesis supervisor: Doc. Ing. Andrej Lališ, Ph.D.
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Zásady pro vypracování

Při zpracování bakalářské práce se řiďte následujícími pokyny:

- Cílem práce je vytvořit převodní systém provázání leteckých taxonomií a kontextuálních informací v modelu STAMP, kterými lze reprezentovat řídící strukturu a její části.
- Analyzujte současné letecké taxonomie z pohledu kontextuálních informací.
- Analyzujte systémový přístup k bezpečnosti pomocí modelu STAMP a identifikujte využívané kontextuální informace.
- Navrhněte převodní systém provázání leteckých taxonomií a kontextuálních informací v modelu STAMP.
- Dosažené výsledky vyhodnoťte.

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Rozsah grafických prací: dle pokynů vedoucího bakalářské práce

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Seznam odborné literatury: ICAO, Doc. 9859: Safety Managment Manual, 4th Ed., Montréal, Quebec, 2018.

Arlow, J. a Neustadt, I. UML 2 a unifikovaný proces vývoje aplikací: objektově orientovaná analýza a návrh prakticky. 2., Computer Press, 2007.

Leveson, N., Thomas, J. STPA Handbook, 2018.

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BACHELOR'S THESIS ASSIGNMENT

(PROJECT, WORK OF ART)

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Guidelines for elaboration

During the elaboration of the bachelor's thesis follow the outline below:

- Thesis goal: Creation of alignment system for aviation safety taxonomies and contextual information in STAMP, that could represent safety control structure and its parts.
- Analyze current aviation safety taxonomies in terms of contextual information.
- Analyze systems safety approach by means of STAMP and identify contextual information.
- Propose and create alignment system for aviation safety taxonomies and contextual information in STAMP.
- Evaluate the achieved results.

Graphical work range: according to the instructions of the thesis supervisor

Accompanying report length: minimum of 35 text pages (including figures, graphs and sheets which are part of the main text)

Bibliography: ICAO, Doc. 9859: Safety Managment Manual, 4th Ed., Montréal, Quebec, 2018.

Arlow, J. a Neustadt, I. UML 2 and the Unified Process: Practical Object-Oriented Analysis and Design. 2nd Ed., Addison-Wesley Professional, 2005.

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Bachelor's thesis supervisor: **doc. Ing. Andrej Lališ, Ph.D.**

Ing. Kateřina Grötschelová

Date of bachelor's thesis assignment: **October 9, 2020**

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a) date of first anticipated submission of the thesis based on the standard study duration and the recommended study time schedule

b) in case of postponing the submission of the thesis, next submission date results from the recommended time schedule

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I confirm assumption of bachelor's thesis assignment.

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Student's name and signature

Prague .... December 1, 2022

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Declaration

I hereby declare that the following thesis was done by myself, and all sources of information are cited in accordance with the Guideline for adhering to ethical principles when elaborating a final academic thesis.

I don't have any objection against using this educational work according to § 60 of Act of the Czech Republic No. 121/2000, on Copyright and Rights Related to Copyright and on Amendment to Certain Acts (the Copyright Act.).

In Prague, August 2023

Radek Gabriel

Abstrakt

Cílem mé bakalářské práce je navrhnout převodní systém mezi v současnosti používanou European Co-ordination Centre for Accident and Incident Reporting Systems (ECCAIRS) taxonomií a System-Theoretic Accident Model and Processes (STAMP) modelem. Tento převodní systém má za cíl zvýšit současnou úroveň provozní bezpečnosti. V první části se věnuji současnému stavu provozní bezpečnosti v letectví, což v kontextu této práce znamená představení organizací, které se provozní bezpečností a sběrem dat zabývají. Dále se věnuji vzorku současně používaných taxonomií pro hlášení incidentů a nehod, úvodu do systémové teorie se zaměřením na její využití v provozní bezpečnosti. Konec první části je zaměřen na přehled současné literatury a vědeckých prací na toto téma. Následně pak je vyzobrazeno využití Systems Theoretic Process Analysis (STPA) analýzy na vzorku hlášení událostí, což vede ke vzniku finální podoby převodního systému.

Klíčová slova: European Co-ordination Centre for Accident and Incident Reporting Systems, hlášení událostí, provozní bezpečnost, System-Theoretic Accident Model and Processes, taxonomie

Abstract

The goal of my bachelor's thesis is to propose a conversion system between the currently used European Co-ordination Centre for Accident and Incident Reporting Systems (ECCAIRS) Taxonomy and System-Theoretic Accident Model and Processes (STAMP) model. This conversion system aims to increase the current level of safety. In the first part, I deal with the current state of safety in aviation, which in the context of this thesis means an introduction to organisations that deal with safety and data collection, a sample of currently used taxonomies for reporting incidents and accidents, an introduction to systems theory with a focus on its use in safety. The first part's end focuses on an overview of current literature and scientific works on this topic. Subsequently, the use of Systems Theoretic Process Analysis (STPA) analysis on a sample of occurrence reporting is presented.

Keywords: European Co-ordination Centre for Accident and Incident Reporting Systems, occurrence reporting, safety, System-Theoretic Accident Model and Processes, taxonomy

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Abbreviations

AAIB	Air Accidents Investigation Branch
ADREP	Accident/Incident Data Reporting Program
AIA	Accident Investigation Authorities
ATC	Air Traffic Control
BAGASOO	Banjul Accord Group Aviation Safety Oversight Organisation
CA	Control Action
CAA	Civil Aviation Authority
CAA-CZ	Civil Aviation Authority Czech Republic
CAST	Casual Analysis based on System Theory
CICTT	The Commercial Aviation Safety Team/ICAO Common Taxonomy Team
EASA	European Union Aviation Safety Agency
ECCAIRS	European Co-ordination Centre for Accident and Incident Reporting Systems
ECR	European Central Repository
EEA	European Economic Area
EUROCONTROL	European Organisation for the Safety of Air Navigation
FAA	Federal Aviation Administration
HEIDI	Harmonisation of European Incident Definitions Initiatives
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation

MOR	Mandatory Occurrence Reporting
SDCPS	Safety Data Collection and Processing System
SMS	Safety Management System
SPI	Safety Performance Indicator
SSP	State Safety Programme
STAMP	System-Theoretic Accident Model and Processes
STPA	System-Theoretic Process Analysis
TEM	Threats and Errors Management
UCA	Unsafe Control Actions
VOR	Voluntary Occurrence Reporting

1. Introduction

Aviation is a mode of transport that grows increasingly every year. Because of its stable growth, the industry is more turbulent than ever. The more people use airplanes, the more it attracts the state governments to ensure that their people are safe or that the aviation companies care about being safe.

The main aspects of aviation are the speed of transportation, the safety of transportation and the ecology of the transportation. In all these aspects, aviation plays a significant role by being the quickest, the safest and arguably the cleanest in an ecological way. During the time, in all aspects, the progress was made. It is worth noting that in the early stages of aviation, there wasn't a big focus on ecology, but safety was, is and will always be the key focus.

To stay the safest as possible, aviation has been progressing and so did its safety. The first major point of interest was to make sure; aviation uses appropriate materials for building the aircraft. Then the focus was on the human factors, to make sure, they have the right abilities. Afterwards the main focus changed again and was about organisations and their culture and policies. And the last change of the focus is the one we are experiencing today – the focus is on the aviation as a system connecting all the involved subjects.

To choose a correct way of finding the relationships of the subjects, it is necessary to fully understand the aviation industry. For doing so, the System Theory becomes useful. The industry represents a whole system, where the subjects are individual subsystems.

For making sure that we find all the needed relationships, there is an instrument based on System Theory called System-Theoretic Process Analysis (STPA). After choosing the instrument, the appropriate data are needed together with knowledge regarding the system.

Since the era, when the focus was on organisations, the reporting systems were introduced. These systems are for reporting the occurrences or when involved subject thinks, that there is something wrong. These data are collected and analysed. For easier and more systematic analysis, the taxonomy was founded to allow the reporting identities to use the same reporting language.

The current reporting language in Europe is called European Co-ordination Centre for Accident and Incident Reporting Systems (ECCAIRS) Taxonomy. It is suitable to use this language and use for its new purpose, for the newest trend in aviation safety – finding the relationships and interfaces between the entities, to make sure they can't cause hazards.

2. Current state of Aviation Safety

Aviation safety plays a key role in aviation as we know it today. *"Safety is a state in which risks associated with aviation activities, related to, or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level."* [1]

The government makes sure that flying in aircraft is safe. They do this by creating regulations. To enforce safety regulations, it is important to define what aviation oversight is. ICAO defines safety oversight as a "function performed by a State to ensure that individuals and organisations performing an aviation activity comply with safety-related national laws and regulations." [2]

In today's world of aviation, we can find many different organisations that take part in aviation safety. For a brief introduction, I would like to bring them in topological order.

2.1. Organisations of a global scale

In terms of global scale organisations, the examples are International Civil Aviation Organisation (ICAO) and International Air Transport Association (IATA).

- ICAO – was founded as an organisation under the United Nation agency with focus on air travel. Founded in year 1944, the main goal is to uniform aviation standards worldwide resulting in smoother communication between all participating parties. There are 193 member countries to this date. ICAO issues recommendations that are then expected to be legislatively accepted by the member states. The major benefits can be found as the system of codes (that can represent countries, airlines (call signs), airport and not to forget – types of aircraft) and Freedoms of the air (there are currently 9 freedoms that allow movements of aircraft). [3]
- IATA – was founded as an organisation connecting airlines around the world. IATA's members are 301 airlines. The goal is to represent and defend the interests of airlines and spread knowledge about the benefits of aviation transport. Between their achievements we can mention IATA Clearing House (a system that makes buying a plane ticket between multiple IATA members easier than before. On the side of airlines, it solves the problem of billings between airlines and their

partners), creating a Dangerous Goods Regulations and Live Animals Regulations. [4]

2.2. The organisations of regional scale

There are eight such of organisations globally, to name examples – European Union Aviation Safety Agency (EASA) and Banjul Accord Group Aviation Safety Oversight Organisation (BAGASOO). Their members are countries in their regions of operation; thus, it can more competently work with regional specifics. [5]

- EASA – as its name suggests, it is an agency focused on safety (meaning monitoring, certifications, and regulations) and is subordinate to European Union. This provides EASA with one powerful instrument – EASA creates a technical input to the body of EU that translates it into legislation, so the member states must adopt the regulations. EASA's goal is to standardise the regulations in Europe, with improving safety as a consistent priority. Its member base consists of 31 countries (including 27 EU members + Iceland, Switzerland, Norway, and Liechtenstein). [6]
- BAGASOO – assumed from its name, this organisation is based in Banjul, the capital city of Gambia and includes six more countries in West Africa (namely Ghana, Guinea, Liberia, Nigeria, Cape Verde, and Sierra Leone). The goal is to promote the highest safety standards in the member base. There are four national civil aviation authorities (from Cameroon, Congo, Uganda, and Mozambique) as clients. To be able to stay up to date, BAGASOO has established powerful partnerships with the leaders in aviation (for example Airbus, EASA, Federal Aviation Administration). [7]

2.3. Organisations of national scale

in this group, we can find the highest number of members. I would like to mention two different examples with two different approaches to safety management.

- Civil Aviation Authority (CAA-CZ) – is the civil aviation authority of the Czech Republic. Because it is subordinate to EASA, CAA-CZ is dealing with the preparation of legislation – meaning enforcing regulations of the European Parliament and of the Council and Commission Regulations (EU) to the local legal system. Apart from that, CAA-CZ is also responsible for certifying the pilots (including drone pilots), aircraft and registering aircraft. [8]

- FAA (Federal Aviation Administration) – is the aviation authority in the United States of America. Its mission is to provide the safest, most efficient aerospace system in the world. Their responsibilities are similar to the one of CAA-CZ. However, FAA is solely subordinate to the U.S. government (as we witnessed in the year 2019, it was the president of the U.S. who grounded the fleet of Boeing 737 Max). [9][10]

2.4. Systems dedicated to collecting, processing and analysing data of regional oversight institutions

It is common to see confusion between safety data and safety information. These terms are defined by ICAO Annex 19. Safety data are the data that come directly from measurement or observation, on the contrary, the safety information is data that was already processed to give a reader more telling information in the spectre of the topic. [1] [11]

To have effective safety management, it is it is a must to have well-managed safety data collection, its analysis and overall management capabilities. These are requirements to be able to make the right data-driven decision-making for safety. According to the collected data, the authority is able to see the trends and make decisions for being able to reach the safety targets and objectives. This safety data collection contains data about the current safety situation as well as data from accidents and incidents that have already happened. [1]

In this manner, it is crucial to have qualified personnel to collect and store safety data and the know-how needed to process safety data correctly. People with strong information technology skills with a knowledge of data requirements, data standardisation, data collection and storage, data governance and the ability to understand potential queries that may be needed for analysis are needed. [1]

2.4.1. What to collect

It is up to every organisation to determine the right safety data and safety information for the possibility of the correct safety performance management process contributing to safety decisions. The requirements for safety data and safety information can be found based on a top-down or a bottom-up approach. After choosing the approach, it can be influenced by different considerations, for example national and/or local conditions and priorities or the need to monitor safety performance indicators (SPIs). [1]

There's a possibility of having a bias in the collected safety data. In the case of voluntary reports, the used language can be emotive or aimed at achieving a certain objective of a reporting entity. Because of this reason, we shall use the information with caution. [1]

For a higher quality of collected safety data, it is important to consider collecting the data from both internal and external sources. Taking both sources of data into consideration creates a more accurate view of the safety risks and the organisation's achievement of its safety objectives. [1]

Due to Annex 13, it is required from member States to establish and maintain a database of accidents and incidents to enable the effective analysis of information on actual or potential deficiencies and to be able to determine any preventive actions if needed. Access to this database should be provided to the state authorities responsible for the implementation of the state safety programme (SSP). [1] [12]

Annex 13 requires investigations of accidents and serious incidents of any aircraft of a maximum mass of over 2 250 kg which have occurred in the territory of the member State. The state's accident investigation authority is required to conduct such an investigation. The States may delegate the investigation to another State or regional accident and incident investigation organisation. These investigations are important for bringing up new safety information to support safety performance improvement. [1] [12]

In Figure 1, we can see Typical safety data and safety information sources.

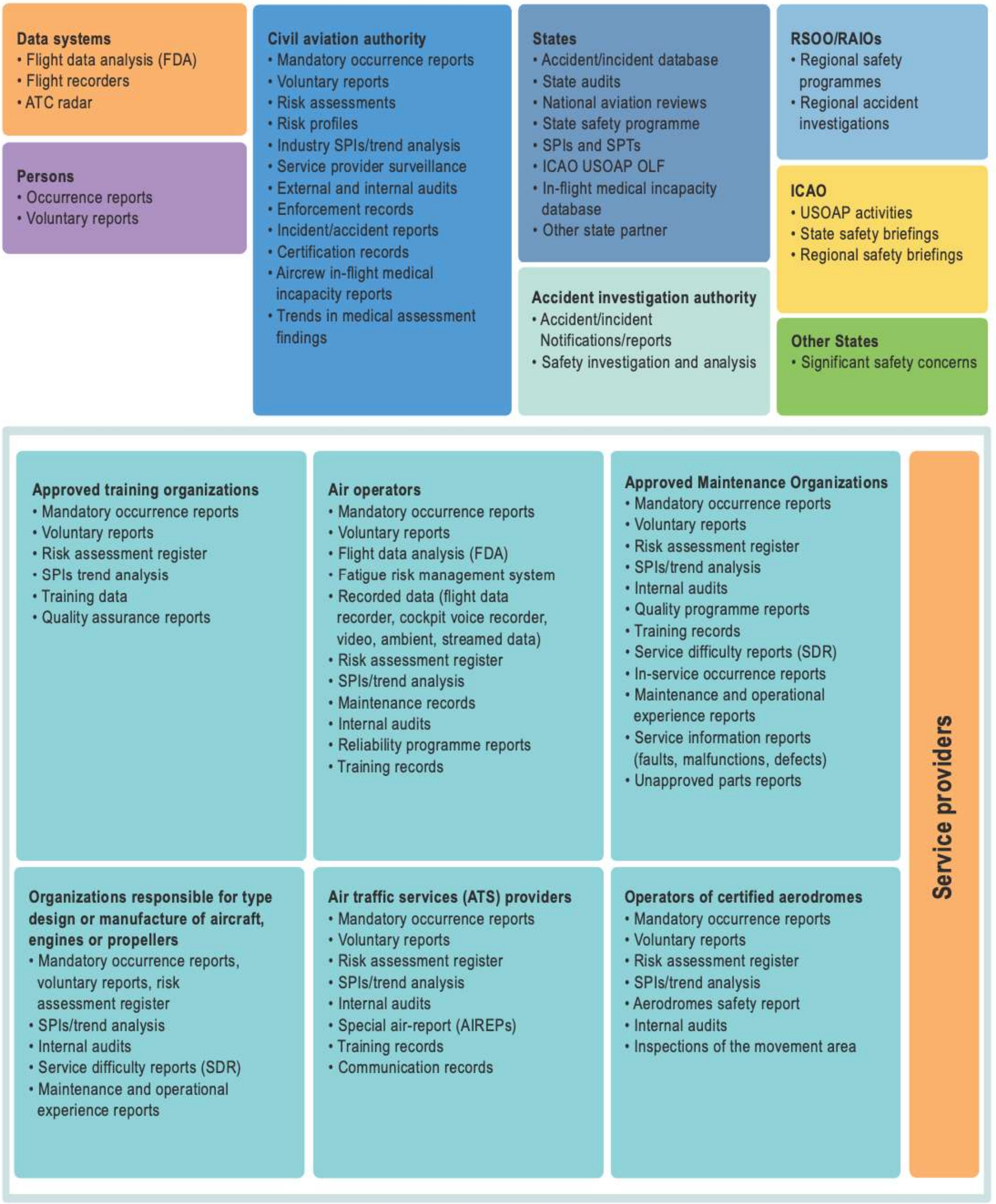

Figure 1: Typical safety data and safety information sources [1]

2.5. Reporting systems

According to Annex 19, member States must establish a mandatory safety reporting system that makes reporting incidents possible. The developed reporting system should be simple to use, meaning simple access, generating, and submitting mandatory reports. Mandatory occurrence reporting (MOR) systems should focus on capturing all the valuable information about an occurrence, including information about what, where, when happened and to whom the report is addressed. The systems should be able to capture some specific hazards known to contribute to accidents, the timely identification and communication of which is considered valuable (for example volcanic activity, routine meteorological conditions, etc.). [1] [11]

Because mandatory occurrence reporting systems tend to collect more technical information (for example hardware failures) than human performance aspects, for a greater range of safety reporting, the implementation of a voluntary occurrence reporting (VOR) system is beneficial. [1]

Reporting of accidents and incidents is relevant to every stakeholder in aviation. It is required from operational personnel to report accidents and certain types of incidents as soon as possible and by the quickest means available to the State's accident investigation authorities (AIA). Serious incidents must be reported. There's a list of examples of incidents that are likely to be serious incidents in Attachment C of Annex 13. [1] [12]

To help with the classification of serious incidents, we can ask the following questions:

1. *"Were these circumstances indicating that there was a high probability of an accident?*
2. *Was the accident avoided only due to providence?"* [1]

If the answer is yes to any of these questions, then the occurrences can be classified as serious and need to be reported. [1]

Because of complexity of aviation system and evolution in aviation safety (including its reporting), there is a need for more specific reporting systems. Examples of these sector-specific reporting systems with its references are provided in Table 1.

Table 1: Examples of sector-specific reporting systems [1]

Reporting System	*Reference*	*For State / Service Provider*	*Year of initial adoption / approval*
Aircraft Accident and incident investigation reporting	Annex 13 — *Aircraft Accident and Incident Investigation*	State	1951
Air traffic incident reporting	PANS-ATM (Doc 4444), *Procedures for Air Navigation Services — Air Traffic Management*	State and service provider	1970
Dangerous goods accident and incident reporting	Annex 18 — *The Safe Transport of Dangerous Goods by Air*	State	1981
Service difficulty reporting	Annex 8 — *Airworthiness of Aircraft*	State	1982
Air traffic incident reporting	Doc 9426, *Air Traffic Services Planning Manual*, Part 2	Service provider	1984
Wild-life/bird strike reporting	Doc 9332, *Manual on the ICAO Bird Strike Information System (IBIS)*	Service provider	1989
	Annex 14 — *Aerodromes*, Volume I — *Aerodrome Design and Operations*	State and service provider	1990
	Doc 9137, *Airport Services Manual*, Part 3 — *Wildlife Control and Reduction*	State and service provider	1991
Laser emission reporting	Doc 9815, *Manual on Laser Emitters and Flight Safety*	State	2003
Fatigue reporting	Annex 6 — *Operation of Aircraft*, Part I — *International Commercial Air Transport — Aeroplanes*	Service provider	2011
	Doc 9966, *Manual for the Oversight of Fatigue Management Approaches*	Service provider	2012
Service difficulty reporting	Doc 9760, *Airworthiness Manual*	State	2014
Aerodrome safety reporting	Doc 9981, *Procedures for Air Navigation Services (PANS) - Aerodromes*	Service provider	2014
Remotely piloted aircraft systems (RPAS)	Doc 10019, *Manual on Remotely Piloted Aircraft Systems (RPAS)*	Service provider	2015
In-flight incapacitation events and medical assessment findings	Annex 1 — *Personnel Licensing*	State	2016
Dangerous goods accident and incident reporting	Doc 9284, *Technical Instructions for the Safe Transport of Dangerous Goods by Air*	State and service provider	2017

2.5.1. Filtering the data

After collecting all the necessary data, they must be processed correctly. Safety data processing is defined by ICAO as "manipulation of safety data to produce meaningful safety information in useful forms such as diagrams, reports, or tables". During the process, there are four important considerations related to safety data processing: data quality, aggregation, fusion, and filtering. [1]

Data quality – relates to data that is clean and fit for purpose. Four aspects are involved in data quality [1]:

a) cleanliness;
b) relevance;
c) timeliness;
d) accuracy and correctness.

Data cleansing is the process of detecting and correcting (possibly removing) corrupted or inaccurate records from a record set, table, or database and refers to identifying incomplete, incorrect, inaccurate, or irrelevant parts of the data and then replacing, modifying, or deleting the dirty or coarse data. [1]

Relevant data is data which meets the organisation's needs and represents their most important issues. An organisation should assess the relevance of data based on its needs and activities. [1]

Data timeliness is a function of its currency. For making the decisions, used data should reflect what is happening as close to real-time as possible. The volatility of the situation often requires judgement. To name an example – data was collected on the same aircraft type and same route, with no significant changes for a period of 2 years. This data may provide a timely reflection of the situation. By contrast- data collected on an aircraft no longer in service and during the past week may not provide a meaningful and timely reflection of the current reality. [1]

Data accuracy refers to values that are correct and reflect the given scenario as described. Data inaccuracy commonly occurs when users enter the wrong value or make a typographical mistake. This problem can be overcome by having skilled and trained data entry personnel or by having components in the application such as spell check. Data values can become inaccurate over time, also known as "data decay". Movement is another cause of inaccurate data. As data is extracted, transformed, and moved from one database to another, it may be altered to some extent, especially if the software is not robust. [1]

2.5.2. Implementation of Safety Management Manual in real life

This ICAO advice was implemented into EASA rules as "Regulation (EU) No 376/2014". To summarize the regulation:

The Regulation aims to improve aviation safety in the European Union (EU) and globally. It ensures that important safety information related to civil aviation is reported, collected, stored, protected, exchanged, disseminated, and analysed. The key points are:

- Mandatory reporting:
  Aviation professionals listed in the regulation must report occurrences that could pose significant risks to aviation safety. These include events related to aircraft operations, technical conditions, air navigation services, and aerodromes.
- Reporting system:
  Each organization in an EU Member State must have mandatory and voluntary reporting systems for collecting, evaluating, processing, analysing, and storing reported occurrences. Small organizations may have a simplified mechanism.
- Storage of safety occurrences and recommendations:
  Member States and the EASA submit collected occurrences to a European central repository managed by the European Commission. This repository also contains safety recommendations from Member States' safety investigation authorities.
- Risk classification:
  There is a common European risk classification scheme that categorizes the overall safety risk of an occurrence based on the likelihood of an accident outcome and the potential for that outcome to occur. This helps entities assess occurrences and prioritize efforts to prevent reoccurrence.
- Exchange of information and access to ECR data:
  Through the European central repository (ECR), EU Member States and the European Economic Area (EEA) countries exchange safety-related information. Access to the ECR data is restricted to authorized parties involved in regulating civil aviation safety or safety investigation authorities within the EU.
- Confidentiality and protection of sources of information:
  Reports must be handled to ensure they are used only for safety purposes. The identity of the reporter and mentioned individuals must remain confidential. A "just culture body" is designated to implement just culture requirements,

promoting fairness, and avoiding prejudice against employees based on occurrence reports. [13]"

2.6. Safety Taxonomy

To be able to work with reported data systematically, it is important to use standardized language. For data to be captured and stored using meaningful terms, it is important to be categorized using taxonomies and supporting definitions. A standard language is established by common taxonomies and definitions improving the quality of communication and information. By sharing a common language, the aviation community's capacity to focus on safety issues is greatly enhanced. Taxonomies enable facilitating information sharing and analysis and exchange. Examples of taxonomies include [1]:

a) Aircraft model: The organisation can build a database with all models certified to operate;
b) Airport: The Organisation may use ICAO or IATA code to identify airports;
c) Type of occurrence: An organisation may use taxonomies developed by ICAO and other international organisations to classify occurrences.

Not to forget an industry's common taxonomies e.g.:

a) Accident/Incident Data Reporting Program (ADREP) taxonomy is a part of ICAO's accident and incident reporting system. It is a compilation of attributes and the related values that allow safety trend analysis on these categories. [1]
b) Harmonisation of European Incident Definitions Initiatives for ATM (HEIDI) taxonomy was created for use by European Organisation for the Safety of Air Navigation (EUROCONTROL). [14]
c) Threats and Errors Management (TEM) taxonomy, primarily developed by safety experts and crewmembers, has a goal of being a more user-friendly taxonomy. Therefore, it is suitable to use by captains for occurrence reporting needs. [14]
d) ECCAIRS taxonomy is the taxonomy currently used for sharing data at European level and beyond. Based on ADREP taxonomy, it is the core of ECCAIRS reporting system. [14]

One of the most important taxonomies are hazard taxonomies. The first step in the risk management process is often the identification of a hazard. Beginning with a commonly recognized language, the safety data are more meaningful, easier to classify and simpler to process. The generic and specific components may be included in the structure of a hazard taxonomy. [1]

To allow users to capture the nature of a hazard with a view to aid in identification, analysis and coding, the generic component is needed. The Commercial Aviation Safety Team/ICAO Common Taxonomy Team (CICTT) has developed a high-level taxonomy of hazards which classifies hazards in families of hazard types (Environmental, Technical, Organisational, and Human). [1]

For adding precision to the hazard definition and context is the specific component. It enables more detailed risk management processing. When naming a hazard, the following criteria may be helpful for formulating hazard definitions [1]:

a) clearly identifiable;
b) described in the desired (controlled) state;
c) identified using accepted names.

Not always are common taxonomies available between databases. In these cases, data mapping ought to be used to allow the standardization of safety data and safety information based on equivalency. For example, an aircraft type, a mapping of the data may show that a "Boeing 787-9" in one database is equivalent to a "789" in another. This may not be a simple process as the level of detail during safety data, and safety information capture may differ. Most safety data collection and processing systems (SDCPS) will be configured to assist with the standardization of data capture for easing the burden of data mapping. [1]

2.7. Limitations of the current state of aviation safety

The current state of aviation safety comes from its historical development. There has been started four different eras that continue to this day. These eras are shown in Figure 4. [1]

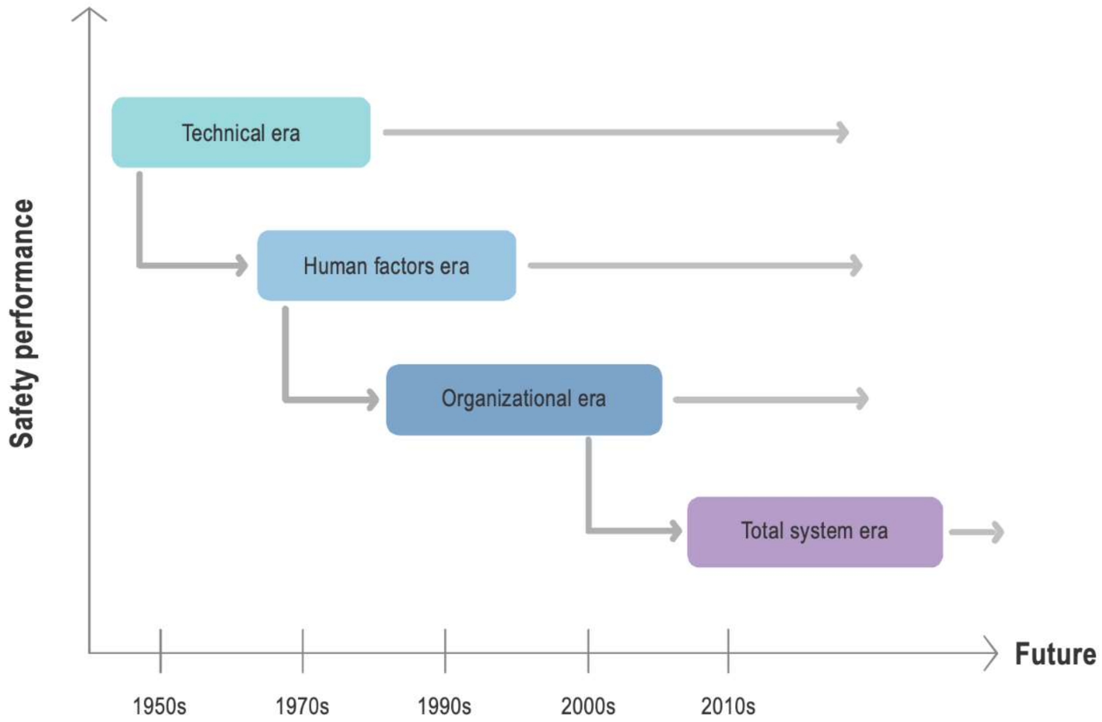

Figure 2: The evolution of safety [1]

1) The technical era – is the era that lasted from the early 1900s until the late 1960s, aviation was quickly gaining publicity and more and more people were discovering the possibility of flying. The first safety deficiencies were initially related to the technical factors of the newest form of mass transportation. Because of these issues, the main focus of the effort was on the investigation and improvement of technical factors. By the 1950s, there was a gradual decline in the frequency of accidents because of technological improvements, and the safety processes were extended to regulatory oversight and compliance. [1]
2) The human factors era – By the early 1970s, the technical advances and enhancements to safety regulations were the reason why the frequency of aviation accidents had significantly declined. Because of this progress, the next main focus was on the human factor, for example, the "man/machine" interface. Regardless of all the invested resources in human error mitigation, the human factor continued to be cited as a recurring factor in accidents. Until the early

1990s, the human factor tended to focus on the individual, without full consideration of organisational and operational context. [1]

3) The organisational era – since the mid-1990s, safety began to be viewed from a systematic perspective and organisational factors, human factors and technical factors were included as well. The "organisational accident" was introduced as a notion, considering the impact of things such as organisational culture and policies on the effectiveness of safety risk controls. In addition, routine safety data collection and analysis using reactive and proactive methodologies made it possible for organisations to monitor known safety risks and detect emerging safety trends. These improvements provided the learning and foundation which lead to the current safety management approach. [1]
4) The total system era – from the early 21st century, many countries and service providers had embraced the safety approaches of the past and evolved to a higher level of safety maturity. The implementation of SSP or Safety Management Systems (SMSs) has begun, and the safety benefits are visible. Unfortunately, the focus of safety systems was largely on individual safety performance and local control, with minimum focus on the wider context of the total aviation system. For these reasons, many accidents and incidents have occurred, showing the interfaces between organisations as a negative contribution. [1]

The constant evolution of safety leads to a point where countries and service providers are seriously considering the interactions and interfaces between the components of the system, i.e., people, processes, and technologies. This was the reason for a greater appreciation for people's role in the system. One of the benefits for safety comes from a collaboration between service providers and between service providers and countries. This perspective leads to many collaborations between service providers for solving safety issues, e.g., ICAO Runway Safety Programme. [1]

For the constant improvement of a collaborative total system approach, the interfaces and interactions between the organisations need to be well understood and managed. In my thesis, I focus on these interactions to make sure there are no emergent properties that cause safety hazards. For doing so, I use STPA analysis to identify these interactions. [1]

2.8. A systemic approach to aviation safety

To be able to understand a systemic approach, we need to understand the System Theory.

For the first time in history, system theory was used (in engineering) after World War II to help deal with the increased complexity of the systems being built. Another purpose of creating this theory was to help understand the complexity of biological systems. For such systems, separation, and analysis of separate, interacting components (subsystems) are the main properties that distort the results for the system as a whole because the component behaviours are coupled in non-obvious ways. The first use of these ideas was in the missile and early warning systems of the 1950s and 1960s. [15]

To name a few unique aspects of System Theory:

- The system cannot be treated as the sum of its part but as a whole. The common describing statement is "the whole is more than the sum of its parts."
- There are "emergent properties" in such a system. These properties are not a summation of individual components, but they "emerge" when the components interact. For treating emergent properties adequately, we need to take into account all their technical and social aspects.
- Emergent properties arise by how components interact and fit together (from relationships among the parts of the system). [15]

The main idea can be illustrated in a following scheme:

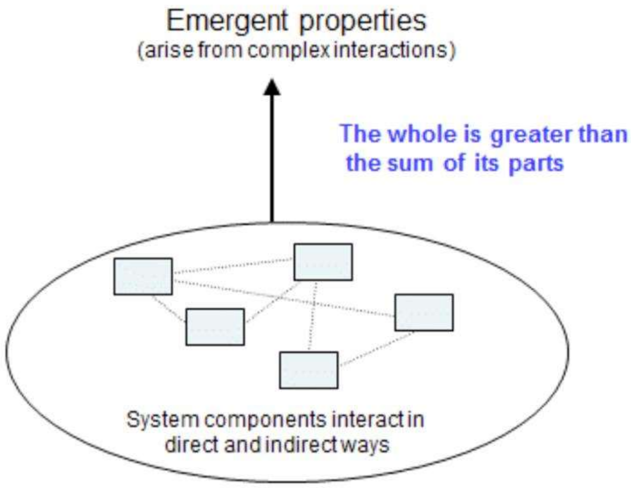

Figure 3: Scheme of emergent properties [15]

Figure 2 illustrates the previously stated aspects. In case emergent properties arise from the interactions among components and from individual component behaviour, then it is logical that controlling emergent properties, such as security, safety, maintainability, and operability, requires controlling the behaviour of the individual components and the interactions among the components. Adding a controller to the figure is important. The controller's purpose is to control actions on the system and get feedback to define the impact of the control actions. This is a standard feedback control loop. [15]

The controller imposes constraints on the behaviour of the system. To name a few safety constraint examples – aircraft must maintain enough lift to remain airborne unless landing, aircraft must remain a minimum distance apart, and toxic substances must never be released from a plane. [15]

By adding the controller into the scheme, we end up with its final version (Figure 3):

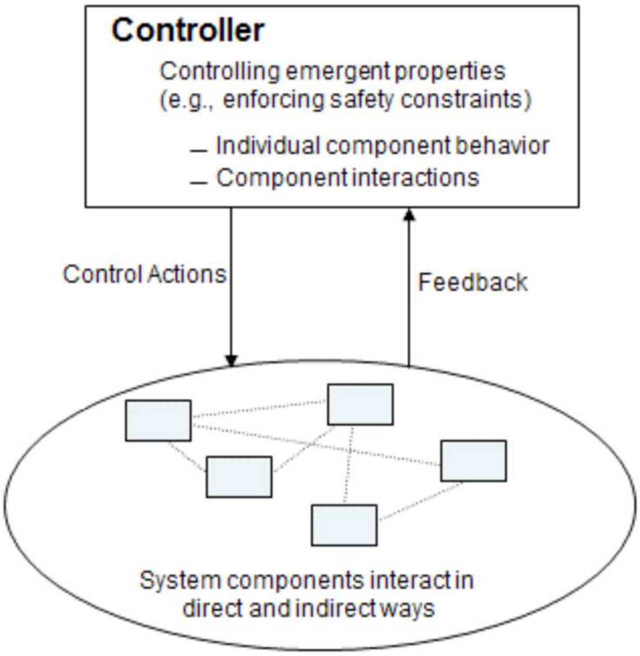

Figure 4: Scheme of emergent properties with controller included [15]

For explaining the model above, let's use a simple example. Consider the international or national airspace. If each airline were allowed to optimize its schedule by flying using any route and at any time, chaos might be the result if everyone tried to land at Heathrow, Chicago, or New York at 5 pm. To avoid such conflicts, there is a need of introducing system-level air traffic control (ATC) to control two emergent properties: safety and throughput. ATC is responsible for maintaining adequate separation among the aircraft and for optimizing the overall throughput in the system. [15]

This model contains everything we do today in safety engineering. Control is interpreted broadly, for example, component failures and unsafe interactions may be controlled through design, such as using barriers, redundancy, interlocks, or fail-safe design. Safety can be also controlled through processes, namely development processes, maintenance processes, manufacturing processes and procedures, and general system operating processes. At last, safety may be controlled using social controls such as government regulation, insurance, culture, law and the courts, or individual self-interest. The behaviour of humans can be partially controlled through the design of the organisational or societal incentive structure. [15]

2.8.1. STAMP

System-Theoretic Accident Model and Processes (STAMP) is the new accident causality model based on previously explained systems theory, which provides the theoretical foundation for STPA. The traditional model of causality beyond a chain of directly related failure events or component failures is expanded to include more complex processes and unsafe interactions among system components. [15]

In this theory, safety is not treated as a failure prevention problem but rather as a dynamic control problem. There are no causes left out from the STAMP model, but more causes are included and the emphasis changes from preventing failures to enforcing constraints on system behaviour. [15]

To name a few advantages of using STAMP [15]:

- STAMP works top-down rather than bottom-up, allowing to work on very complex systems
- There is software, humans, organisations, safety culture, etc. included as causal factors in accidents and other types of losses without having to treat them separately or differently.
- It is possible to develop more powerful tools, such as STPA, accident analysis – Casual Analysis based on System Theory (CAST), identification and management of leading indicators of increasing risk, organisational risk analysis, etc.

It is important to mention that STAMP is not an analysis method, but it is a model or a set of assumptions about how accidents occur. It is an alternative to the classical chain-of-failure-events (or Swiss cheese slices or dominos) that are basis of traditional safety analysis techniques (such as Fault Tree Analysis, Event Tree analysis, etc.). Exactly as traditional analysis methods are constructed on the presumption about why accidents occur in a chain-of-failure-events model, new analysis methods may be constructed using STAMP as a basis. Because the chain-of-failure events model is a subset of STAMP, tools based on STAMP may include as a subset all the outcomes derived using the older safety analysis methods. [15]

There are two most widely used STAMP-based tools, STPA and CAST. STPA is a method of proactively analysing the potential cause of accidents during development so that hazards can be controlled or eliminated where possible. On the other hand, CAST is a retroactive analysis method that examines already occurred accidents/incidents and identifies the causal factors that were involved. [15]

In my thesis, I further continue with STPA only, since I focus on creating a system for an occurrence prevention and STPA is an adequate instrument. STPA can find mistakes in systems during their creations, that could result in occurrences. Also, I focus on STPA because I work with a reporting system. Reporting system needs to be prepared for use-cases of everything that might happen in the future – same as STPA is working with future occurrences. For this reason, I decided to use STPA instead of CAST.

2.8.2. STPA

System-Theoretic Process Analysis (STPA) is still a relatively new hazard analysis technique that was developed based on an extended model of accident causation (STAMP). STPA assumes that accidents can be caused by component failures and by unsafe interactions of system components in addition. [15]

To name a few advantages of STPA compared to the traditional hazard/risk analysis techniques:

- It is possible to analyse very complex systems. With STPA, "unknown unknowns" can be identified early in the development process, and either be eliminated or mitigated, previously these "unknown unknowns" were found only in operations.
- As opposed to the traditional hazard analysis method, STPA is able to be started in early concept analysis to assist with identifying safety requirements and constraints with goal of improving the safety/security of the system architecture and design from the scratch, eliminating the costly rework involved when design flaws are found later in the development.
- There are both human and software operators included in STPA, ensuring including all potential casual factors in losses.
- Documentation of system functionality is often missing or difficult to find in large, complex systems. This documentation is provided by STPA.
- It is easy to integrate STPA into system engineering processes and into model-based system engineering. [15]

Many evaluations compared STPA with traditional hazard analysis methods like event tree analysis or fault tree analysis. STPA identified all causal scenarios from traditional analyses and added one unique scenario[1]. Often the extra STPA scenarios are software-related and non-failure. It must be noted that STPA compared to the traditional methods was much less costly in terms of time and resources. [15]

2.9. Review of scientific literature

During my research of scientific literature dealing with my topic, I found many sources dealing with different elements of my topic separately (focused on STAMP or ECCAIRS, but not their alignment) but just one dealing with my topic as a whole. It is a bachelor thesis written by Johana Martinovská[2], [16] titled as "Alignment of Aviation Safety Taxonomies and Event Types in STAMP", published in year 2022 at Czech Technical University in Prague. This thesis is similar to mine, but I focus on contextual information, not on event types.

My taxonomy source is an ECCAIRS Taxonomy. The last version is on the ECCAIRS website[3].

For gathering knowledge about aviation oversight, my main source is ICAO Doc 9734 – ICAO Safety Oversight Manual[4]. Mainly Part A dedicated to the establishment and management of a State's Safety Oversight System, Second Edition released in 2006.

In the case of Safety data collection and processing systems, my source is ICAO Doc 9859 – ICAO Safety Management Manual[5], Fourth Edition released in the year 2018. [1]

STPA Handbook[6] by Nancy G. Leveson and John P. Thomas was chosen as a source for STPA methodology. The book also introduces a STAMP model with Systems Theory. [15]

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[1] Source:https://dspace.mit.edu/bitstream/handle/1721.1/114753/AHS-final.pdf?sequence=1&isAllowed=y
[2] Source:https://dspace.cvut.cz/bitstream/handle/10467/103830/F6-BP-2022-Martinovska-Johana-BP%20-%20Martinovska.pdf?sequence=-1&isAllowed=y
[3] Source: https://aviationreporting.eu/en/taxonomy-browser
[4] Source: https://www.icao.int/WACAF/AFIRAN08_Doc/9734_parta_cons_en.pdf
[5] Source: https://www.skybrary.aero/sites/default/files/bookshelf/5863.pdf
[6] Source: http://psas.scripts.mit.edu/home/get_file.php?name=STPA_handbook.pdf

3. Methodology

The goal of my bachelor's thesis is to create a conversion system for linking aviation taxonomies and contextual information in the STAMP model, which can be used to represent the control structure and its parts. From ECCAIRS Taxonomy, the entities have been chosen for further development of my thesis because certain entities with their attributes and values can be considered as contextual information.

To make it possible to connect ECCAIRS taxonomy (contextual information) with STPA analysis, we need to define the right terms from STPA. To do so, the STPA Handbook [15] is very useful.

3.1. STPA Analysis

To do so, it is necessary to understand what the STAMP model is and how to make an STPA analysis. This knowledge comes from STPA Handbook. STPA analysis comes in 4 steps [15]:

1) Defining the purpose of the analysis
2) Modelling the control structure
3) Identifying Unsafe Control Actions
4) Identifying loss scenarios

3.1.1. Defining the purpose of the analysis

The first step can be further divided into four parts [15]:

1. Identifying losses
2. Identifying system-level hazards
3. Identifying system-level constraints
4. Refining hazards (optional part)

Under the term "loss", we can understand, for example loss of human life or human injury, property damage, environmental pollution, loss of mission, loss of reputation, loss or leak of sensitive information or any other loss that is unacceptable to the stakeholders.[15]

After identifying losses, identifying of system-level hazards follows.

"There are three basic criteria for defining system-level hazards:

- *Hazards are system states or conditions (not component-level causes or environmental states)*
- *Hazards will lead to a loss in some worst-case environment*
- *Hazards must describe states or conditions to be prevented* [15]"

To do so, the determination of what is a system and what are its boundaries is needed. Most frequently, the parts that system designers have some control of, are included in the system and the rest are considered to be environment. This distinguishment is important because losses may involve aspects of environment. An example is when a nuclear power plant releases water vapor into the air. The power plant cannot control the direction of the wind but can control when to release. Other examples of system-level hazards might be when UAV does not complete surveillance mission or Satellite is unable to collect scientific data. [15]

System-level constraints:

The last mandatory part of the first step is to identify system-level constraints. A system-level constraint means there are certain conditions or behaviours the system must meet to avoid dangers and prevent any losses. Each constraint must be traceable to one or more hazards, and every hazard is traceable to one or more losses. Constraints may also define how the system must minimize losses in case of hazard occurrence. Examples can be Redundancy of components or units or Frequent maintenance. [15]

3.1.2. Modelling the Control Structure

The second step of STPA analysis is Modelling the Control Structure. Control Structure is a hierarchical "top-down" system made up of connected feedback control loops. A good Control Structure makes sure the whole system behaves the way it's supposed to. The controller oversees the process it's in charge of by taking control actions and getting information back (feedback) about how things are going. The downward arrows represent control actions, and the upward arrows represent feedback. An example of how such a Control Structure looks like is shown in a Figure 10 that follows. [15]

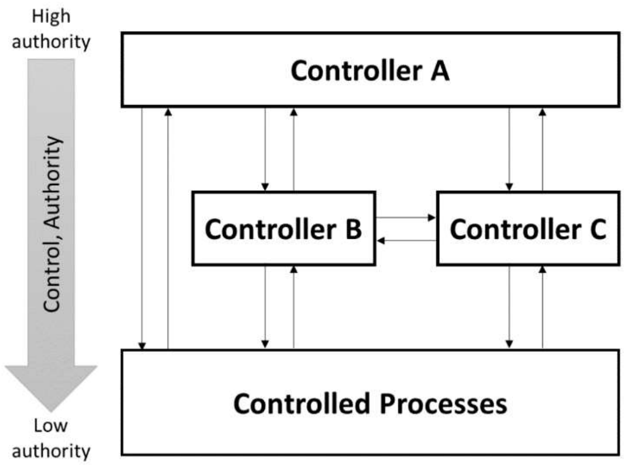

Figure 5 Example of Control Structure [15]

3.1.3. Identifying Unsafe Control Actions

Identifying Unsafe Control Actions is step 3 of the STPA analysis. The Unsafe Control Action is a control action that can become a hazard in very specific cases. For finding such cases, a table is made to identify the potential unsafe control actions.

The table consists of all the control actions (CAs) from previous step. These CAs are then modified to find a way, how they can lead to hazard/contribute to creation of incident or accident. This step changes control actions into Unsafe Control Actions (UCAs).

To make this change, there are 4 possibilities how to make UCAs from CA [15]:

1) By not providing control action resulting in a hazard
2) By (incorrectly) providing control action resulting in a hazard
3) By providing control action too early, too late, or out of order resulting in a hazard
4) When stopped too soon or applied for too long while providing control action

UCAs consist of five parts [15]:

1) Source – the source of the control action
2) Type – one of the four types of unsafe control action (provided, not provided, providing too early/late/out of order, providing stopped too soon/applied for too long)
3) Control Action – the control action or command by itself

4) Context – information usually using “when”, “while” or “during” that describes the situation when control action is transforming into unsafe control action
5) Link to Hazard – connects the unsafe control action with its related hazard or hazards

The example case follows.

Air Traffic Controller's	instructions	given	too late for safe operating	[H-1]
<Source>	<Type>	<Control Action>	<Context>	<Link to Hazard>

3.1.4. Identifying loss scenarios

"*Definition: A loss scenario describes the causal factors that can lead to the unsafe control actions and to hazards.* [15]"

Loss scenario of two types must be considered [15]:

a) *“Why would Unsafe Control Actions occur?*
b) *Why would control actions be improperly executed or not executed, leading to hazards?”*

For my thesis, this step is not necessary because it is based on already mentioned unsafe control actions and hazards, further not expanding my contextual information vocabulary.

3.1.5. Analysis of the first occurrence

To do the analysis, I gained the data from Air Accidents Investigation Branch reports from the United Kingdom. I worked with three different reports, because real occurrence data are important for having a real-life examples of interactions between entities and the actual procedures. This provides an insight into today's aviation. Whole analysis has been performed on the first occurrence. Other two occurrences, because of gained experience from the previous accident, were just used in terms of a source of information for modelling the control structures (Figures 6 and 7). The first example is the accident from London Heathrow Airport that happened on 26 February 2019 at 2302 hours (UTC). For a quick introduction of the accident, the synopsis will serve its purpose: *„The aircraft's take-off clearance was cancelled because a maintenance vehicle that had been manoeuvring on an adjacent taxiway entered the runway. The vehicle driver had become disorientated."* [17]

The first step (identifying losses, identifying system-level hazards, and Identifying system-level constraints) performed in a following way:

Losses:

[L-1] Environmental loss

[L-2] Loss of customer satisfaction

[L-3] Loss of mission

[L-4] Loss of or damage to a vehicle

[L-5] Loss of life or injury to people

System-level hazards:

[H-1] Aircraft violate minimum separation standards on the ground [L-2]

[H-2] Aircraft airframe integrity is lost [L-1, L-2, L-3, L-4, L-5]

System-level constraints:

[SC-1] Aircraft must satisfy minimum separation standards from other aircraft and objects [H-1]

[SC-2] Aircraft airframe integrity must be maintained under worst-case conditions [H-2]

After the first step was finished, I continued with the second step – modelling the Control Structure. By taking the essential entities from the report, the control structure was created (Figure 5).

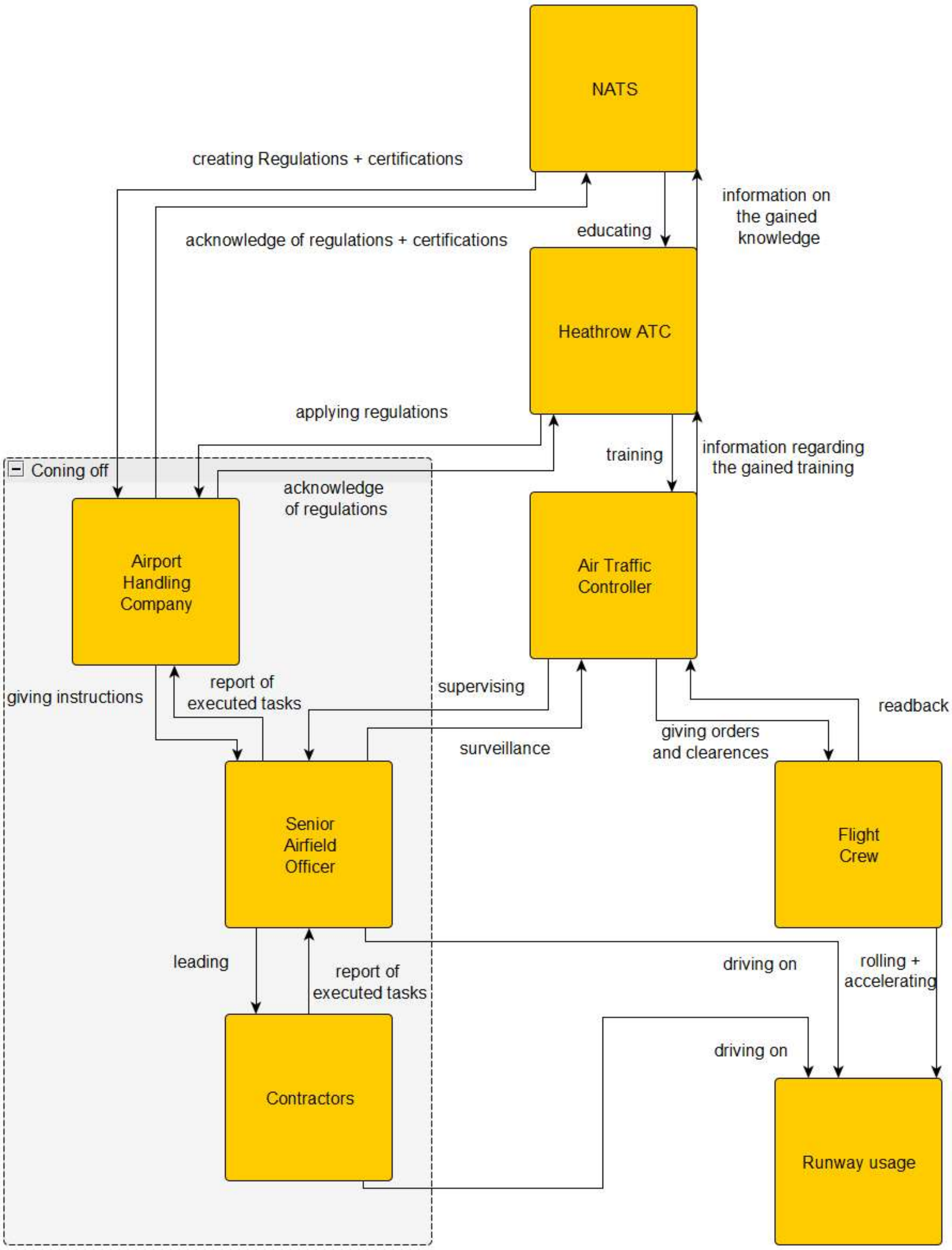

Figure 6: Control Structure of Occurrence 1

In the Figure 5, the highest-level controller in this incident is NATS (National Air Traffic Services). This organisation provides air traffic control services to aircraft flying inside UK airspace and these services are provided at 15 UK's biggest airports too. In my case it is educating Heathrow ATC, and the feedback is information on the gained knowledge. The second connection of NATS is with the Airport Handling Company. The control action is creating regulations + certifications, and the feedback is acknowledgement of regulation + certifications.

The second highest-level controller is Heathrow ATC. It is the entity that represents department of Air Traffic Controllers. Because of this relation, it provides training (control action), so the Air Traffic Controller's feedback is information regarding the gained training. Heathrow ATC is also connected with Airport Handling Company, by applying regulations (control action) and as feedback is acknowledgement of regulations by Airport Handling Company.

The next entity is already mentioned as Air Traffic Controller. Its job is to interact with Flight Crew by giving orders and clearances that Flight Crew has to readback. The other connection is with Senior Airfield Officer. Air Traffic Controller is supervising its work and movements on the ground. As feedback is a surveillance.

Airport Handing Company relates to Senior Airfield Officer. The company gives instructions (control action), and the Senior Airfield Officer reports Completed tasks (feedback) – based on the instructions.

Senior Airfield Officer is leading (control action), and Contractors' feedback is report of executed tasks.

The Contractors and Senior Airfield Officer are driving on the (control action) entity Runway. There isn't any feedback needed.

Flight Crew relates to Runway. Flight Crew executes Rolling + accelerating on the Runway (control action).

After modelling the control structure was finished, I continued with the step 3 of the STPA analysis – identifying Unsafe Control Actions. The Unsafe Control Action is a control action (from Figure 5) that can become a hazard in very specific cases. For finding such cases, the table (Table 2) was made to identify the potential unsafe control actions.

Table 2: Unsafe Control Actions

Control action	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopped too soon, applied too long
creating regulations + certifications	CAA does not provide any created regulations and certifications for safe operations	CAA creates regulations and certifications not usable for daily operations	CAA created regulations and certifications too late to be effective when expected	CAA regulations and certifications stopped too soon to be completed
educating	CAA does not educate Heathrow ATC for emergency situations	CAA is educating with outdated procedures	CAA educates too late for Heathrow ATC to be able to have appropriate procedures	CAA educating is stopped too soon for complete training
applying regulations	Heathrow ATC not applying regulations regarding safety [H-1]	Heathrow ATC is applying outdated procedures	Heathrow ATC applying regulations too late for optimal operations	Heathrow ATC applying regulations for too long leading to postponements
training	Heathrow ATC does not train Air Traffic Controllers for unexpected scenarios	Heathrow ATC is training Air Traffic Controllers with outdated procedures [H-1]	Heathrow ATC trains Air Traffic Controllers too late to operate effectively	Heathrow ATC training of Air Traffic Controllers stopped too soon to be fully completed [H-1,H-2]
giving orders and clearences	Air Traffic Controller is not giving orders and clearances for optimal traffic flow [H-1,H-2]	Air Traffic Controller is giving incorrect orders and clearances [H-1,H-2]	Air Traffic Controller giving orders and clearances too early for safe operations [H-1]	Air Traffic Controller stopped giving orders and clearances too soon for safe operations [H-1,H-2]
supervising	Air Traffic Controller not supervising to have situation awareness [H-1]	Air Traffic Controller supervising without knowledge of valid regulations	Air Traffic Controller supervising too late to have real-time data [H-1]	Air Traffic Controller supervising stopped too soon to be aware if actions were completely performed [H-1]
leading	Senior Airfield Officer does not provide leading for contractors to be coordintated [H-1]	Senior Airfield Officer is leading in a wrong way [H-1]	Senior Airfield Officer leading provided too late to be performed on-time	Senior Airfield Officer leading stopped too soon to be completed
giving instructions	Airport Handling Company is not giving instructions to perform tasks	Airport Handling Company giving instructions for a different task	Airport Handling Company is giving instructions too late to be coordinated	Airport Handling Company stopped giving instructions too soon to completely understand the task
driving on	Contractors are not driving on Runway at approved time	Contractors are driving on Runway without permission	Contractors driving on Runway too early to be safe	Contractors stopped driving on Runway too soon for safe operations
rolling + accelerating	Flight Crew not rolling + accelerating on Runway while being on the RWY	Flight Crew rolling + accelerating on Runway without being cleared to	Flight Crew rolling + accelerating on Runway too early for their clearance to be valid	Flight Crew rolling + accelerating on Runway for too long to stay on it

This table (Table 2) contains all the control actions (CAs) from previous step. These CAs are then modified to find a way, how they can lead to hazard/contribute to creation of incident or accident. This step changes control actions into Unsafe Control Actions (UCAs).

3.1.6. Analysis of the second occurrence

The second accident happened at London Gatwick Airport on 12 August 2019. Boeing 787 was parked on a stand with specific push back procedure because of the stand's limited clearance from the blast screens. This aircraft was pushed back using incorrect line resulting in the aircraft tail cone struck into the blast screen. [18]

The result of investigation is that the Headset operator did not check the clearance between objects and the aircraft. [18]

Since my thesis is focused on contextual information, I will continue just by creating control structure of the occurrence (Figure 6), because it provides all the necessary information for achieving the goal of my thesis (control structure provides objects and relationships between them).

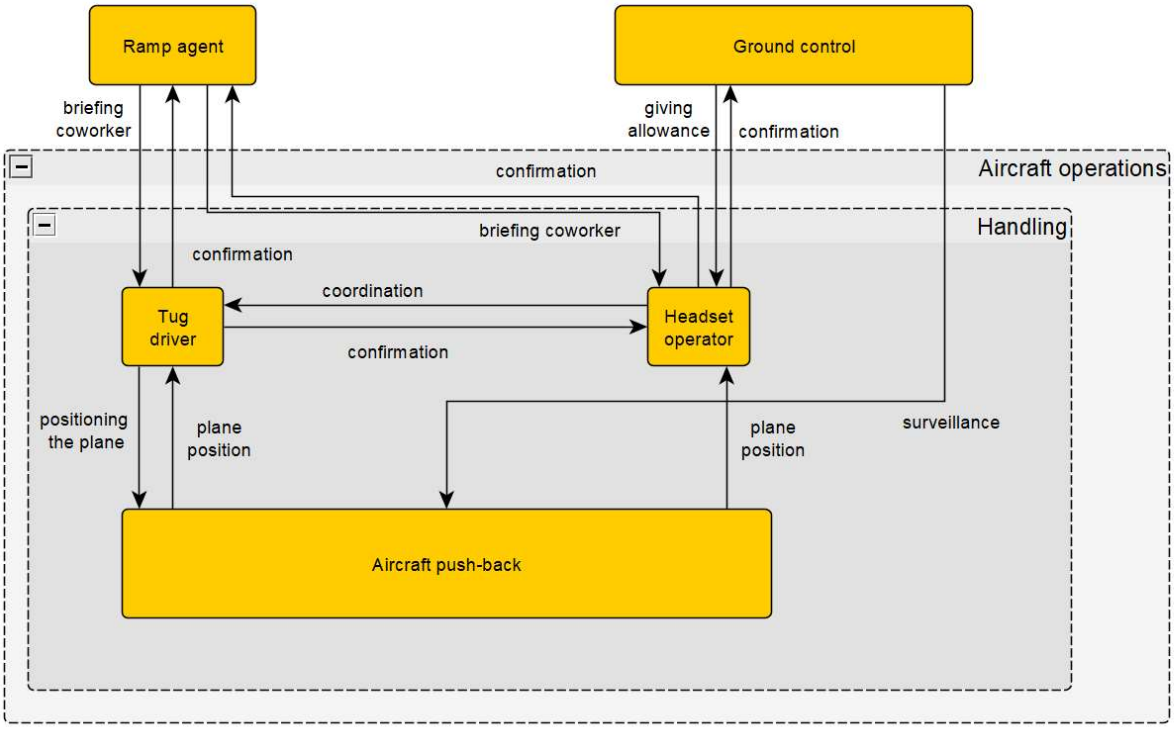

Figure 7: Control Structure of Occurrence 2

3.1.7. Analysis of the third occurrence

The third occurrence is classified as serious incident by AAIB. The Boeing 747-8F was transporting a helicopter. The helicopter had fuel in its fuel cells and during the transport, the fuel was leaking. The leak was noticed by a ground operations agent during an intermediate stop at Prestwick International Airport, UK on 30th March 2017 (UTC). [19]

The investigation found out that the mistake was made by the handling company that did not prepare the helicopter for transportation properly. The control structure of Occurrence 3 is shown in the picture below (Figure 7).

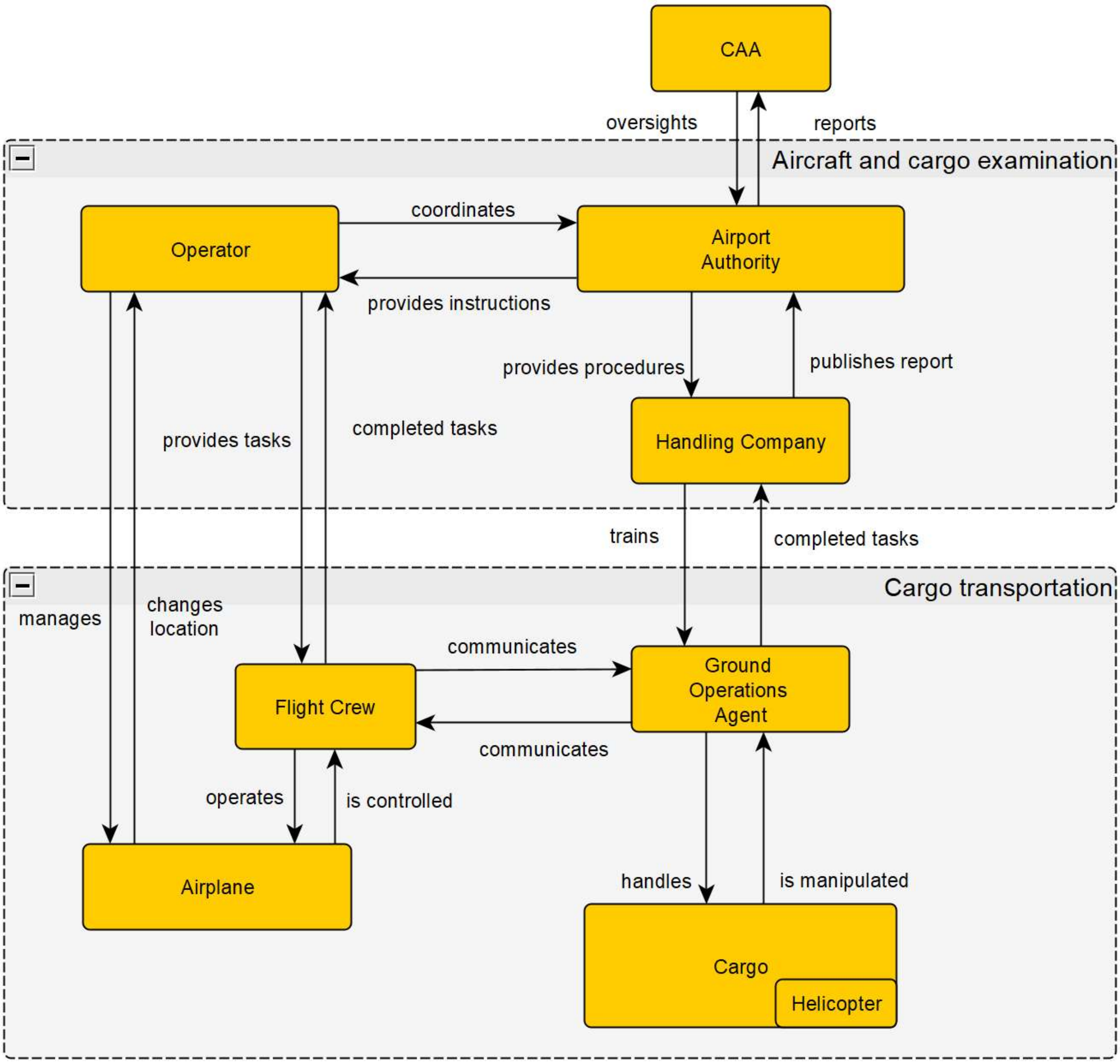

Figure 8: Control Structure of Occurrence 3

3.2. Processing the ECCAIRS

My source of safety taxonomy is an ECCAIRS Taxonomy Browser. It is based on ICAO ADREP Taxonomy. This taxonomy is currently used in Europe for unified occurrence reporting. Because its history, the source of origin is a set of definitions and descriptions used during the gathering and reporting of accidents/incidents to ICAO. This taxonomy is used in ECCAIRS Reporting Form. All the drop-down lists consist of values from ECCAIRS Taxonomy and the labels next to the cells are their related attributes. Figure 8 shows how does the ECCAIRS Reporting Form looks like.

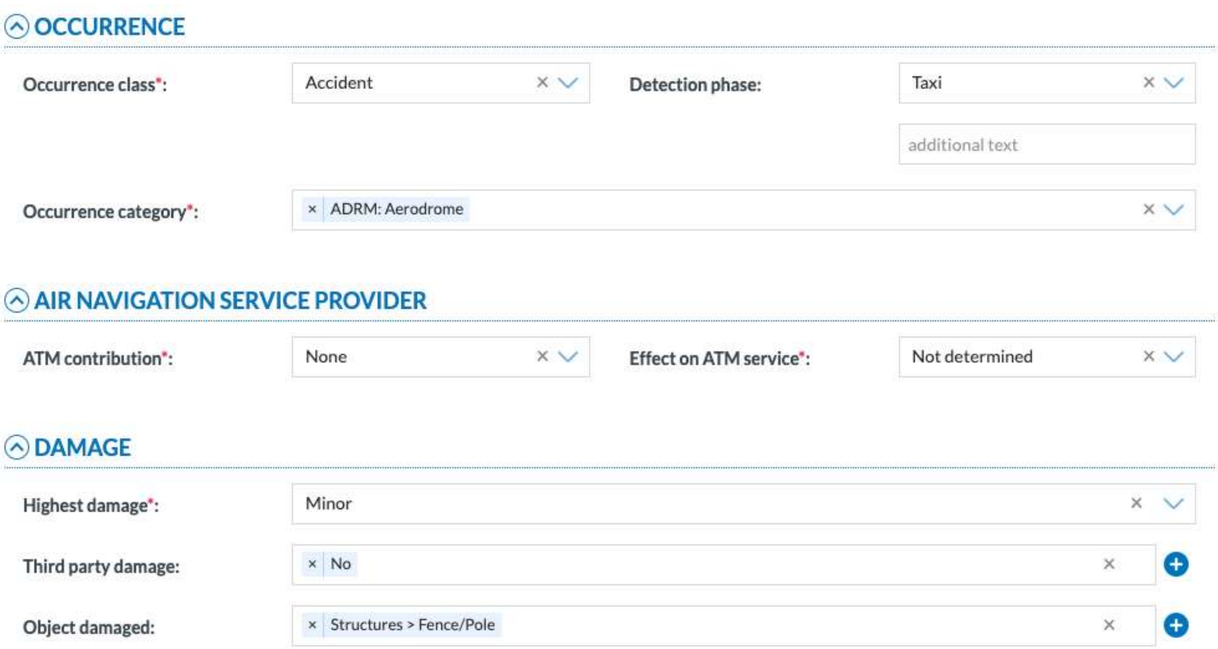

Figure 9: Example of ECCAIRS Reporting Form

Currently, the ECCAIRS Taxonomy is divided into a 3-level system. The top level is represented by entities. In this moment (ECCAIRS Taxonomy version 5.1.1.2), there are 53 entities in total. These entities can further include own structure, represented by Parent and Child entities. For example, entity Runway has 3 Parent Entities (Aerodrome General, Aircraft, Runway Incursion) but on the other hand, entity "Occurrence" has no Parent Entity (or Entities). During doing my work inside the ECCAIRS taxonomy, I have discovered an interesting example of a structure within Entities only (Figure 9). It is the longest Entity-only structure that I found during working on my thesis.

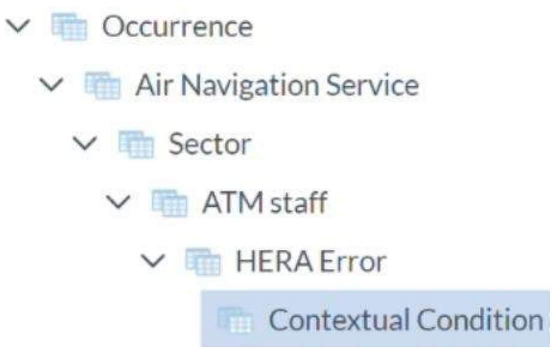

Figure 10: Structure of Entities

Also, it is worth noting where it is possible to find entities in ECCAIRS Reporting Form (Figure 10).

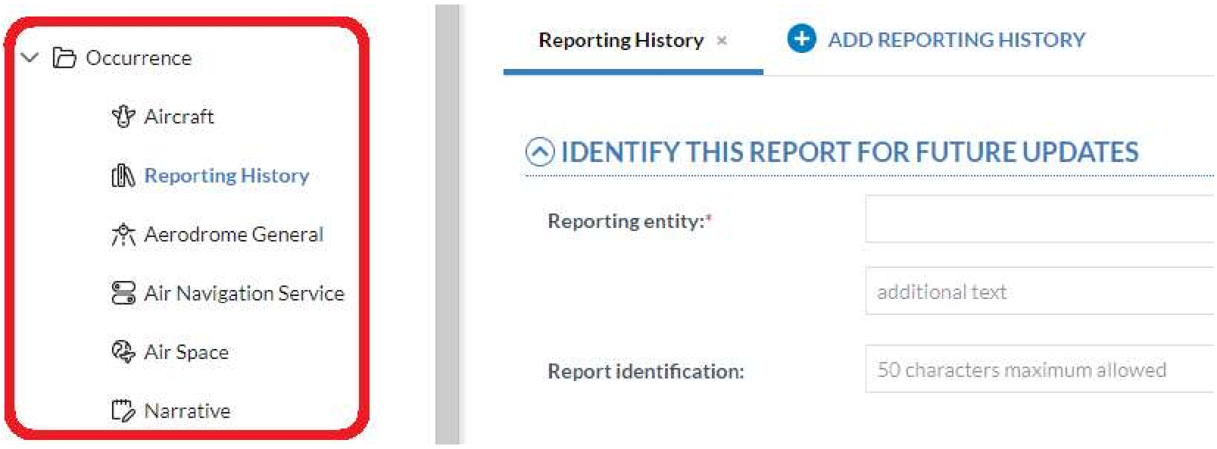

Figure 11: Entities in Reporting Form

The second level consists of Attributes. These Attributes further describe their Entity. For example, under the Entity "Engine" there are Attributes "Manufacturer/model"," Engine cycles" or "Date of inspection" to name a few. Position of attributes in ECCAIRS Reporting Form is showed in the figure bellow (Figure 11).

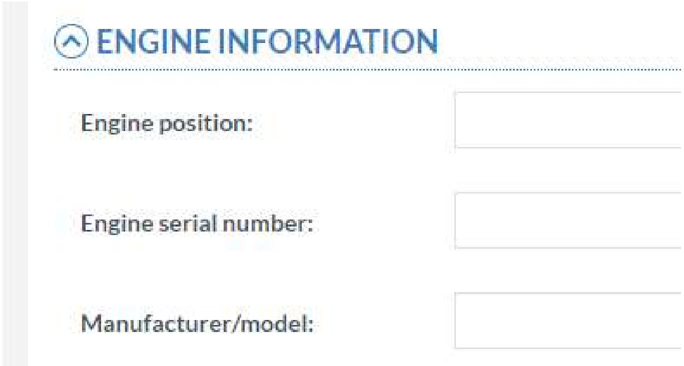

Figure 12: Attributes of Engine Entity

The third level of ECCAIRS Taxonomy structure is based on Values. This information describes attributes specifically for each reported occurrence. Attribute can be described by Manual Entry Value, or a value chosen from Value List. Example of an attribute with manual entry value is attribute "Engine position", where user can type engine's position. Attribute with dedicated value list is attribute "Manufacturer/model". Demo of exact value list is shown below (Figure 12).

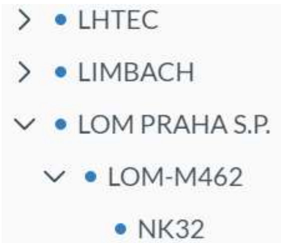

Figure 13: Example of Value List

It is important to point out the fact that user of ECCAIRS Taxonomy Form that is reporting an occurrence is working with values of attributes that are grouped into entities that describe what kind of information it is (related to what topic – aircraft, aerodrome, etc.). This is the way how a specific occurrence is described in a report.

For making the work with ECCAIRS more systematic, it is possible to download the latest version of ECCAIRS Taxonomy in an XML format file from the Aviation Reporting website[7]. The other option is to download ECCAIRS Taxonomy in CSV/XSD format, but

[7] https://e2.aviationreporting.eu/taxonomy

unfortunately this solution is not very user-friendly for my type of usage since the taxonomy is separated into many different CSV files.

However, ECCAIRS Taxonomy is not fully utilised in ECCAIRS Reporting Form. The part of the taxonomy used in Reporting Form is called RIT – Reduced Interface Taxonomy. This subset of the taxonomy was created based on mandatory data field (defined by EU Legislation) extended by so-called essential data fields. Currently RIT contains around 280 data fields. [20]

4. Suggestion of Alignment of Aviation Safety Taxonomies and Contextual Information in STAMP

The outcome of my research comes from the mentioned STPA analysis of occurrences and ECCAIRS Taxonomy. It is necessary to understand mentioned topics to be able to make meaningful alignment between them.

Firstly, the data samples from the reports provide valuable information about what subjects are involved directly in the occurrences. Also, the reports provide valuable description of relationships between these subjects, thus making the control structures based on real situations.

The final table (Appendix 1) is based on these control structures data after finding a relevant counterpart in ECCAIRS Taxonomy.

4.1. Creation of data samples based on STPA and ECCAIRS and their conversion

As was previously stated, the 3 events were chosen from Air Accidents Investigation Branch (AAIB) reports from the UK. All the occurrences were chosen with intention to fulfil the spectre of reported objects as much as possible.

First, the focus was on finding counterparts of objects from control structures using ECCAIRS Taxonomy entities only.

Table 3: Entities

Report 1	STPA classification	ECCAIRS
NATS	Controller	n/a
Heathrow ATC	Controller	ATM staff
Airport Handling Company	Controller	Ground Handling
Air Traffic Controller	Controller	ATM staff
Senior Airfield Officer	Controller	Ground Handling
Contractors	Controller	Ground Handling
Flight Crew	Controller	Flight Crew Member
Runway	Subsystem	Runway

In Table 3 we can see that the data from Control structure (Figure 5) are paired with their ECCAIRS Taxonomy counterparts, unfortunately already after the first occurrence's alignment, it was visible, that this output is not usable in real life. Because of this reason, my next step was to focus one level below – on attributes.

After a brief look at attributes, I have discovered that I need to focus primarily on values to see, where exactly are the counterparts I am looking for. The objects identical or similar to the ones in my control structures, are hidden in values.

Initial step was to extract all the data from created Control structures into an excel table, so it would be more convenient for me to work with them and easier align the counterparts. A part of this table is shown as Table 4, that follows.

Table 4: Terms from Occurrence 1

Occurrence 1	Terms from Control Structure
	NATS
	Creating regulations + certifications
	Educating
	Heathrow ATC
	Knowledge
	Training
	Applying regulations
	Air Traffic Controller
	Improved performance
	Supervising
	Giving orders and clearances

After extracting all the data, I had to find their counterparts. For this reason, I tried to insert these terms into ECCAIRS Reporting Form and from this form I would clearly see the right attributes and entities that these terms are associated with. This method proved my assumption that not all terms I am looking for are included in RIT. For this reason, I had to download whole ECCAIRS Terminology. I preferred to use the XML version of the taxonomy, because it is just one file that contains all the data, I needed to achieve the goal of this thesis.

Other difficulty that had to be dealt with was the fact that ECCAIRS Taxonomy is not always offering the right terms for my use-cases. To name an example, from Control structure in Occurrence 1 was taken the term "Leading". The closest ECCAIRS Taxonomy counterpart I could find was "Supervision". After checking the explanation of this term, it was explained just like "Supervision". However, this value is under the Entity HERA Error, so the alignment is not perfect, but still very accurate and the closest term from all the ECCAIRS Taxonomy I have found.

In worse cases, I was not able to align any counterpart with a term from occurrence's control structure. This happened in 5 cases from all the occurrences. An example is a term "Runway usage" that represents usage of runway as a controlled process.

A specific case happened while searching for correct counterpart for a term "Flight Crew". In this case, I have chosen a whole entity "Flight Crew Member" as a counterpart. This happened because there wasn't a better counterpart within the taxonomy. Also, there isn't a counterpart describing Flight Crew as a whole occupation of a cockpit.

A sample of alignment of Occurrence 1 follows in the Table 5. Complete alignment based on all occurrences is to be found in Appendix 1.

The Appendix 2 contains data from all 3 occurrences separated into 2 lists – list of Objects and a list of Relationships. Objects represent controllers and controlled processes in STPA's terminology and Relationships represent control actions and feedbacks in STPA's terminology.

Table 5: Sample from Occurrence 1

Terms from Control Structure	Entity	Attribute	Value	Explanation
NATS	Reporting entity	Reporting Entity	NATS	United Kingdom (NATS)
Creating regulations + certifications	Explanatory Factor	Expl factor subject	Certification	The interface between humans in relation to certification standards
	Explanatory Factor	Expl factor subject	Human interface-regulations	The interface between humans in relation to regulations
Educating	Explanatory Factor	Expl factor subject	Training in progress	Examination, check or training in progress
Heathrow ATC	Aerodrome General	Location indicator	EGLL (LHR) : London/Heathrow	EGLL (LHR) : London/Heathrow
Knowledge	Explanatory Factor	Expl factor subject	Regulatory requirements	Factors related to the knowledge of regulatory requirements.
Training	HERA Error	Task list	Training	Training
Applying regulations	Explanatory Factor	Expl factor subject	Regulatory requirements	Factors related to the knowledge of regulatory requirements.
Air Traffic Controller	ATM staff	Category	Executive controller	The category of the air traffic management person was executive controller.
Improved performance	Events	Event Type	Knowledge Events	Events involving the knowledge of an individual or a crew/team collectively
Supervising	HERA Error	Task list	Supervision	Supervision

5. Validation

To validate the result of my thesis properly, I have chosen 3 occurrences different from the ones used to create the conversion table.

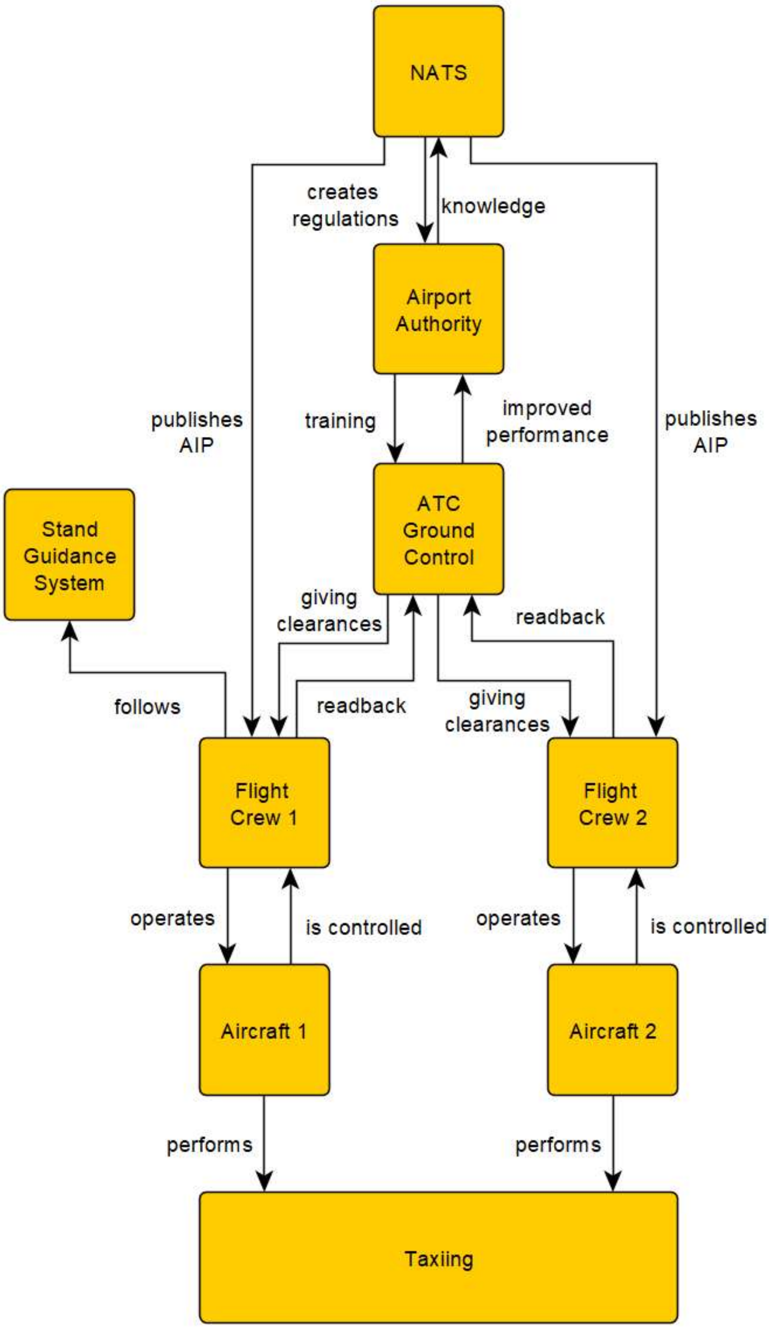

Figure 14: Control Structure Validation 1

The first validation occurrence happened on 28th September 2022 at 18:50 at London Heathrow Airport. After a Boeing 757 (Aircraft 1) landed on the aerodrome, it taxied to a parking stand where a Stand Guidance System was not turned on. Because of this issue, the aircraft stopped approximately 20 meters from the final parking position. Because of these 20 meters, taxiing Boeing 777-300(ER) (Aircraft 2) collided with a tail section of the aircraft (Aircraft 1). A model of control structure (Figure 13) was made based on this information.[21]

The second validation occurrence happened on 21st September 2018 at 17:35 after take-off from Edinburgh Airport. After the aircraft gained altitude of 17 000 ft, the Cabin Pressure warning illuminated, and an audio warning sounded. The flight crew performed all the tasks from Quick Reference Handbook designated for situations like this. After descending to altitude 10 000 ft, the flight crew contacted operations department of the operator and informed about the situation. Operations department based on Minimum Equipment List approved the suggestion to continue the flight to destination. Based on this information, the control structure was made (Figure 14). [22]

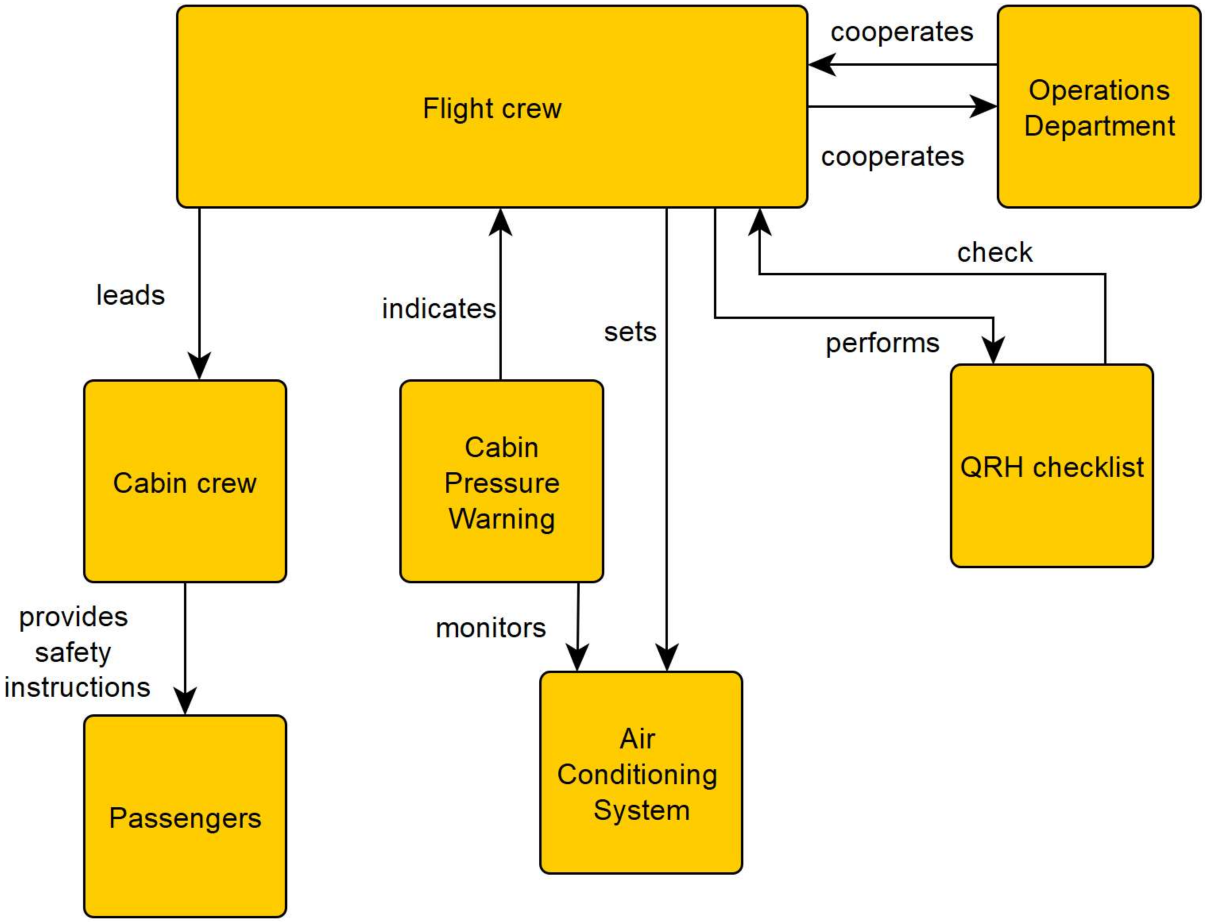

Figure 15: Control Structure Validation 2

The third occurrence is an accident that happened on 25th July 2022 at 13:00 at St Albans. This occurrence is a very different one compared to the other occurrences mentioned throughout the thesis. This accident involves a drone as the only involved aircraft. I chose this specific occurrence to show how aviation is a fast-paced field, that today we are already investigating drone occurrences in a detail. The drone type is Sky Mantis manufactured by a company called Evolve Dynamics. What happened is that the drone lost electrical power and because of this it fell from the sky (approximately 20 meters). The loss of electrical power was caused by separation of electrical connections because of thermal damage. During modelling of the control structure, I have realized that in current state of ECCAIRS Taxonomy and ECCAIRS Reporting Form, just a very few objects from the control structure would find an equivalent counterpart. During my research, I discovered that the manufacturer of involved drone is currently not included in ECCAIRS Taxonomy. Because of missing support of drone reporting, modelling the relationships would be pointless since there is currently no counterpart related to utilization with drones. The objects of control structure are showed in following table (Table 6). [23]

Table 6: Objects from Validation occurrence 3

Motor	Batteries	Electronic Speed Controller
Main Camera Board	Downward Ultrasonic Obstacle Avoidance Sensor	Propeller
Battery Connectors	3 Axis Gimbal	Power Port Module
Obstacle Avoidance Sensors	Flight Controller	GPS Module
Camera	Antennas	Flight LED

5.1. Reporting validation occurrences in ECCAIRS Reporting Form

To find the right counterparts, ECCAIRS Reporting Forms were filled in with the information from occurrence reports. After the term (from control structure) was found in the conversion table, the Reporting Forms were filled out. The outcome of this way of validation is about how much information from control structures is possible to be reported. The second outcome is based on tracing the inserted data. Based on their position, it should be the same like in the excel file Appendix 1. From validation control structure 1 I have extracted data showed in Table 7. Items written in bold letters are Objects and those that aren't, are relationships between them.

Table 7: Terms of Control Structure Validation 1

Terms from Control Structure
NATS
Creates regulations
publishes AIP
Airport Authority
training
knowledge
ATC Ground Control
improved performance
giving clearances
Stand Guidance System
Flight Crew
follows
operates
readback
Aircraft
is controlled
performs
Taxiing

Starting with NATS, while trying to input NATS into ECCAIRS Reporting Form, the only possibility for me to input this information is to insert it into "Reporting Entity" data field

(Figure 16).

Figure 16: NATS data field

Because this value (NATS) is inserted into "Reporting entity" data field, it indicates the attribute where this value is – Reporting entity attribute. Utilization of ECCAIRS Taxonomy browser is needed for finding the right entity of this attribute. This can be done in two ways. First option is to manually search in the browser by opening all the entities until the attribute is found. This option is very time consuming and prone to human error. The second option is to use a search box in the top left corner of the browser.

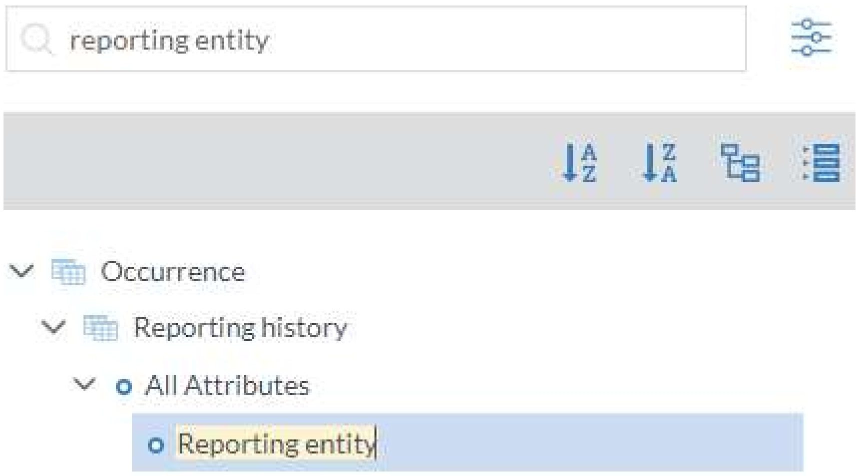

Figure 17: Utilization of a search box

In Figure 17 it is shown that the only entity that attribute "Reporting entity" is connected to is "Reporting history". Now it is possible to assemble a path, how it is possible to find "NATS" in ECCAIRS Taxonomy.

Table 8: ECCAIRS Reporting Form path of "NATS" term

Term from Control Structure	Entity	Attribute	Value
NATS	Reporting history	Reporting entity	NATS

In Table 8 the path of NATS is shown. The term "NATS" is also to be found in Appendix 2. The paths are the same, meaning the validation is positive and my suggested alignment is in this case correct.

Different case is with a term "ATC Ground Control". The closest term that is in available in the reporting form is "Air traffic control" that is under the "Controlling agency" attribute with its path displayed in Table 9.

Table 9: ECCAIRS Reporting Form path of "Air traffic control" term

Term from Control Structure	Entity	Attribute	Value
ATC Ground Control	Aircraft	Controlling agency	Air traffic control

This alignment is not the only possible. The term "ATC Ground Control" in the control structure is used in a way that describes the person in Air Traffic Management that is in charge or managing the ground traffic. This fact is considered by my suggested alignment that is shown in a Table 10.

Table 10: Suggested path of Ground control

Term from Control Structure	Entity	Attribute	Value
Ground control	ATM staff	Category	Other

In this case, when the object of the control structure was pointing at a certain person, I would choose my suggested alignment over the one that is currently used in ECCAIRS Reporting Form.

During the validation, many terms were used just in the validation control structures and not the ones used to make suggested alignment. Example of such a term (e.g., performs) is showed in the Table 11.

Table 11: ECCAIRS Reporting Form path of "Personnel Task Performance Events" term

Term from Control Structure	Entity	Attribute	Value
Performs	Events	Event type	Personnel Task Performance Events

This way the whole suggested alignment was validated. The result of validation is to be found in Appendix 3.

In Appendix 3, the colours are used for better grouping of terms. The validation was performed in a "suggested alignment vs current ECCAIRS Reporting Form alignment" way.

Green colour indicates that the term is in suggested alignment determined in the same way that currently in ECCAIRS Reporting Form is. Orange colour indicates that the term is currently not a part of ECCAIRS Taxonomy. Red colour indicates that the term is in different position in ECCAIRS Reporting Form compared to the suggested alignment. Blue colour indicates that the term is not used in ECCAIRS Reporting Form at all. However, these terms are included in suggested alignment system in Appendix 4 since they are part of the Taxonomy. Grey colour indicates that the term form validation control structures has not been used in suggested alignment.

Also, the G column in Appendix 3 is important, because it shows, if the term is or is not in current ECCAIRS Reporting Form.

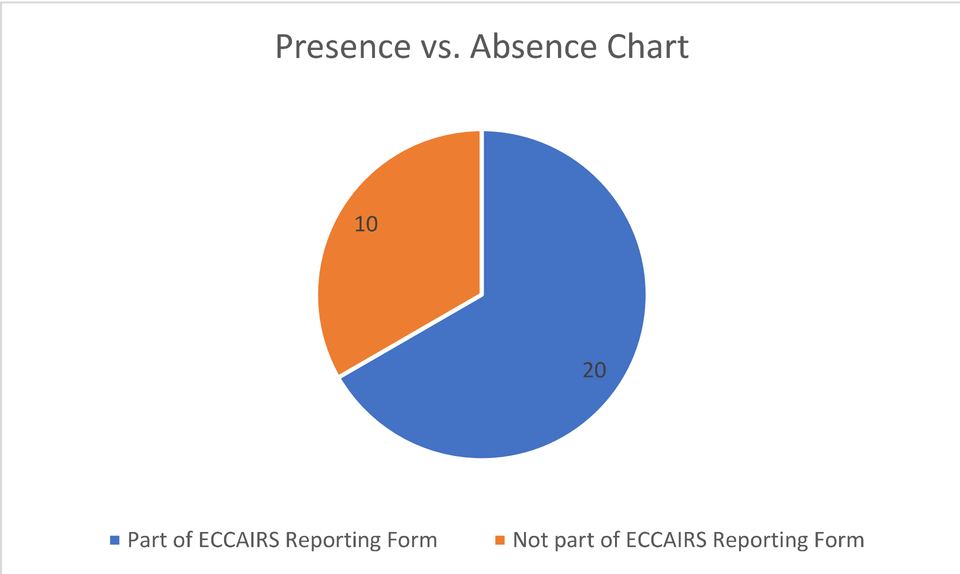

Figure 18: Presence vs Absence Chart

After the validation it has been found out the following:

20 out of 30 terms used in validation control structures are currently used in ECCAIRS Reporting Form (Figure 18).

10 out of total 30 terms used in validation control structures were not part of suggested alignment. These terms were afterwards identified in ECCAIRS Taxonomy, and their path has been identified. 9 out of 10 of these "new" terms have been aligned with a term from ECCAIRS Reporting Form, 1 out of 10 of these terms have been found outside the Reporting Form, meaning in ECCAIRS Taxonomy.

8 out of total 30 terms used in validation control structures have been confirmed by current ECCAIRS Reporting Form as being aligned in the same way as suggested.

5 out of total 30 terms used in validation control structures are currently not part of the Reporting Form. However, all 5 of these terms exist in ECCAIRS Taxonomy and are aligned in Appendix 4.

4 out of total 30 terms used in validation control structures were not found (in Reporting Form nor Taxonomy).

3 out of total 30 terms used in validation control structures have different path compared to my suggested alignment. All the results are showed in Figure 19.

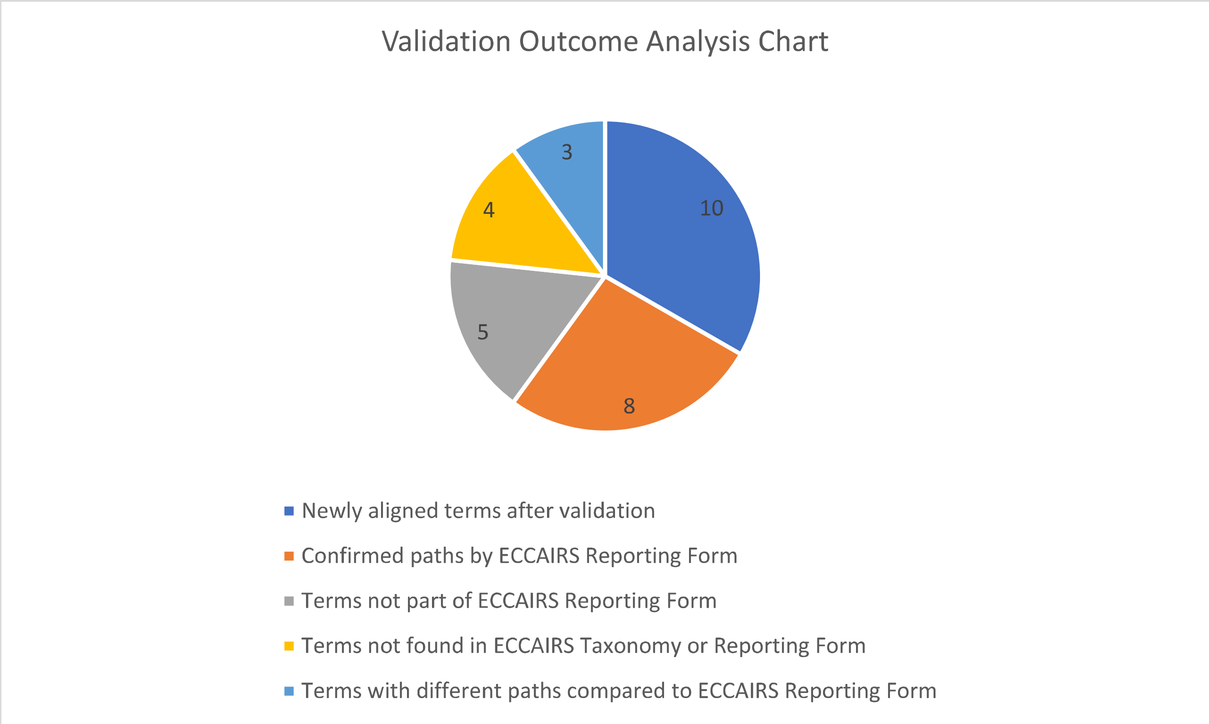

Figure 19: Validation Outcome Analysis Chart

After the validation has been done, the newly identified terms have been added into suggested alignment, resulting in a creation of Appendix 4.

Validation of Validation occurrence 3 has not been performed because of lack of any support in ECCAIRS Taxonomy (Reporting Form included) for any drone-related topics. Because of this issue, it wouldn't be beneficial for the result of my thesis.

6. Discussion

The goal of this thesis was to create an alignment system for current aviation safety taxonomy and contextual information in STAMP. As current aviation safety taxonomy has been chosen the ECCAIRS Taxonomy because this is the taxonomy currently used by EASA for mandatory and voluntary occurrence reporting. It is safe to say that this taxonomy is more than relevant and is the main aviation safety taxonomy in European region.

Contextual information in STAMP has been presented by STAMP's control structure. Control structure is a mandatory step of STPA analysis. Because of this fact, the control structure is created during every STPA analysis, demonstrating the complexity of the system in which the occurrence happened, so it provides contextual information, resulting in being the source of data that was needed for creation of this thesis.

Creation of control structures showed that it is very subjective in naming the subjects or relationships between them. For example, relationships "communicates", and "coordinates" are describing nearly the same type of relationship. Coordination is achieved by communicating and communicating is used for coordination in aviation industry.

Trying to align data from control structures with ECCAIRS taxonomy was accompanied with many difficulties, mainly caused by a complexity of the taxonomy, thus finding the right counterparts took very extensive effort. Taxonomy XML file opened in Microsoft Excel contains exactly 7 238 320 cells filled with data in 234 403 rows and 151 columns, meaning to process this amount of data, a powerful computer is needed. Outside of a being demanding on computer hardware, also it is difficult for a person to orientate within ECCAIRS Taxonomy file.

In my case, MS Excel uses just 1 thread of a computer's CPU, so the search can sometimes take a tens of seconds up to minutes. Sorting the results is often impossible, because sorting of more than 400 000 search results has never finished in my cases, resulting in application's crash and loss of unsaved data. Because of these reasons, finding the most accurate counterparts was very time demanding.

After the suggested alignment was made, the validation provided valuable feedback. It showed that most of the suggested alignment made was in corelation with ECCAIRS Reporting Form.

Also, the validation proved that the alignment of ECCAIRS Taxonomy and contextual information in STAMP is possible. Validation showed that with every additional control structure that was analysed, the suggested alignment system expanded.

Other outcome of the validation is that ECCAIRS Reporting Form is possible to use for involvement of STAMP's control structure elements only after further extension. For extension could be used current ECCAIRS Taxonomy, but based on my validation, not even ECCAIRS Taxonomy is completely compatible with information that are used for modelling control structures.

Unfortunately, with further extension of ECCAIRS Reporting Form, the user-friendliness will be lowered, which can result in users providing less accurate data during reporting with a vision of saving time.

The part of my thesis, where I was aligning terms from control structures with ECCAIRS Taxonomy terms was a bit repetitive. Because of this repetitiveness, I concluded there is an opportunity for some kind of automatization, for example of creating a software that would automatically extract terms from control structures (labels of objects and relationships) into a first column of a table, and after search of these exact terms (search in ECCAIRS Taxonomy) is done (automatically by the software), the results will become source for a drop-down lists with suggested ECCAIRS Taxonomy counterparts (the paths will be showed too). This solution would save user a noticeable amount of time.

During my work with ECCAIRS Taxonomy, I tried briefly to analyse CSV files in which ECCAIRS Taxonomy is shared with public. During this research, I have discovered a file called "ResponsibleEntityList.csv" that contains only entities that are identified as Controllers by STAMP.

7. Conclusion

The utilization of STAMP model can be very beneficial for all the stakeholder in aviation industry. To name an example – with increased safety, less occurrences will happen, resulting in cost-savings. This is achieved by doing the analysis at the beginning of designing the system, thus it is the most cost-efficient for eventually suggested improvements/changes. With lower expenses for the airlines, they can provide better product to the customers, resulting in customer's higher satisfaction and more frequent use of the service. Also, with higher safety comes higher confidence between customers and airlines, resulting in more people convinced of high level of aviation safety, thus more customers using the service of aviation transportation, bringing more money into the industry.

In my thesis, I focus on how to utilize this safety approach in coordination with current aviation reporting system used in Europe. The reason why was used the aviation reporting system is simple because it is widely used across many countries and since it is widely used on everyday basis, the implementation of STAMP approach would be the most effective in this way. To do so, I've done STPA analysis on 3 occurrences based on their investigation reports. From this step, to find the best possible way how to bring contextual information from these analyses to current safety reporting, I have used control structures. Control structures were used as a source of information that are used in STAMP analysis, that can be paired with their ECCAIRS Taxonomy counterparts.

During my extensive work with ECCAIRS Taxonomy, I have discovered a few typos and misspelled terms within the Taxonomy, that resulted in me reporting them to EASA. I consider this to be an unexpected benefit of my thesis. I expect the changes based on my suggestion to be made in following ECCAIRS Taxonomy version.

The alignment's effectiveness has been showed by performed validation that pointed out a few important information. The alignment between STAMP model and ECCAIRS Taxonomy is possible, just a further extension of the taxonomy needs to be done. The utilization of current ECCAIRS Reporting Form is also possible, but the extension needs to be bigger, since the Reporting Form is currently using just a small part of ECCAIRS Taxonomy.

These extensions need to be done by using the terms that are used in STPA analysis, so a cooperation with more entities from aviation sector is suggested (to gather their STPA data).

My thesis is then applicable as an example how to further work with STAMP model and current ECCAIRS Taxonomy. It can also be used as a starting position for a further development based on my suggested alignment system. The limitation of this thesis would have been eliminated by analysing more occurrences, resulting in extension of my current suggested alignment system.

8. References

[1] Doc 9859 Safety Management Manual. Fourth Edition. International Civil Aviation Organization, 2018. ISBN 978-92-9258-552-5.

[2] Safety Oversight. SKYbrary [online]. [cit. 2022-11-21]. Retrieved from https://skybrary.aero/articles/safety-oversight

[3] About ICAO. ICAO [online]. [cit. 2022-11-20]. Retrieved from https://www.icao.int/abouticao/Pages/default.aspx

[4] About us. IATA [online]. [cit. 2022-11-20]. Retrieved from https://www.iata.org/en/about/

[5] Regional Safety Oversight Organisations (RSOOs). EASA [online]. [cit. 2022-11-20]. Retrieved from https://www.easa.europa.eu/domains/international-cooperation/easa-by-country/rsoo?field_easa_rsoo_node_type_target_id%5B2449%5D=2449-&field_easa_rsoo_node_type_target_id%5B2450%5D=2450

[6] The Agency. EASA [online]. [cit. 2022-11-20]. Retrieved from https://www.easa.europa.eu/en/the-agency/the-agency

[7] BACKGROUND. BAGASOO [online]. [cit. 2022-11-20]. Retrieved from https://www.bagasoo.org/background/

[8] Responsibilities. CAA-CZ [online]. [cit. 2022-11-20]. Retrieved from https://www.caa.cz/en/authority/responsibilities/

[9] About FAA. FAA [online]. [cit. 2022-11-20]. Retrieved from https://www.faa.gov/about

[10] Liptak, Kevin. Trump administration grounds Boeing 737 Max planes. CNN [online]. [cit. 2022-11-20]. Retrieved from https://edition.cnn.com/2019/03/13/politics/donald-trump-boeing-faa

[11] Annex 19 to the Convention on International Civil Aviation. Second Edition. International Civil Aviation Organization, 2016. ISBN 978-92-9249-965-5.

[12] Annex 13 to the Convention on International Civil Aviation: Aircraft Accident and Incident Investigation. Tenth Edition. International Civil Aviation Organization, 2010. ISBN 978-92-9231-526-9.

[13] SUMMARY OF: Regulation (EU) No 376/2014. EUR-Lex [online]. [cit. 2022-11-21]. Retrieved from https://eur-lex.europa.eu/legal-content/EN/LSU/?uri=CELEX:32014R0376

[14] Stojić, Slobodan & Vittek, Peter & Plos, Vladimír & Lalis, Andrej. (2015). Taxonomies and their role in the aviation Safety Management Systems. eXclusive e-JOURNAL. 3. ISSN 1339-4509

[15] LEVESON, Nancy G. a John P. THOMAS. STPA Handbook [online]. 2018 [cit. 2022-11-22]. Retrieved from http://psas.scripts.mit.edu/home/get_file.php?name=STPA_handbook.pdf

[16] MARTINOVSKÁ, Johana. Alignment of Aviation Safety Taxonomies and Event Types in STAMP. Prague, 2022. Bachelor thesis. Czech Technical University in Prague. Retrieved from https://dspace.cvut.cz/bitstream/handle/10467/103830/F6-BP-2022-Martinovska-Johana-BP%20-%20Martinovska.pdf?sequence=-1&isAllowed=y

[17] AAIB investigation to Airbus A300b4-622R(F), D-AEAD. In: AAIB Bulletin [online]. December 2019 [cit. 2023-08-06]. Retrieved from https://www.gov.uk/aaib-reports/aaib-investigation-to-airbus-a300b4-622r-f-d-aead

[18] AAIB investigation to Boeing 787-9 Dreamliner, G-CKWB. In: AAIB Bulletin [online]. March 2020 [cit. 2023-08-06]. Retrieved from https://www.gov.uk/aaib-reports/aaib-investigation-to-boeing-787-9-dreamliner-g-ckwb

[19] AAIB investigation to Boeing 747-8R7F, LX-VCF. In: AAIB Bulletin [online]. July 2018 [cit. 2023-08-06]. Retrieved from https://www.gov.uk/aaib-reports/aaib-investigation-to-boeing-747-8r7f-lx-vcf

[20] Electronic Reporting. Aviation Reporting [online]. [cit. 2023-07-25]. Retrieved from https://aviationreporting.eu/en/ElectronicReporting

[21] AAIB investigation to Boeing 777-300(ER), HL-7782 and Boeing 757-256, TF-FIK. In: AAIB Bulletin [online]. June 2023 [cit. 2023-08-06]. Retrieved from https://www.gov.uk/aaib-reports/aaib-investigation-to-boeing-777-300-er-hl-7782-and-boeing-757-256-tf-fik

[22] AAIB investigation to DHC-8-402 Dash 8, G-PRPC. In: AAIB Bulletin [online]. July 2019 [cit. 2023-08-06]. Retrieved from https://www.gov.uk/aaib-reports/aaib-investigation-to-dhc-8-402-dash-8-g-prpc

[23] AAIB investigation to Evolve Dynamics Sky Mantis, (UAS registration n/a) 250722. In: AAIB Bulletin [online]. January 2023 [cit. 2023-08-06]. Retrieved from https://www.gov.uk/aaib-reports/aaib-investigation-to-evolve-dynamics-sky-mantis-uas-registration-n-slash-a-250722