High Reliability Organizations in a Changing World: The Case of Air Traffic Control

HIGHLIGHTS

- A gap between HRO theory and practice is apparent in air traffic control.
- HRO Theory principles apply thoroughly only in operations whilst relevant knowledge spreads across the investigated air traffic control organisations.
- Application of HRO principles ensures higher efficiency and effectiveness in air traffic control.
- Understanding of HRO principles increases safety and resilience level in air traffic control.

ABSTRACT

Organisations, which operate relatively error-free for a prolonged period, are called highly reliable organisations (HROs). Examples of such organisations are mainly found amongst those sectors, where failures have a high risk of resulting in harm to human life such as healthcare, chemical or nuclear power plants or the aviation industry.

High Reliability Organisations Theory (HROT) stresses five characteristics, which HROs need to have to achieve high standards of stable operations. This paper provides insights on how one of the most important HRO within the aviation sector, i.e., Air Traffic Control (ATC), applies HROT in practice. As ATC is a service provider set up to maintain the high safety levels within the aviation industry, this is an exemplary case to investigate theory versus practice.

Data for the empirical study relied on two Air Navigation Service Providers (ANSPs), which were able to cover all aspects of the research questions, i.e. the German ANSP Deutsche Flugsicherung GmbH as a large organisation and the U.K. ANSP Air Navigation Solutions Ltd. as a smaller one. Data were collected using seventeen semi-structured interviews with ATC management experts across three managerial levels and review of 672 documents.

The findings suggest that although HRO theoretical principles are followed within the case organisations to a very large extent, the HROT applies predominantly in the areas of operations. Any indirectly or only loosely connected areas with ATC operations follow principles found in non HROs. The findings also support the strong correlation of a high level of resilience and HROT. From a policy and management perspective this raises the question, whether HROT needs to further adapt to consider parts of an organisation that are truly relevant to operate in a relatively error-free manner for prolonged periods rather than just organisations as a whole.

Keywords: High Reliability Organizations, Air Traffic Control, Air Navigation Service Providers, risk management, safety, aviation.

1. INTRODUCTION

Civil and military aviation form an integral part of our global society (IHLG, 2017). Ever since the first flight by Orville Wright in 1903, aviation has grown from the dream of a few individuals to a worldwide multi-billion-dollar industry. Despite pressure from various crises – economic, political, or even events like the COVID-19 pandemic - the world's appetite for travel has not been satiated by any other existing method of transportation (Liu et al., 2020; Overton, 2020; Hanock & Georgiadis, 2021).

The civil aviation industry claims to contribute 3.5 trillion American dollars to the world economy (Aviation Benefits Beyond Border, 2022) and provide 87.7 million jobs worldwide (Aviation Benefits Beyond Border, 2022). Over the last 60 years, air transport has grown from a low volume luxury product for a few enthusiasts into a commodity product in highly industrialised countries, available to most of their people at competitive prices. More than 1,400 airlines and over 33,299 aircraft are in service around the globe, connecting more than 3,700 airports. This service is supported by 162 air navigation service providers (Aviation Benefits Beyond Border, 2022). It is not all plain sailing, however. Flying has been blighted by consistent accidents and tragic events ever since its early days. Catastrophes such as the Croydon mid-air collision in 1922 (Croydon Airport Society, 2020), Air France flight 447 (Bureau d'Enuqetes et d'Analyses, 2012), and the Überlingen accident (BFU, 2004) have brought infamy to an industry that relies on safety to ensure passengers use its service. Air transport has always had to face catastrophic accidents and, whilst they happen rarely, the consequences are often fatal.

The safety of air travel will form a critical part of its future success. Recent decades have shown just how much progress can be made when an emphasis is placed on safety, reducing risk, and managing crisis situations. Due to the nature of aviation, the factors that give impetus to improving safety are manifold. Regardless of whether these changes are motivated by financial considerations or otherwise, the collective aim of improving safety standards remains unshaken. Nonetheless, the economic pressures of a changing industry (one that has shifted from the pursuit of a privileged few to a cheap and widely accessible mode of transport for many) have led to concerns that safety in aviation is under threat (Papatheodorou & Platis, 2007). Governmental intervention through deregulation (Gillen, 2006; Moses & Savage, 1990; Tretheway & Waters, 1998) has increasingly introduced more market-oriented environments into not only civil aviation, but also military aviation, yet still with a long way to go. Economic deregulation and market liberalization have put pressure on all aviation stakeholders to become more efficient and reduce their costs; this can potentially raise challenges for the effective monitoring of safety standards (Papatheodorou & Platis, 2007). 'High reliability' has, therefore, become a watchword in aviation.

Safety and efficiency for the sake of cost reduction are often at odds with one another and within aviation, political influence and stakeholder interests are deemed to have a high risk of conflicting with safety (Hollnagel, 2013). Any participant in the aviation sector must be stable and reliable to avoid catastrophes. If trust in the safety of air travel diminishes, the whole industry might be bound to collapse. The High Reliability Organisations Theory (HROT) provides an answer as to how the high standard in aviation organisations can be maintained. One sector of this industry stands out for its primary purpose of maintaining safety: Air Navigation Services (ANS). In line with that, the fundamental question this paper will aim to answer is *to what extent do highly reliable organisations apply HROT principles in daily organisational practice?*

The paper is divided into four parts. Within the Literature Review section, we are going to explain in brief air traffic management, risk, safety and crisis management, key regulations of

importance for our research while a full focus will be given to HROT and its principles. In Methodology and Sample, research design and process are explained, while in the Results and Discussion part, the key research findings are elaborated. In the Conclusion part, research results are summarized, recommendations and research limitations are presented as well as areas for potential research improvements.

2. LITERATURE REVIEW

2.1. Air Traffic Management

In 1946, ICAO published as one of its first documents, i.e. Doc. 4444 – Air Traffic Management, which until today describes all the relevant elements for the provision of Air Traffic Management (ATM), but especially Air Traffic Control (ICAO, 2016). The document details air traffic management as "the dynamic, integrated management of air traffic and airspace including air traffic services, airspace management and air traffic flow management – safely, economically and efficiently – through the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions" (ICAO, 2016, p. 25). With this definition it becomes clear that the service provided to aircraft had evolved significantly over time. Gone were the days of lookouts on the ground, with focus shifting towards an integrated approach that would support the industry.

ATM is made up of three distinct parts, namely Air Traffic Services (ATS), Air Traffic Flow Management (ATFM) and Air Space Management (ASM) (ICAO, 2016). It is important to note that an Air Navigation Service Provider (ANSP) (such as the case organisation in this paper) normally provides all these services.

2.2. Risk, Safety and Regulatory Framework

The risk of facing a dangerous situation is naturally of paramount importance to safety understanding and management. One needs to know when to face it to understand how to face it, which ultimately defines the requirement for preparation. Since its early days, risk management has provided organisations with the required process to assess, identify and mitigate risks (Mehr & Hedges, 1963). The origins of risk management derive from insurance strategies. The risk management cycle consists of several steps and is laid out in Figure 1 as discussed by Elkhweldi and Elmabrouk (2015). Initially, risks need to be identified and subsequently assessed and quantified to identify appropriate countermeasures. These countermeasures then need to be implemented and continuously controlled. Hence, risk management does not represent a final product, but rather an ongoing process.

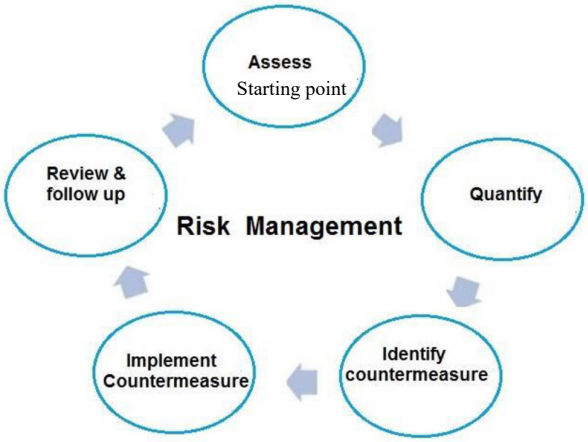

Figure 1: Risk Management Cycle, Souce: Elkhwedi & Elmabrouk, 2015, p.2

Safety management, although largely similar in its views and processes, aims to simultaneously understand how occurrences happen while also focusing on the prevention of harmful outcomes against humans (Vogt & Leonhardt, 2006). In the context of aviation, Roelen and Klompstra (2012) explain that safety management corresponds to a managerial process with two responsibility levels:

- State level

States need to establish safety programs that correspond to a set of activities and regulations with the aim to improve safety.

- Service providers level

Aircraft operators, airport operators, maintenance organisations and air traffic service providers are individual actors who are part of the safety program. These actors need to implement safety management systems (SMS), which are acceptable to the respective state as per regulation from ICAO and EASA (ICAO, 2013; Müller et al., 2014; Performance Review Commission, 2010). In practice, this means to identify safety hazards, to ensure the implementation of remedial action that is necessary to maintain the agreed safety performance, to provide continuous monitoring of this safety performance and to guarantee a continuous improvement of the SMS (DFS GmbH, 2016). While safety understanding affords an insight into what is done and where it generally comes from, the second part - crisis management - forms a critical part of refocusing the observer's attention on what would happen if safety regulations were absent.

In the context of Air Traffic Management (ATM), it is crucial to consider the regulatory framework that guides the aviation industry, particularly within the European context. A noteworthy initiative shaping the future of ATM in Europe is the Single European Sky ATM Research (SESAR) joint undertaking. SESAR, established to enhance the overall performance and efficiency of European airspace, outlines a comprehensive multiannual work program that serves as a guiding framework for research and development efforts. As part of our exploration into High Reliability Organizations (HROs) within the aviation sector, it is recommended to integrate a thorough examination of how HRO principles align with the objectives outlined in the SESAR multiannual work program (2022). By doing so, we can draw specific connections between the theoretical foundations of High Reliability Organizations (HROs) and the practical implementation strategies advocated by SESAR.

For instance, one of the key focus areas within the SESAR work program pertains to the optimization of air traffic flow and airspace utilization. This aligns seamlessly with the HRO principle of 'sensitivity to operations,' emphasizing a proactive approach to identifying and

addressing potential issues within the operational environment. Investigating how Air Navigation Service Providers (ANSPs), such as those in our study – the German ANSP Deutsche Flugsicherung GmbH and the U.K. ANSP Air Navigation Solutions Ltd., integrate HRO principles in accordance with the objectives set by SESAR can provide valuable insights into the harmonization of theoretical frameworks with practical, industry-specific requirements.

In the area of crisis literature, researchers such as Weick, Sutcliffe and Obstfeld (1999) recognize the use of HROT as a strategy for crisis intervention, which addresses the challenges of uncertainty and incomplete knowledge. This concept of preventing, addressing, and recovering from a crisis is a common pattern in all crisis management literature (Bourrier, 2011). When Hermann (1963) discusses organisational behaviour in an organisation because of crisis, his concept of *viability* already demonstrates a method of preventing crisis. Furthermore, he identifies that a *"crisis will be formulated along three dimensions. An organizational crisis*
(1) threatens high-priority values of the organization,
(2) presents a restricted amount of time in which a response can be made, and
(3) is unexpected and unanticipated by the organization" (Hermann, 1963, p. 64).
This is of particular significance within HROT, as the same approach is picked up and addressed. Therefore, it can be concluded that HROT is based on the concepts of risk, safety and crisis management as will now be further highlighted in the next section of this paper.

2.3.High Reliability Organisations Theory

High Reliability Organisations Theory is founded on two different streams in risk, safety, and crisis management, namely Disaster Incubation Theory (DIT) and Normal Accident theory (NAT). DIT noted that systems have a certain vulnerability and tendency to fail due to unnoticed, previously unconsidered events, which could create a significant disturbance. But also, even after an event, learning (not always achieved yet theoretically required) will not prevent future events from taking place. In particular, the management of any system takes a key role in disaster prevention. Also, the correlation of risk and complexity is a common theme in DIT. The more complex and coupled a socio-technical system is, the higher the risk of unwanted and unseen events becomes, which can end in catastrophe. This concept forms a core part of another element in the understanding of high reliability and is found in the literature on NAT (Perrow, 2011). Perrow investigated the Three Miles Island accident and the Bhopal disaster in detail before publishing his Normal Accidents Theory, where he states that any organisation operating in a high-risk environment that requires complex technology is unable to reach accident-free operations and will eventually fail.

Perrow´s NAT approach was challenged by several academics (Roberts K. H. & Bea, 2001; Rochlin, 1986) as being too narrow in its point of view. The critics around NAT centred on providing examples of organisations that operate in critical infrastructure or similar environments with a catastrophic potential, yet relatively error free over longer periods of time (Rochlin, 1986). The Berkeley group, consisting of Todd LaPorte, Gene Rochlin, and Karlene Roberts, raised the question of how some companies, although highly hazardous, can operate error free for a very long time and are still able to be efficient producers (LaPorte & Consolini, 1991). The group investigated organisations with large-scale operating systems that perform at extraordinary levels of safety and productivity (Roberts K. H., 1990) and would normally be bound to fail according to NAT. Examples are nuclear powerplants, fire fighters, air carriers and air traffic control. They published the results of their work in the book Managing the Unexpected (Weick & Sutcliffe, 2007).

The research of the Berkeley group concludes that, in contrast to NAT, accidents are not inevitable (Weick & Sutcliffe, 2007; Bea, 2008; Werner, 2012). As proof of this, examples of organisations that according to NAT should have failed or must fail are provided, amongst them again air traffic control. For a long period, none of these organisations showed any tendency to come close to a failure of their complex systems.

HROT does acknowledge the fact that there are some thriving organisations that seem to contradict NAT or DIT. Furthermore, HROT raises the question of what makes these organisations resistant to failure, or, to use a term introduced earlier, so resilient. Weick and Sutcliffe (2007) state in the very first sentence in their book that "unexpected events often audit our resilience" (Weick & Sutcliffe, 2007, p. 1). With this initial statement, the key terms - also highly relevant for this research - are introduced: unexpected events and resilience. At the same time, throughout all the literature around HROT, organisational resilience against unexpected events is the nature of avoiding any failure. This key theme is also the one element that stands against DIT and NAT. To develop an understanding of resilience and high reliability, HROT investigates characteristics of such high reliable organisations to provide a deep understanding of how to avoid their likely failure (Roberts K. H. & Bea, 2001).

According to Roberts and Bea (2001), any organisation that can be classified as HRO shares three key principles:

1. It aggressively seeks to know what it does not know.
2. It balances efficiency with reliability and
3. It communicates the big picture to everyone.

The Berkeley Group further refined the principles into five characteristics in organisations responsible for the high reliability of operations (Weick & Sutcliffe, 2011):

1. preoccupation with failure,
2. reluctance to simplification,
3. sensitivity to operations,
4. commitment to resilience and
5. deference to expertise

These characteristics are also referred to as the five dimensions of high reliability (Shrivastava et al., 2009).

HROT uses elements of risk management, safety management and crisis management to form a key part of its principles. It is important to emphasize that there has been no evidence from the literature whether it is required that a (highly reliable) organisation should operate as a whole according to the HRO principles; nonetheless, the available literature always refers to an organisation as highly reliable in its entirety. Given that, it can be concluded that the principles should in theory be followed across an organisation.

As previously stated, such resilience is fostered via learning from incidents (Jordan, 2010; Müller et al., 2014; Ali et al., 2015), which HROT emphasises (Weick & Sutcliffe, 2007). In summary, HROT is the theory of how organisations are meant to be set up (as a whole) to operate relatively error free over prolonged periods. It uses key elements of risk management und resilience and relies on five distinct principles. HROs are primarily found amongst organisations, where a failure has a likely catastrophic outcome.

3. METHODOLOGY AND SAMPLE

For this research a mixed-methods approach has been implemented. This applies *questionnaire*, *document analysis and semi-structured interviews* to explore the understanding and level of

integration of HROT principles into the case company. This mixed methods process aims to build on the strengths of each approach while minimising their respective weaknesses. Furthermore, the research is based on content analysis, as described by Hsieh and Shannon (2016). According to Yin (2003) and Gerring (2007), a single embedded case study is better suited to covering a single case with various embedded units of analysis. The levels of analysis are the three major management levels within the operational support and operational area of the case organisations. Literature on case studies suggests purposive sampling as the most appropriate sampling approach within small-N case studies (Gerring, 2007; Woodside, 2010) but also HROT research grounds on specific cases with small samples such as the Cerro Grande Fire (Nisengard et al., 2007; Weick & Sutcliffe, 2007) or the Three Mile Island incident (Hopkins, 2001). The benefits of purposive sampling are evident and reflected in this research. Singleton et al (1988), as quoted by Strydom and Venter (2002), refer to purposive sampling as a method, relying on the judgement of the researcher. Such samples are a composition of elements containing most characteristic or typical attributes of the population. Another aspect in choosing the approach is access to data as ANSPs and other HROs require very high security levels, which significantly restrict access to personal and data. Thus, it would not have been possible to access more organisations through one single researcher. The selection of the two organisations, therefore, was based on the ability to access the key individuals in the hierarchy, so that each layer of analysis could be addressed with the required number of experts.

Regarding document analysis, 672 documents were collected. These documents can be sorted into six categories such as 27 Operational Notices (OPNOT), 9 Safety Notices (SN), 77 Safety Cases (SC), 211 Supplementary Instructions (SI), 3 Temporary Desk Instructions (TDI) and 345 Temporary Operating Instructions (TOI). The document analysis was undertaken using the NVivo software. Three rounds of analysis were undertaken with the aid of the software. In the first round, the different documents were categorised based on their nature, such as temporary operating instructions, safety cases, etc. In the second round, the documents were analysed with reference to the five principles of HROT indicated by Weick and Sutcliffe (2011). A third analysis was used to create word clouds, which were used to correlate the most frequently employed terms across the various documents, thus making them comparable to HROT.

When it comes to in depth interviews, seventeen (17) experts were interviewed in total from the case company between 2018 and 2019. In the context of this study, an expert is defined as a person who has extensive knowledge in their profession and department within the case company. Sometimes these experts are also referred to as *subject matter experts* but because the interviews used managers exclusively, the term has not been used in this paper as normally these types of experts are regular employees rather than managers. These experts have been specifically chosen as they reflect the management and the organization as a whole across the management layers. With the implementation of structures, processes and procedures being a managerial responsibility, the first approach has been made to the members of the organization, who oversee it.

All interviewed experts can be classified into either basic managers, executive managers, or senior managers as presented in Table 1:

Interview - Sample		
Role in Organization	**No**	**Citation Code**
Basic Manager in Training	Interviewee 1	E1
Basic Manager Operations ATC	Interviewee 2	E2
Basic Manager Operations Engineering	Interviewee 3	E3
Executive Manager Training	Interviewee 4	E4
Executive Manager Operational Support HR1	Interviewee 5	E5
Executive Manager Operational Support HR2	Interviewee 6	E6
Executive Manager Operational Support MD	Interviewee 7	E7
Executive Manager Operational Support R&D	Interviewee 8	E8
Executive Manager Operational Engineering	Interviewee 9	E9
Senior Industry Expert ICAO &EASA	Interviewee 10	E10
Senior Manager Training	Interviewee 11	E11
Senior Manager Operational Support Safety	Interviewee 12	E12
Senior Manager Operational Support Safety/Audit	Interviewee 13	E13
Senior Manager Operations ATC	Interviewee 14	E14
Senior Manager Operations Head of Unit 1	Interviewee 15	E15
Senior Manager Operations Head of Unit 2	Interviewee 16	E16
Senior Manager Operations Staffing	Interviewee 17	E17

Table 1: Interview Sample Overview

To conform to standard ethical protocols, the interviewees were fully informed of the purpose of the research. The interviews themselves were recorded and subsequently transcribed. The content of the interviews was converted into text to be used by the NVivo software package, which identified common trends and patterns within the responses. Three rounds of analysis were undertaken utilising software. The interview was set up for 45 minutes, with a 15-minute non-interview part at the beginning to allow for clarification of questions and administrative topics before the start. The interview guide itself is structured in four main question-banks (see appendices A and B). Additionally, notes have been made where required by the interviewer to capture specific points or to help with follow-up questions during the interview itself. This approach is recommended by interview guidance (Fontana & Frey, 1994; Seidman, 2013) and reduces the chance for errors and erroneous data. The interviews have been conducted in German and English, based on the mother tongue of the interviewee, which allows the individual to speak freely and in his or her own language. The biggest challenge to the researchers was to gain access to the individual experts for interviews. ANSPs are referred to as critical infrastructure organisations and access to specific information and people is highly restricted. The interviewer has been able to access the key individual through door openers, who organised access to data and members of staff. All interviewees have signed a consent form before the interview. This contained several data protection requirements out of which one prohibited any direct citation of what an interviewee would have said. As a result of this requirement, the subsequent Results and Discussion section does not include any reference to direct quotes.

4. RESULTS AND DISCUSSION

4.1. Document Analysis

Document analysis results are in line with the conclusions from the literature review. This is particularly evident with the words *safety, resilience* and *air traffic control officer* having been used very frequently in the documents. Just the term safety is mentioned 13,849 times which

is around twenty times per document (see Figure 2). This conforms with the high reliability understanding in that safety is one of the most important aspects when it comes to the principles of HROT.

As part of the analysis, word counts have been used to serve as indicators whether certain key terms, commonly used in the context of HROT were part of the organisational language. The latter is an element, which forms part of organisations as they evolve over time and commonly reflect their culture, which is also part of the HROT principles by Weick and Sutcliffe (2007). To visualise the results, word clouds have been used, where a larger font size reflects a higher count of the specific word compared to words appearing in smaller font size in the word cloud. This allows an easy way to identify, which words have been used most often. The colours used in the word clouds serve the purpose of increasing the readability and are not otherwise related to the collected data.

It can be firmly stated that all documents describe processes and relationships as well as instructions and security-relevant topics in a very detailed and transparent way. Whenever documents directly address ATC operations such as SI or TOI, they have a risk analysis spreadsheet attached to it, addressing, and providing mitigation strategies for the potential risks identified. All documents can be viewed by all employees at any time. This is in line with HRO, as information sharing is of high relevance and is pursued actively. Each document has at least three editors from different organisational functions, ensuring a broad overview of the subject by different experts.

Figure 2: Word Cloud 1, Source, NVivo Output

No explicit reference to HROT was identified within the documents. Nevertheless, the frequently used words in the documents are comparable and often analogous to the key terms of HROT (Word Cloud 1). The font size of the word cloud reflects the number of times, a specific word was found in the document. This again leads to the conclusion that the documents are of high relevance. The influence factors are from various sources but no reference to cost factors can be taken from the documents.

Table 2 shows the most used words across all document categories, which equals roughly ten times per document.

Word	Count	Similar Phrases
safety	13849	safety
system	10635	system, systems, system's

case	7435	case, cases

Table 2: Word Count across all documents, own research

The document analysis' results indicate that HROT is rooted into the operational areas as all documents that could be identified originate from this area, whereas in the operational support areas none of these HROT documents can be identified. When examining these elements, the document search may be seen as the most objective element of the research, as the process drew on pre-existing documentation in a *studio ex post facto* approach, which provided clear indications of the approaches adopted by the organisation. The objective nature of the document search provides more certainty than some of the more subjective issues - particularly the expression of opinions. However, it should be noted that there may have been conscious or subconscious sorting or censoring of the information provided. Despite this, there was a clear indication from these documents that the organisation was adopting HRO processes and values. It is important to note that no documentation in line with these principles has been provided by the organization indicating a gap between theory and practice as HROT refers to an organization as a whole. Looking at the findings, this complies with the concepts of HRO or Weick and Sutcliffe (2007).

There was a clear preoccupation with failure, as indicated by the dominant keywords within the documents (Figure 2), as well as the high level of detail presented regarding the way in which precision should take place to avoid failure. The safety case and the supplementary instruction documents were particularly notable for their strong preoccupations with failure, demonstrating the alignment with HRO requirements. Importantly, this was a strong indication of a HRO element being satisfied, particularly when considering the definition of Hopkins (2007), who had stated that a preoccupation with failures was indicated by constant search for potential weaknesses or lapses within a system.

Likewise, the high level of detail - including the depth of information and length of some of the documents - combined with the high degree of background data provided also demonstrated a reluctance to simplify, which was the second of the requirements set out by Weick and Sutcliffe (2011). Sensitivity to operations also appeared to be a focus within all the documents, with the aim to create a resilient business.

It is notable that the commitment to resilience appeared to be less prevalent in the documents, potentially indicating a lower level of emphasis. However, while this was absent in many of the categories of documents, it is notable that it was present within the safety case notifications. While there are only 77 of these documents out of the total of 672 referring directly to resilience commitment, it becomes apparent that there were indirect references to this in a larger number of documents. Therefore, while there appears to be a lower level of preoccupation with failure in the documentation, Hopkins's (2007) approach would indicate that the preoccupation with failure should also be indicative of attempts to increase overall resilience, as potential weaknesses within systems may be seen as precursors to larger unwanted events. Despite this, the safety case documents may be read within the context of the approaches provided by Sutcliffe (2010), Weick (1987) and Youngberg (2004), who argued that every event should be treated as a significant incident, with a high level of attention as if it were the first.

Deference to expertise was the most commonly observed compliance with the HRO criteria identified by Weick and Sutcliffe (2011). The deference to expertise is seen in the systems as well as the content. For example, the requirement that all documents need to be signed by the three members of staff, including a subject matter expert, as well as a manager and a safety oversight employee provides a high level of assurance. Therefore, the deference to expertise is based not only on the issue itself, but on the management and safety of those issues, which also links back to the preoccupation with failure, while the three signatures may also support a reluctance towards complication.

As mentioned in the literature review, Roberts and Bea (2001) stated that there are three principles for an organisation to be classified as an HRO: organisations undertaking aggressive approaches to seek knowledge regarding what they do not know; attempts to balance efficiency with reliability; and communication of the big picture to everyone in the organisation. Therefore, given the above findings, it is not only the Weick and Sutcliffe (2011) requirements that are satisfied, but also the principles laid out by Roberts and Bea (2001). This suggests that in answer to the research question, the hypothesis that HROT principles are applied to a high degree is largely validated. Despite this, it is necessary to look further at the in-depth interviews, otherwise the documents may be considered as "fantasy documents" as indicated by Birkland (2009), Clarke (1999), and Rijpma (2003), where it was hypothesised that the documentation may be generated to prove activity.

4.2.Expert Interviews

The experts stated that they are aware of HRO-principles and that HROs can be characterised by: defined goals, consistent standards, and well-planned operations; the ability to adapt to changing circumstances and to operate safely in a highly dynamic and critical environment; doing all that is possible to avoid accidents; experienced employees providing professional services; a safety culture that is continuously reviewed and adapted; striving for improvements in all aspects and seeing mistakes as a chance to improve; a clear communication strategy and a commitment to resilience. Thus, respondents shared a consensus of what really makes an HRO. In their opinion, this is safety, reducing risks, and experienced staff. It is for this reason that E1, for instance, states that ATC is so reliable and safe because it is about human life and not objects (E1, 2020). The following Word Cloud 2 (Figure 3) shows the most frequent words used by experts such as safety, reliability, resilience that are closely related to the HRO principles. Moreover, experts (all of them) identified key factors that make impact on general awareness about HRO principles and dimensions. They agreed that HRO should be founded within organizational culture, set by specific rules and regulations.

Figure 3: Word Cloud 2, Source: NVivo Output

When it comes to a possible difference between operational and non-operational areas, the experts agree that all parts of the organisation must embrace HRO-principles, but there is a difference regarding the extent of their influence. In some areas or activities, such as finance or HR, HRO-principles must not be carried out in detail. The operational staff generally is not concerned about costs, since getting the job done and getting it done safely is their main concern. Thus, safety has a higher relevance in operative areas. Nevertheless, a person unaware of HROT principles might have problems in understanding the reasons why an HRO works in

a specific way, meaning they have an HRO-deficit, experts explained (E11, Senior Manager Training; E15, Operations Head of Unit).

Most experts mentioned that there was a difference between adherence to HROT principles before and after 2012 when European Commission imposed sets of regulations such as the implementation of the performance scheme that aimed to set binding targets for the EU Member States. These targets were set to increase the efficiency of the European ATM network. For this purpose, Key Performance Areas (KPAs) namely a) Safety, b) Capacity, c) Cost-Efficiency and d) Environment have been introduced (European Commission, 2019). The performance scheme is set up in different periods, which are called Reference Periods (RPs). The first RP was covering 2012-2014, the second one started 2015 and finished in 2019. The third one started 2020 to cover the years until 2024.

In line with above mentioned, experts were of the impression that before 2012, systems and procedures were tested more carefully and that after 2012, implying that cost efficiency trumped safety (E6, Executive Manager Operations Support HR2). There were also some positive aspects, such as an improvement in communication, a better safety culture, and more open-mindedness, especially in leading positions (E14, Senior Manager Operations ATC). Results further show that most of the interviewees (apart from Interviewee E1, Basic Manager in Training) have the impression that before 2012, the guiding rule was safety first. After 2012, when more and more cost aspects appeared, an increased number of people got the impression that the focus changed from safety to economy. On the other hand, many of the interviewees stated that safety has always been a major aspect in ATC and has not changed over time. It can therefore be assumed that people's perception is in some way associated with their individual work experiences.

All interviewees agreed that safety and resilience are of paramount importance for an ANSP, and that all regulation objectives should have this in mind. Thus, safety is the highest priority, although capacity and cost-efficiency are the main focus areas. Interviewees agreed that safety always comes first whatever the circumstances and whilst the specifics have changed over time, the priority has not. Moreover, the examined documentation on safety reporting did not reveal significant changes after 2021 leading to the conclusion that the introduction of the EU regulation did not have an impact on the level of resilience.

In terms of the HROT principles, the results were indicative of a strong reluctance to simplify, with reference made to the governance, and the role of the regulatory framework necessitating a focus on causes of failure and ongoing prevention of failure. However, one of the respondents noted (E3, Basic Manager Operations Engineering) that the power to determine what was and was not safe was a governmental issue and that sometimes ambivalence emerges. Sensitivity to operations also appears to be present in the interviews, particularly with reference to the details provided, and a commitment towards resilience was clear in the responses given. It is unsurprising that regulatory influences were identified as a significant influence.

The principles outlined by Roberts and Bea (2001) were more evident, as the interviews were a clearer demonstration of the desire to identify causes of failure, and the way in which these were incorporated into the organisational culture, due to internal influences regarding safety, as well as external influences such as regulations. Communication also appears to be present, as the interviewees indicated that knowledge has proliferated throughout their organisation, even if it is different between the operational and non-operational staff. There is also a clear demonstration that there is a balancing of efficiency with reliability, with multiple respondents (E3, E4, E9, E10, E11, E12, E13, E14, E15, E16, E17) noting that safety is important, but that

this is not the only important factor. This suggests that in answer to the research question, the hypothesis that HROT principles are applied to a high degree is in fact validated.

Regarding the identification of external and internal influences Figure 4 shows the most frequent topics mentioned by interviewed experts such as *regulations, European Commission (regulations), government influence etc.*

Figure 4: Word Cloud 4, Source: NVivo Output

In line with above mentioned, the in-depth interviews' results show that the main influential factors are regulations emerging from national civil aviation/competent authorities, the European Union, and ICAO as well as airline, airport, and internal demands and cost drivers. According to the interviews' results, EU regulation, national regulation and cost drivers belong to the influential factors with the highest ratings. Nevertheless, many experts (E2, E3, E4, E6, E7, E8, E11, E12, E13, E14, E17) believe that regulations are the main factor, which makes ATC an HRO, since they set the compliance and auditing framework for every ANSP.

In summary, the results appear to be aligned with the theoretical approaches towards HRO and HROT, although no single aspect may be seen as singularly persuasive, given that each approach provides different levels of information. The data also show a difference between the individuals` perception of the level of integration of the HROT principles on the one hand and the knowledge of the experts on the other. Many key elements of HROT principles could be outlined by the experts without specifically being able to link it to the theory. Also, the impact of potential external influence such as EU regulation was often identified as significant by the experts but could not be supported by the available data such as safety records.

5. CONCLUSION

This paper aimed at investigating the importance and application of HRO principles in complex organizations as is the case with air traffic control. Throughout the examined documents, the organisations under investigation exhibited a high level of compliance with the HRO principles examined in the literature review. In fact, such was the degree of conformity with these principles that the case organisations clearly fulfil the requirements to be considered as HROs, as laid out by both Roberts and Bea (2001) and Weick and Sutcliffe (2011). Whilst there was no explicit reference to HROT in the documents, the language used reflects close similarities to HROT principles described in the literature review. In any case, the documentation per se is insufficient to determine the status of an organisation, as documents do not always translate into practice. When considering the organisation from a holistic perspective and drawing on

the documents combined with interview answers, the claim that the organisation does adopt HRO practices (even if these are not explicitly discussed) is more persuasive than other suggestions.

Whilst these two methods (i.e., document analysis and interviews) did provide significant insight about the topic in question, they also shed light on some intriguing conclusions that might require further investigation. First, the expert interviews showed the evident disconnection between how operational staff viewed their superiors' knowledge of HROT principles and the level of knowledge that their superiors could be proven to have. One of the reasons for this issue is the inherent challenge of quantifying levels of understanding, which despite the use of different data collection methods, remains a prohibitively intangible quality. Another interesting finding from the expert interviews was that respondents believed that 2012 marked a watershed in how safety was perceived within ATC. The experts' opinions seem to have been influenced by their individual experiences within their respective roles. Despite this, there was a widespread agreement among interviewed experts that safety is the most important component of ATC, which is unchanged up until today.

The combination of two methods in this research represents an integrated effort to track HRO within ATC. The literature provides no evidence as to whether an HRO can only be seen as operating according to the HRO principles in its entirety, whilst HROT also does not separate operations from management of an organisation per se. The present paper thus can extend the theory by means of expert interview results, since it can show that HROs such as ATC operates according to HRO principles independent from commercial aspects and at different levels. At the same time, the paper shows that within an HRO there are areas with less or no adherence to HROT principles whilst still the organisation as such delivers a relatively error-free outcome.

From a more general perspective, the findings extend HROT by identifying the way in which there may be a separation of theoretical principles from practice, where practice may be present without specific reference to the theory. Furthermore, the theory was also extended with reference to the importance of culture, and the way it may be inspected by external as well as internal factors. Most of the literature surveyed organisations from the inside out, whereas this study considered the organisation within its environment. Any finding from this research, including its conclusions is applicable to any organisational structure known to be highly reliable, which is another significant contribution.

Limitations and recommendation for future research

Although this research goes a long way in addressing many of the existing literature's shortcomings, new studies are needed to bridge the gap between the assumptions of the pre-pandemic world and the conditions that will exist in its aftermath, whatever they may be. This research must be backed up by further undertakings to confirm the relevance and validity of the empirical evidence presented here. The current research innovates and contributes by collecting and analysing data from within an ANSP, as HROT literature has not to date provided insights applied in this area most probably because of access restrictions. ANSPs are locked up and access is restricted to data as well as members of staff. The need to provide views from different ANSPs has been addressed to some extent as the two case organisations, i.e., the German ANSP and its UK-based branch operate independent from each other and under different regulatory oversight (i.e. BAF in Germany and CAA in the United Kingdom); this allows two distinct points of view on the same subject matter.

Moreover, it is recommended to incorporate an analysis of the SESAR joint undertaking multiannual work program within the broader examination of HROs in the air traffic control domain. This integration will enhance the depth and relevance of the present study, shedding light on how theoretical principles align with and contribute to the overarching objectives of regulatory initiatives, ultimately influencing the safety and efficiency of air navigation services in the European airspace.

Further research may also be undertaken in the field of data collection. In this context it may prove possible that other data collection methods such as narrative interviews or ethnographic interviews lead to other results. To ensure adequate representation, a series of case studies should be conducted to expand the data over more than the two from this study. Therefore, further research may concentrate on other HROs outside aviation and replicate the present examination. In this way, it would be possible to check whether the present results can be fully applied to other companies or other sectors too.

Finally, it is recommended to HROT researchers to explore the wider applicability beyond organisations, which are likely to return catastrophic outcomes in case of a failure, to include less critical organisations. The principles of HROT allow an organisation to improve the resilience of their operations, which is supportive to any business continuity planning. A new category of HROs can be classified through research to introduce organisations, which produce constant output with a relatively low error rate.

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Appendices

Appendix 1

Documnetary Analysis - Sample - categorisation of analysed documents
1. Operational Notices (OPNOT) - Information pertaining to all members of staff with relevant information that does not affect the current standard operating procedures. A total of 27 documents of this type have been provided.
2. Safety Notices (SN) - Information to all members of staff regarding relevant safety related information. A total of 9 documents of this type have been provided.
3. Safety Case (SC) - Documents that describe intended changes to systems or organisational structures and assesses them against inherit risks that need to be mitigated. A total of 77 documents of this type have been provided.
4. Supplementary Instructions (SI) - Instructions to ATC and ATC-Support Staff about operating procedures. Supplementary instructions replace standard operating procedures. This permanently changes the procedures that are laid out in the operating manual -Manual of Air Traffic Services Part II– (MATS-Pt.II). They are lifted into the MATS-Pt.II once a year. A total of 211 documents of this type have been provided.
5. Temporary Desk Instructions (TDI) - Temporary instructions to staff manning the “Desk” (operational managing position), advising the managing staff about how to deal with certain situations. This does not directly affect the procedures laid out in the MATS-Pt.II. A total of 3 documents of that type have been provided.
6. Temporary Operating Instructions (TOI) - Instructions that temporarily changing the contents of MATS-Pt.II, which would then result in a SI. A total of 345 documents of this type have been provided.

Appendix 2

Expert Interview Guide	
1. Question-Bank:	**2. Question-Bank:**
HRO awareness – personal and organizational Main question: Can you please describe, what High reliability Organizations mean to you? Central questions: How familiar are you with HRO? How familiar is the company? Which employee groups are more and which are less? How do you yourself see the HRO?	HRO awareness – factors Main question: What is the most important aspect of HROs and how is this reflected in the organization? Central questions: Safety? Risk Management? Admin side of things?
3. Question-Bank:	**4. Question-Bank Type of Influence**
External Influence Main question: Where does the main influence for HRO in your organization come from? Central questions From the outside or inside? Who influences?	Main question 1: How are you/your company/your colleagues influenced? Main question 2: What does that result in? (good/bad/ugly) Main question 3: What is the main "countermeasure" or way to deal with it? Central questions What would be needed to be done? Who could do something? Is it a risk? If so, for what? Safety, Finance, etc.?