Flight crew teamwork and decision-making: the influence of roles and attitudes

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Declaration

I, Tom Becker confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Abstract

Using empirical data on serious safety relevant events in commercial aviation over the period 2000 - 2020 we found that most events occurred with the flight crew team setting with the Captain (Pilot-In-Command/PIC) as Pilot Flying (PF), the pilot acting on the controls, and the Co-Pilot (Second-In-Command/SIC) as Pilot Monitoring (PM), the pilot responsible for observing the aircraft flight path and the actions of the pilot flying. This *role assignment effect* was described by previous research in the 1990s and our research confirms that it is still present thirty years later in today's aviation system, despite training pilots in crew resource management, a method developed to foster pilot teamwork and, in particular, to foster effective intervention behavior of the SIC. Further results revealed by online surveys support the conclusion from our field data analysis that the role assignment effect constitutes a latent systemic safety issue in the aviation system. We found that not only do negative effects of the status hierarchy between the pilots on a commercial flight deck still persist as a barrier for effective intervention, but also that pilots seem to be generally reluctant to use hard interventions such as taking away control. Furthermore, we found the more pilots see themselves as safety/risk managers rather than as aircraft operators/system managers and the more they value human factors, the more safety oriented and the more cautious they are in flight operations as well as the higher they view the status of the SIC. Additional findings from surveys of pilots including decision-making scenarios support the notion that pilots may be influenced in their safety relevant decision-making by business requirements and cognitive biases such as the *framing effect*. In combination with the fact that we also found in our analysis of field data that most of the events occurred in *normal operation*, meaning with technical airworthy aircraft and no emergency, and that we judged nearly all events as preventable by the pilots, led us to the conclusion that those events primarily originate from an *operational syndrome* due to a combination of the following factors: a salient (efficiency) goal, risky decision-making and missing or ineffective intervention. We discuss the implications of our research and propose, based on our research on the psychology underlying safety relevant events in aviation, fundamental organizational reforms regarding flight crew roles, their risk-management, and their team setting on commercial aircraft flight decks to mitigate the discovered safety risks.

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List of Abbreviations and Acronyms

ALARBO	As low as required by one (in a team or organization)
ALARP	As low as reasonably practical
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATCO	Air Traffic Controller
CBTA	Competency Based Training and Assessment
CCC	Crew Coordination Concept
CRM	Crew Resource Management
EASA	European Union Aviation Safety Agency
EBT	Evidence Based Training
ECCC	Enhanced Crew Coordination Concept
ETTO	Efficiency Thoroughness Trade Off
FAA	Federal Aviation Administration
FSF	Flight Safety Foundation
HRO	High Reliability Organizations
ICAO	International Civil Aviation Organization
IATA	International Air Transport Association
NASA	National Aeronautics and Space Administration
NTSB	National Transport Safety Board
PDI	Power Distance Index
PIC	Pilot in Command
PF	Pilot Flying
PM	Pilot Monitoring
PS	Pilot Supervising
RE	Resilience Engineering
SIC	Second-In-Command
SOP	Standard Operating Procedure
TEM	Threat and Error Management
TETO	Thoroughness Efficiency Trade Off

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Preface

In 2019 the International Civil Aviation Organization (ICAO), a specialized agency of the United Nations based in Montreal, Canada, celebrated its 75th birthday. It was founded in 1944 based on the Chicago Convention which created a body to "promote the safe and orderly development of international civil aviation throughout the world" (International Civil Aviation Organization (ICAO), 2019b). It currently has 193 member states. Based on their joint global aviation safety plan (GASP) outlining safety as a core value, ICAO agreed on a global safety target of zero fatalities in commercial operation by 2030 and beyond. For ICAO safety is not only a top priority, but they highlight that safety is "the highest priority of ICAO's strategic objectives" thereby setting the standard for commercial aviation (International Civil Aviation Organization (ICAO), 2019a).

Nevertheless, accidents and serious incidents continue to happen in commercial aviation. Although the aviation industry has been successful in reducing the yearly rate of fatal accidents from around 12 per million departures at the end of the 1950 to 0.07 per million flight departures by 2022 (Airbus, 2023), fatal accidents are still happening in commercial aviation. This thesis aims to understand the psychology of flight crew decision-making and teamwork to contribute to the further improvement of flight safety and help achieve the goal of zero fatalities in aviation.

Based on empirical findings regarding incidents, serious incidents and accidents in the period 2000-2020 we elicit a systemic safety issue rooted in the team- and role setting employed on commercial aviation flight decks that obviously hinders the aviation industry from further reducing the incidence of safety relevant events and which highlights the need for further research. Based on our findings we propose that this further research be focused on the influence of roles and attitudes on the safety relevant decision-making and teamwork of flight crews on commercial aircraft. By using online surveys of pilots' experience in practice and their attitudes towards their roles and teamwork on the flight deck we also investigate the association of pilots' occupational picture and pilots' attitudes towards the hierarchical flight deck roles of the Pilot in Command (PIC) and Second-in-Command (SIC) as well as the two functional roles of the Pilot Flying (PF) and Pilot Monitoring (PM). The survey is augmented using decision-making and intervention scenarios allowing us to estimate the potential influence of pilots' attitudes on their inflight decision-making and intervention behavior. In discussing our results, we develop options for improvement of safety relevant decision-making and teamwork on the flight deck, then conclude with recommendations for the industry as to how to progress towards its set goal of zero fatal accidents.

1 Background of the research

1.1 Safety Performance of commercial aviation

The risk of experiencing an accident while traveling by air is low, but it is still not zero. In 2022 the International Civil Aviation Organization (ICAO) reported a global accident rate for the year 2021 of 1.93 accidents per million departures for scheduled commercial operations (International Civil Aviation Organization (ICAO), 2022b). According to ICAO this value "provides an overall indicator of safety performance for air transport operation" as it is "based on scheduled commercial operations involving fixed-wing aircraft with a certified MTOW[1] over 5 700 kg" which includes small business jet aircraft up to the biggest commercial airliners. The cited accident rate value for 2021 results from 48 accidents within 24.92 million departures which includes 4 fatal accidents accounting for 104 fatalities while transporting 2.3 billion passengers, compared to 4.5 billion passengers, pre-pandemic in 2019. The mean of the global accident rate over the five-year period of 2017-2021 was $M = 2.40$, $SD = .39$. Within this five-year period ICAO counted in total 396 accidents of which 30 were fatal accounting for a total of 1205 fatalities (International Civil Aviation Organization (ICAO), 2022b).

ICAO's Global Aviation Safety Plan (GASP) 2023-2025 currently seeks to maintain a decreasing trend of the global accident rate to achieve its aspirational safety goal of zero fatalities in commercial operations by 2030 and beyond (International Civil Aviation Organization (ICAO), 2023). However, the measurement of accidents, fatal accidents and their rates describe the tip of the iceberg of safety relevant occurrences in aviation only. Based on ICAO's standardized classification scheme for Accident/Incident Reporting (ADREP) the industry uses further occurrence types such as serious incidents and incidents for describing different levels of severity and safety impact.

While an incident is defined as "an occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation", a serious incident is defined as "an incident involving circumstances indicating that there was a high probability of an

[1] MTOW = Maximum Take-Off Weight

accident …". Examples of relevant incidents are listed in their Aircraft Accident and Incident Investigation Manual (ICAO Annex 13) and it is further noted in the definition for serious incidents that "the difference between an accident and a serious incident lies only in the result" (International Civil Aviation Organization (ICAO), 2020a). Unfortunately, ICAO's recurring annual safety reports do not contain any information on measurements based on the latter occurrence types. Nevertheless, serious incidents and incidents are evaluated in regard to specific occurrences classified as global high-risk categories of occurrences such as runway excursions and incursions, controlled-flight-into-terrain, loss-of-control and midair collisions.

Within the industry there are other stakeholders as well providing insight into aviation's safety performance on a global basis such as the International Aviation Transport Association (IATA) or some aircraft manufacturers[2]. Moreover, individual states (by means of their respective accident investigation authority), or regional and regulatory organizations, such as the European Aviation Safety Agency (EASA), all report their own statistics, however sometimes differing from ICAO in event sampling, e.g., by excluding certain types of aircraft or type of operation such as training, maintenance, or test flights.

All, including ICAO, have in common that they are focused on negative safety events only although safety research has shown that this focus is narrowed and may not provide sufficient learning opportunities to further improve the aviation system (Flight Safety Foundation, 2021). Despite this caveat the industry was already able to improve its safety performance over time. According to websites (see footnote 2) of the two major manufacturers Airbus and Boeing both the all-accident and the fatal-accident rates significantly reduced until today. Both their statistics are reaching back into the beginning of the commercial jet era at the end of the 1950s when the yearly all accident rate per million flights was as high as 50 and the fatal accident rate as high as nearly 12. By entry of newer generation of aircraft and better technical reliability the all-accident rates could be lowered below 10

[2] On their website IATA provides an interactive safety report enabling certain selection, e.g. the time period starting from 2005 https://www.iata.org/en/publications/safety-report/interactive-safety-report/.
On their accident statistics website Airbus presents a dashboard with accident statistics reaching back to 1958 https://accidentstats.airbus.com. A similar analysis is provided annually by the manufacturer Boeing which provides a statistical summary of commercial jet airplane accidents from 1959 onwards https://www.boeing.com/resources/boeingdotcom/company/about_bca/pdf/statsum.pdf.

and the fatal-accident rates below 4 at the end of the 1960s. The fatal-accident rates have then been constantly decreasing since the 1970s towards their reported value in 2022 of 0.07 making ICAO's goal of zero fatalities by 2030 and beyond to look achievable (Airbus, 2023).

However, as mentioned by a leading aviation journal already in 2017, this goal looked achievable some years ago (Learmount, 2017) after IATA praised the year 2017, with 19 fatalities 'only', as the safest year in civil aviation's history (International Air Transport Association (IATA), 2021). What followed is already etched on the collective memory of the aviation industry due to the major disasters caused by the flawed entry into service of the new B737 MAX aircraft causing 346 fatalities with two crashes. Moreover, other fatal accidents, especially those linked to the mentioned high-risk categories such as runway excursions continue to happen and new high-risk categories such as from turbulence emerge (Flight Safety Foundation (FSF), 2023). This highlights the fact that the effective prevention of fatal accidents and further reduction of the all-accident rate in commercial aviation is neither easy to achieve nor will it be easy to maintain.

1.2 Aviation as a complex socio-technical system

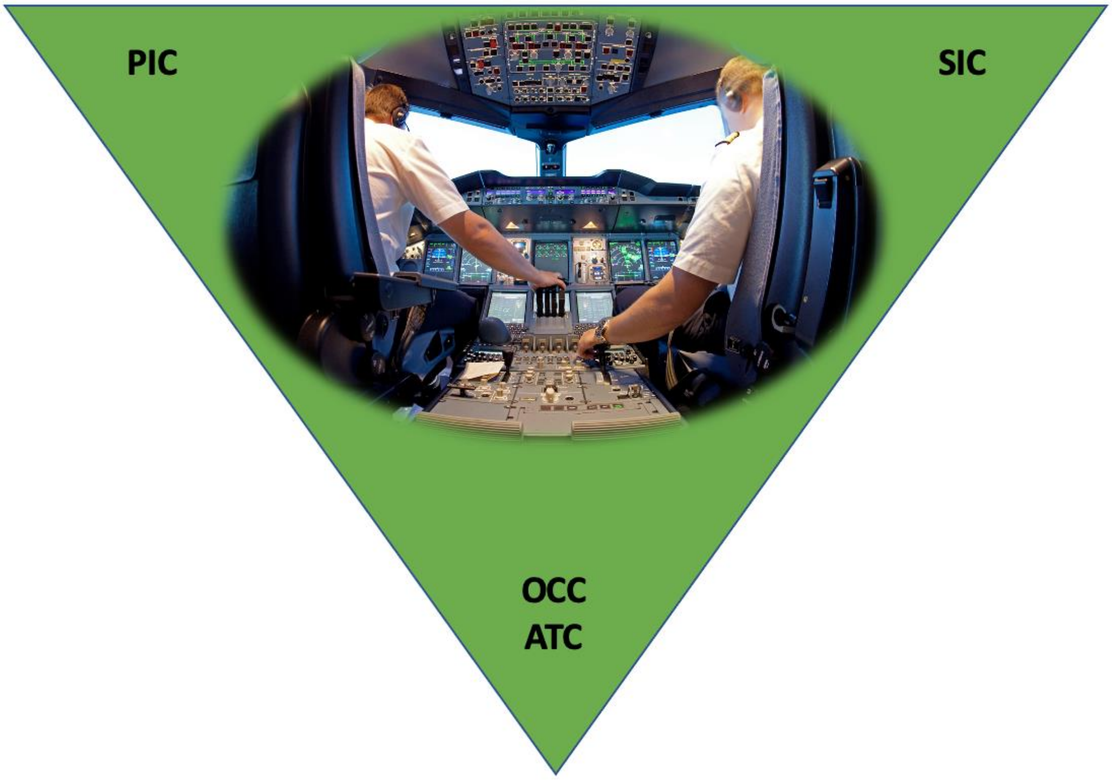
According to Bouarfa, Blom, Curran, & Everdij (2013) the aviation industry is an example of a complex socio-technical system with interactions between a variety of facilities, users, technical systems, human resources, rules, and procedures. This means that the safety performance of commercial aviation is influenced by many variables. Like other high-risk domains such as healthcare, maritime operation, or certain process industries, aviation also has a long tradition in safety research which in the case of aviation reaches back more than a hundred years to the early beginnings of powered flight (Seedhouse, Brickhouse, Szathmary, & Williams, 2020). This research was often overlapping in disciplines containing scientific work in the fields of engineering and different social sciences such as psychology, sociology or cognitive systems engineering, e.g., as performed by the two parallel research fields of High Reliability Organizations (HRO), which studies high-risk-environments ethnographically with an organizational perspective, and Resilience Engineering (RE), which has a more systemic approach focusing on practitioners' expertise, "namely the ability of individuals to cope with complexity, rather than on 'their' errors" (Le Coze, 2016). However, although a lot has changed in aviation over the years in terms of the technology used, traffic volumes and complexity of aviation systems, the initial basic concept of humans interacting with technical systems to deliver a service has not changed at all. Therefore, the main influencing factors for safety in such systems are still the reliability of the technical equipment used and the safety relevant performance of the practitioners using it, or, in other words, the human reliability.

These two main factors – technical and human reliability – are further influenced by other systemic and organizational factors such as the safety culture people are working in, the type of training they receive, the quality of operations manuals, the effectiveness of quality and safety management systems and many others. Therefore, a model used in safety research to describe socio-technical systems has a triangle or funnel shape showing a wider *blunt end* which represents the system regulators, the organizational management (e.g., an airline management) and system developers (e.g., aircraft manufacturers) which influence the opposite smaller edge called the *sharp end* representing the practitioners (e.g., pilots) who act directly at the frontline of operations (Cook & Woods, 1994).

The blunt end normally has only indirect influence on safety performance, e.g., via aircraft and systems design and regulations, policies or procedures for those actually operating the aircraft. The most direct influence on safety performance during actual flight operations is from those practitioners at the sharp end of the aviation system who are in control of the aircraft. These humans are most obviously the pilots who make up the flight crew of an aircraft and whose responsibility is to safely operate the aircraft (International Civil Aviation Organization (ICAO), 2022a, para. 4.5.1). However we can also include in this view the humans in immediate contact with the flight crew who have the possibility of influencing the flight crew's decision-making such as air traffic controllers, whose responsibility is to safely separate the aircraft within the airspace (ICAO, 2016), and the personnel of airline operations control centers (OCC) such as dispatchers or flight operation officers who are responsible for the operational management of their fleets or ground handling staff organizing the ground operation (Bruce, 2011).

The resulting control team can be modeled by a bottom-up triangle (see figure 1-1), showing at the upper end the flight crew, adopting the hierarchical positions of the pilot-in-command (PIC) and the second-in-command (SIC); at the lower edge of the triangle the respective air traffic controller (ATCO), the operations (OPS) person(s), e.g., flight operations officer (FOO) or handling agent who is in contact with the flight crew at a given time. While the respective ATCO, FOO or handling agent usually have further team-members around them and most often direct contact to their respective organization at the blunt end, the two pilots are mostly acting separated from the blunt end taking decisions independently and on their own. For this reason, the role of the PIC has full legal authority to take independent decisions in the interest of safety (International Civil Aviation Organization, 2005, para. 2.3.1). This is the case even during situations with inflight technical issues of the aircraft as the flight crew has usually no or only limited direct contact to maintenance support when inflight. Furthermore, cabin crews, passengers, or other persons in contact with the flight crew have only peripheral influence on the flight crew's safety relevant decision-making but may act as a source of information. Therefore, the flight crew behavior and decision-making when operating the main technical system in aviation - the aircraft - is pivotal for the prevention of accidents in actual flight operations.

Figure 1-1: Aircraft Control Team[3]



[3] Picture: © Adobe Stock 340700009

1.3 Research Objective: understanding flight crew teamwork and decision-making

To support the aviation industry in achieving its goal of zero fatalities by 2030 and beyond, this research aims to investigate the human reliability and contribution to accident prevention at the sharp end of commercial aviation operation. More specifically we investigate the preventative capacity of flight crews on board of the aircraft meaning their safety relevant teamwork and decision-making. As current risk assessments and research on the topic of reduced crew or single pilot operations in commercial aviation are still ongoing and revealing safety concerns (Bailey, Kramer, Kennedy, Stephens, & Etherington, 2017; EASA, 2023), the aircraft generations currently in use for commercial air transport will still be in use 2030. Thereby also the current crew complement of having a minimum of two qualified pilots on the flight deck will prevail at least up to 2030 and even beyond irrespective of further technological evolution regarding possible autonomous or semi-autonomous flight operations in the coming years thereby making the safety relevant teamwork and decision-making a crucial factor for the safety performance of the aviation industry and ICAO’s vision zero.

We investigate the influence of roles and attitudes on flight crews’ teamwork and decision-making based on research findings ranging back to the beginning of the human factor era in high-risk-industries in the 1980s. The research first intends to analyze field data to determine the current influence of flight crews’ teamwork and decision-making on the safety performance of commercial aviation. Further research will include eliciting pilots’ experience in routine operation and their attitude towards teamwork and decision-making on the flight deck.

2 Literature review on flight crew teamwork and decision-making

2.1 The history of Crew Resource Management (CRM)

The importance of effective flight crew teamwork for the prevention of aviation accidents has been confirmed by various findings of accident and incident investigations (Broome, 2011; Jentsch, Barnett, Bowers, & Salas, 1999; National Transportation Safety Board (NTSB), 1994; Orlady, 1982) and safety research (J. E. Driskell & Salas, 1992; James E. Driskell, Goodwin, Salas, & O'Shea, 2006; K. Mosier, Fischer, & Orasanu, 2011; Paris, Cannon-Bowers, & Salas, 2000; Salas, Burke, Bowers, & Wilson, 2001; Salas, Wilson, Burke, Wightman, & Howse, 2006). By the late 1970s research by NASA found that several jet transport accidents in the US involved failures of decision making, leadership, pilot judgment, communication and crew coordination (Cooper, White, & Lauber, 1980). According to Helmreich (2006) this sparked the development of specific teamwork training for pilots, known today as Crew Resource Management (CRM) training and which emerged in the early 1980s (Robert L. Helmreich & Foushee, 2010) to address the human factor in accidents as initially highlighted by Beaty (1969).

As described by Helmreich (2006) CRM training was initially focused on correcting behavioral deficits primed by status hierarchy effects such as a lack of assertiveness by junior Co-Pilots and authoritarian behavior by the pilot in command (PIC) of the flight. One prominent incident, one of many exemplifying the need for this training (see Cooper et al., 1980), was the world's worst ever aviation accident on Tenerife (1977) with 583 fatalities when two B747 aircraft collided on the runway. A contributing factor identified in the investigation[4] of this accident was a steep cross-cockpit-authority gradient manifested in suppression by the PIC of critical concerns raised by the other crew members.

Since its introduction more than four decades ago CRM-training has evolved and, in 1995, became a mandatory training item for all pilots (International Civil Aviation Organization (ICAO), 1998). In 2005 CRM-training was augmented by training in a practical concept called threat and error

[4] https://www.skybrary.aero/accidents-and-incidents/b742-b741-tenerife-canary-islands-spain-1977

management (TEM) to help pilots with their risk-management (Klinect, 2005; Merritt & Klinect, 2006). Threat and Error Management (TEM), also named as the 6th generation of CRM (R. L. Helmreich, 2006), was developed based on insights from observation of pilot's routine work called Line Operation Safety Audit (LOSA) starting in 1994 by the University of Texas in cooperation with a major US airline (Klinect, 2005). During normal routine flights there were trained observers sitting behind a flight crew and watching them how they dealt with threats and hazards regarding their flights. The observer focused especially on crew cooperation as well as on the detection and management of error. Although pilots are annually checked on their safety relevant performance in simulator missions to revalidate their license (license proficiency check) and at least once a year during actual flight operation (operator's line check) it was believed that there might be significant differences between flight crew behavior in a check-situation and on normal routine flights so that an observational style was deemed appropriate to capture real life flight crew behavior in a non-punitive and a research founded environment (Merritt & Klinect, 2006).

Based on their previous research on CRM and their findings from these observations the researchers then developed the TEM-Model which has been introduced by ICAO since 2002 (Raggett, 2017). Within this model the *threats* are defined as external influences that can lead to crew error, e.g., weather, aircraft malfunctions, time pressure, etc., and which have to be managed by the flight crew to prevent *unwanted aircraft states*, e.g., safety relevant events such as aircraft upsets, wrong runway line-ups, hard landings, overruns, etc.

> Remark: This concept was recently evolved further by a joint working group consisting of members of the National Aeronautics and Space Administration (NASA) and Flight Safety Foundation (FSF) incorporating all possible kinds of influences on a system in a complex socio-technical environment. To capture the context and the resilience potential of such systems more comprehensively they enlarged the concept of threats to incorporate all internal and external influences on the system and named those *pressures*. The concept of errors and undesired states was enhanced to incorporate positive reactions on those pressures and their resulting positive outcomes as well. Based on insights from the research discipline of resilience engineering the concept of error was therefore expanded to *adaptations* and the

resulting outcome as *manifestations*. The PAM model can thereby be used either for sharp end operator's risk management, for specific analysis of human behavior at the sharp end as well as for safety analysis from a systems perspective (Flight Safety Foundation (FSF), 2022b). However, this model is too new to be already widespread in aviation so that this research will concentrate on the established TEM-model.

Accordingly, for the past twenty years, CRM/TEM-training covering pertinent cognitive and social skills such as effective communication, workload-management, decision-making, monitoring and intervention has been viewed as comprehensive human factor training and recognized as necessary to safely operate an aircraft. Collectively referred to as non-technical skills (NOTECHS) these skills complement the required technical skills such as manual flying and procedural skills (European Union Aviation Safety Agency (EASA), 2023; Flin, O'Connor, & Crichton, 2008). These technical and non-technical skills, combined with defined appropriate knowledge and attitudes (KSA), make up the set of competencies that all professional pilots, irrespective of their hierarchical position or functional role within a flight crew, are required to be trained and assessed in so as to gain and annually revalidate their pilot license as those globally agreed competencies are presumed necessary for safe aircraft operation (International Civil Aviation Organization (ICAO), 2020b).

2.2 From skills to competencies

The European Aviation Safety Agency (EASA) "has identified CRM as one of the most important safety factor in the domain of Commercial Air Transport (CAT) Aeroplane operations" (EASA, 2017). In their briefing for flight operations inspectors, they provide a comprehensive outline of CRM/TEM in practice which reads as follows:

> "Crew Resource Management (CRM) training encompasses a wide range of knowledge, skills and attitudes including automation management, monitoring and intervention, resilience development, surprise and startle effect management, safety culture and cultural differences; together with all the human dimensions which each of these areas entails. CRM can be defined as a management system, which makes optimum use of all available resources (equipment, procedures and people) to promote safety and enhance the efficiency of flight

operations. CRM training improves the cognitive and interpersonal skills needed to manage the flight. In this context, cognitive skills are defined as the mental processes used for gaining and maintaining situational awareness, for solving problems and for making decisions. Interpersonal skills include communication and a range of behavioural activities associated with teamwork. These skill areas often overlap with each other and they also overlap with the required technical skills. Furthermore, they are not confined to multi-crew in cockpit but also relate to single pilot operations and cabin crew. CRM also expand beyond the cockpit doors as crews interface with other aircrafts, controllers and ground support (operations personnel, airport personnel, ground service providers, etc…)."

Threat and error management (TEM) was introduced in the 1990s. The philosophy of threat and error management is the practice of thinking ahead in order to prevent and mitigate errors and operational threats and manage Undesired Aircraft States (UAS) which can result from these. A foundation of TEM is the acceptance that threats and errors will occur and that they have to be identified and managed. Human error can happen. When errors occur (whether committed by an external agent or by the crew), the flight crew shall detect and respond in an appropriate manner. The behaviours of effective error detection and management are best illustrated by verifying and cross-checking actions and their effects (action- control), and evaluating the quality of decisions made. When errors are not detected or properly addressed, the level of risk increases. TEM has been instrumental in the development of Evidence Based Training (EBT) as a pilot training concept; indeed the EBT pilot competences are used as countermeasures in the TEM model."

Published in 2013, ICAO's manual of evidence-based training contained a list of eight pilot core competencies and their respective behavioral indicators. These are in alphabetical order: *Application of Procedures, Communication, Aircraft Flight Path Management, using automation and using manual control, Leadership and Teamwork, Problem Solving and Decision-Making, Situation Awareness* and *Workload Management* (International Civil Aviation Organization, 2013). The introduction of evidence-based training was a paradigm shift in pilot training as it is rather targeted at developing and assessing the pilot core competencies mentioned above by using certain training topics (evidence from accident and incident investigations) instead of training pilots traditionally in purely task specific scenarios or maneuvers, e.g., to recover and manage an engine failure during take-off or some other given scenarios. The idea behind that change was that the complexity of the aviation system makes it impossible to foresee every possible malfunction or disruption in actual flight operation. Focusing on training pilots on the competencies mentioned above should enable them to cope even with unexpected situations or those they were not specifically trained for (International Civil Aviation Organization, 2013; Lundstrom, 2006).

In the meantime, this concept has evolved further and is now called *Competency Based Training and Assessment* (CBTA) (International Air Transport Association, 2022; International Civil Aviation Organization (ICAO), 2020b). It includes the EBT approach and was augmented by a ninth competency which is *application of knowledge*. The CBTA approach is used as the foundation not only in pilot and instructor training or even in initial pilot selection such as aptitude testing, but for training and checking of other aviation professionals such as air traffic controllers (ATCOs), flight operation officers (FOO) or aircraft maintenance personnel as well. As outlined by IATA "the goal of competency-based training and assessment is to provide a competent workforce for the sake of a safe and efficient air transportation system" (International Air Transport Association, 2022). Regarding pilots these competencies include all knowledge, skills (formerly divided into non-technical and technical skills) and attitudes the industry presumes a pilot requires to safely operate an aircraft. Furthermore, with TEM there is a practical risk management tool for pilots integrated into all training elements.

2.3 Pilot roles

In the interests of providing a coordinated workflow on the flight deck the teamwork of a dyadic flight crew is additionally organized by a prescribed role framework. Firstly, there are the hierarchical positions of the Pilot-In-Command (PIC), also known as Commander[5], and the Second-In-Command (SIC), also known as the Co-Pilot, defining legally that the PIC has the final responsibility for the safe operation of the aircraft (International Civil Aviation Organization (ICAO), 2022b, para. 4.5.1). Secondly, there are two distinct functional intra-cockpit roles, each allocated to one of the two crew members: (1) the pilot flying (PF), sometimes called the handling pilot or pilot on controls and (2) the pilot monitoring (PM), previously - until 2003 called the Pilot-Not-Flying (PNF) (Federal Aviation Administration (FAA), 2003). The PF operates the controls of the aircraft, either manually or via the autopilot system, while the PM is responsible for monitoring the aircraft’s flight path, the aircraft systems and the actions of the PF (Federal Aviation Administration (FAA), 2017; Flight Safety Foundation (FSF), 2014). The decision as to which of the pilots acts as PF and as PM is ultimately up to the PIC, but it is common practice in commercial aviation that the two pilots alternate these roles by each flight sector (Limor & Borowsky, 2020, p. 45; National Transportation Safety Board (NTSB), 1994, p. 37; R. Sumwalt, Cross, & Lessard, 2015, p. 15). In only rare cases is there a requirement that the PIC must act as PF, e.g., during certain low visibility weather conditions or within operation from or to certain airports when mandated by the regulatory authorities of the airport’s state or the aircraft operator (airline), e.g., Aspen or Funchal. Nevertheless, the subsequent flight will then usually be flown with the SIC as PF. Accordingly in approximately one half of the flights performed by commercial flight crews, the higher-ranking and usually (though not always) more experienced crew member, the PIC, performs the role of the PF, and the lower-ranking crew member, the SIC, performs the role of the PM. In the other half of the flights, the roles are reversed.

[5] To act in the role of the PIC on a certain aircraft type, pilots require an airline specific command training and a respective endorsement in their pilot license. On successful completion of such training pilots usually upgrade in their rank within an airline from Co-Pilot to Captain. There is only one Captain rank, but within Co-Pilots there might be different ranks such as Second Officer, First Officer, or Senior First Officer depending on internal airline regulation, flight experience and training. However, these Co-Pilot ranks are not a regulatory requirement. When two Captains (PIC-rated pilots) are flying together one is designated as the PIC and the other as the SIC/Co-Pilot. For flying medium and large transport aircraft, PICs need an Airline Transport Pilot License (ATPL) which requires a minimum of 1500 hours of flight experience (European Union Aviation Safety Agency (EASA), 2022; Federal Aviation Administration (FAA), 2023).

3 Study 1: The influence of pilot roles on aviation safety[6]

3.1 Introduction

Evidence that the quality of the flight crew's team performance depends on the crew assignment to these roles (whether PIC or SIC is assigned as PF or PM) – and that flight safety is affected by the role assignment – has been reported by a number of sources. An early quantitative study was reported by Orlady (1982) who analyzed 245 pilot-reported incidents and found that more near midair collisions, takeoff anomalies, and crossing altitude deviations were reported when the PIC was PF; however more altitude deviations, near midair collisions during approach, and landing incidents occurred when the SIC was PF. Orlady also reported that a monitoring failure by the PM preceded a significant operational anomaly in most cases.

In 1994 the US National Transportation Safety Board (NTSB) reported an analysis of all the (37) major flight-crew-related accidents involving US carriers that occurred between 1978 and 1990 (National Transportation Safety Board (NTSB), 1994). The crew assignment at the time of the accident was determined for all 37 accidents which revealed that in 30 of the 37 accidents the captain was the PF at the time of the accident (National Transportation Safety Board (NTSB), 1994, p. 38). Noting this striking inequality – that in more than 80% of the 37 accidents reviewed the PIC was the PF - the report states that: "The Safety Board was unable to determine any particular significance to, or draw any conclusions from, this finding." Despite this inconclusiveness they also found that among the most common errors identified in these events was the "failure to monitor or challenge the other crewmember's errors"; monitoring and challenging errors were found in the majority (31) of the 37 accident cases.

Further research into the issue of flight crew role assignment was conducted by Jentsch et al. (1999) who analyzed 221 reports of US air carrier incidents in which an error or errors occurred that could have compromised flight safety. The analysis used evaluations made by aviation professionals in order to determine loss of situational awareness and tactical decision-making errors in relation to

[6] This study is already published and contains elements from chapters 2 and 3 from this thesis (Becker & Ayton, 2024).

flight crew role assignment. These authors found that more incidents (142 of 221 [64%]) happened with the PIC as PF than the SIC as PF (79 of 221 [36%]) and also found that PICs lost situational awareness more often and made more tactical decision-making errors when they were acting as PF compared to when acting as the PM which they attributed to the additional workload for the PIC as PF. Jentsch et al. concluded that the combination of aircraft control and problem solving, at times when the situation demands the full use of the PIC's cognitive skills, might be a burden for effective accident prevention and could account for both their observation that incidents occur when the PIC is PF and the NTSB finding that more serious accidents occur when the PIC is PF. Such an effect may be aggravated by their finding, as in the Orlady (1982) and NTSB (1994) studies, of failures of monitoring: "… (Co-Pilots) … seemed to be somewhat ineffective at monitoring and challenging the captains' errors, especially when the captains were at the controls" (Jentsch et al., 1999, p. 11).

In a simulator study exploring the relationship between hierarchical role (PIC/SIC) and functional flight deck position (PF/PM) Palmer, Lack, & Lynch (1995) found that the status difference between PIC and SIC significantly influenced pilot behavior in the functional roles of PF or PM: PICs initiated more in-flight transfers of control (i.e., from PF to PM or vice versa) and gave more direct commands in either functional role more often than SICs.

A systematic review of the empirical literature on the effect of crew role assignment on flight safety outcomes by Beveridge, Henderson, Martin, & Lamb (2018) identified sixteen published papers describing eighteen studies (including three studies discussed above) reporting quantitative behavioral measures of varying kinds: flight simulator experiments; flight deck observations of real flights; behaviors reported via interview/questionnaire; accident/incident reviews. Beveridge, et al.'s review summarized substantial evidence of an effect of crew role assignment on performance measures of three factors directly affecting flight safety – namely the flight crew's monitoring, situational awareness and decision-making. Almost all of the reviewed studies (16 of 18) observed significant relationships between crew role assignment and their outcome measurement. The two studies that did not find any such effect were accident/incident data reviews (Boss, 2012; Khatwa, R.; Roelen, 1997) though two other included accident/incident reviews did report effects (Khatwa & Helmreich, 1999; National Transportation Safety Board (NTSB), 1994).

Beveridge, et al. attributed crew role assignment effects to three specific differences between the PIC and SIC: (1) differences in the cognitive workload of each pilot (when the PIC is PF the cognitive burden of aircraft control restricts the PIC's ability to maintain situational awareness and impacts PIC decision-making); (2) differences in the relative expertise of the PIC and SIC (due to inexperience SICs are more likely to lose situational awareness - critical for effective monitoring and compounding the workload effects on the PIC when the PIC is PF); (3) differences in the relative status and authority of the PIC and SIC (e.g. status and authority factors may inhibit the SIC as PM from communicating any observations or concerns; lack of assertiveness or corrective action by the SIC was cited as significant in the majority of the accident/incident review studies). Beveridge, et al. interpreted the research findings as indicating that there may be a greater number of inherent obstacles for optimal crew performance with the PIC as pilot flying: when the PIC is burdened by cognitively demanding pilot flying duties and the subordinate and often less experienced SIC must perform crucial monitoring and support duties.

Subsequent to the publication of Beveridge, et al.'s review Behrend & Dehais (2020) also found evidence for differences in the behavior of the PIC and SIC in a simulator study on go-around[7] decision-making of 62 commercial pilots. A confederate of the researchers joined each participant in the simulator adopting the opposite rank to the pilot and briefed to behave as neutrally as possible without being proactive in action taking. In a simulated landing, where aircraft displays showed a tailwind speed for which company procedures permitted continuation of the approach, but mandated a go-around decision, only about half the pilots chose to go-around. When the pilot being tested was in the PF-role, decisions did not significantly differ between pilots of different rank; but, when in the PM-role, significantly more of the PICs than SICs initiated a go-around.

The review of the empirical literature indicates that both ineffective flight crew teamwork *per se*, as well as its association with flight crew role assignment, are long-standing safety issues in aviation. The measures taken by the industry to date to address this issue have been the establishment and development of human factor training together with initiatives to highlight the importance of the

[7] A "go around" is when, during an approach or landing the flight crew elects to abort the approach or landing. It is a normal flight procedure for which pilots are trained and assessed annually on a recurrent basis.

role of the PM which includes the re-labelling of the PNF to PM in 2003 as described above (Federal Aviation Administration (FAA), 2003). This change was initially proposed by Sumwalt, Thomas, & Dismukes (2002) who remarked that: “Although this change may seem small, we felt that it was important because it described what that pilot should be doing (monitoring) versus what he/she is not doing (not flying).” Sumwalt et al. (2002) had complained that “...the industry has not made monitoring a primary task. For example, when listing Pilot Not Flying (PNF) duties, typically an operator will list duties such as handling radio communications, operating gear and flaps upon request of the Pilot Flying (PF) and keeping a flight log. Monitoring is not one of the duties primarily listed.” In justifying the name change the FAA (Federal Aviation Administration (FAA), 2003) explicitly acknowledged that “Studies of crew performance, accident data, and pilots’ own experiences all point to the vital role of the non-flying pilot as a monitor. Hence, the term pilot monitoring (PM) is now widely viewed as a better term to describe that pilot.”

The 2003 Federal Aviation Administration paper also advocated the improvement of crew monitoring performance via the development and implementation of effective Standard Operating Procedures (SOPs) to support monitoring and cross-checking functions, by training crews on monitoring strategies, and by pilots following those SOPs and strategies. A section addressing “Crew Monitoring and Cross-Checking" was devoted to developing and implementing SOPs to improve monitoring. The advisory circular communicating these changes superseded and canceled a previous circular (Federal Aviation Administration (FAA), 2000) communicating the SOPs for Flight Deck Crewmembers that only three years earlier had made scant reference to monitoring and no reference at all to the monitoring role of the non-flying pilot. Subsequently further industry initiatives have targeted the monitoring behavior of pilots by promoting strategies for improving monitoring performance (Civil Aviation Authority (CAA), 2013; Flight Safety Foundation (FSF), 2014).

In specific regard to the effects of crew assignment there have also been calls for crew assignment to be altered. Thus, Jentsch et al. (1999) concluded that: "The current results point toward a fundamental yet probably unwelcome change for captains: Having the captain at the controls may not always be the best course of action. Instead, the results seem to indicate that captains should consider letting their FOs fly while they concern themselves with the big picture." (p. 12). A similar recommendation was expressed in a report edited by Sexton (2004) of a multidisciplinary team of academics and specialists from the fields of aviation, surgery, intensive care and nuclear reactor safety from Europe and the USA that was convened to investigate how teams operating in these areas should work together to deal with crisis situations to best effect. This group argued that captains are overloaded with multi-tasking when they try to accomplish both the pilot flying and the pilot in command duties and proposed that: "The data suggest that if a crew encounters a high workload situation when the captain is pilot flying, it is best to cede control of the aircraft to the first officer" (John B. Sexton, 2004, p. 18).

Such thinking has had at least some impact on policy. Jentsch et al. (1999) reported that: "At least one major U.S. airline already advises its captains in training to consider handing over control to the FO in an emergency". They also cited Stewart (1992) who, even before publication of the NTSB (1994) paper, revealed that a major European airline had instituted a policy mandating that, regardless of who is assigned as the PF for the flight, the FO (SIC) is at the controls from the enroute descent point to decision altitude. "Such a procedure leaves the captain more free to monitor the progress of the flight in the more difficult flying environments" (Stewart, 1992, p. 262). (A description of this "monitored approach" procedure can be found on www.picma.info).

In order to determine the extent to which these efforts have mitigated the issue of ineffective flight crew teamwork and its association with flight crew role assignments, we sought empirical data about aviation accidents and incidents covering more recent periods – specifically since CRM training was fully implemented in pilot training (1995) and the label change from PNF to PM had been implemented (2003). The only available accident/incident review carried out subsequent to these reforms (Boss, 2012) found no association between crew assignment and accident frequency; however, this study was rather limited in scope. Although Boss (2012) analyzed all major U.S. air carrier accidents between 1991 and 2010 for which the NTSB conducted a major investigation, this was a small set of events (50) and included only 19 that occurred after the year 2000 – too few to analyze statistically. For this reason, we attempted a larger scale analysis of more events. To that end, as well as studying reports of accidents, we also studied reports of safety critical incidents, as investigated by earlier research (Jentsch et al., 1999; Khatwa & Helmreich, 1999; Orlady, 1982). We analyzed 841 events - substantially more than in any other comparable study[8] - that occurred globally over the period 2000-2020 to investigate whether the association between flight crew role assignment and accident/incident frequency has persisted subsequent to the reforms introduced to address it.

3.2 Method and Data

3.2.1 Database Selection

Like other high-risk-domains the commercial aviation industry routinely analyzes their mishaps to learn lessons for future prevention. The conduct of the investigation and reporting of aviation accidents and incidents is regulated on a global basis stipulating that the state in which the event occurred is responsible for the investigation (ICAO, 2020a). Therefore, records of investigation reports are, initially at least, only collated by national investigation bodies. These often only contain selected events, and, in some cases, reports are not drafted in English making it difficult to gather comprehensive global data for research. Although other industry stakeholders such as aircraft manufacturers, regulators and trade associations also maintain accident and incident databases for safety relevant events only ICAO offers a single central and freely accessible repository that theoretically records all aviation accident and incident reports on a global basis. However, the ICAO database is incomplete: some earlier paper-based records are not all included, and it is also restricted to final reports which are not always produced for every incident or accident as recently highlighted by an independent safety organization (FSF, 2022, p. 5).

Notwithstanding these shortcomings we identified a more comprehensive database managed by the Jet Airliner Crash Data Evaluation Centre (JACDEC) in Hamburg, Germany, which not only collates information about safety relevant events in aviation from various different available sources, (e.g. the official websites of the accident investigation branches sometimes provide interim reports for events with no final report), but also presents the raw data of the reports in a format usable for statistical analysis. The database is professionally maintained, such that the content is based on the

[8] The largest number of events included in any comparable study is 245 incidents (Orlady, 1982). Khatwa & Roelen (1997) analyzed 156 fatal accidents though were only able to identify the PF for 24. Khatwa & Helmreich (1999) analyzed crew assignment for 71 fatal accidents and 5 serious incidents but could only identify PF for 58 of these.

internationally agreed Accident/Incident Data Reporting (ADREP)[9] standards and offers a commercial service for researchers, travelers, and insurance companies. It focusses on commercial aviation including only aircraft with >19 seats. Their website[10] claims that the database includes "all known accidents, hull losses[11], serious incidents and incidents in civil aviation… back to 1969".

According to ICAO's Accident and Incident investigation manual an accident is "an occurrence associated with the operation of an aircraft …. in which a person is fatally or seriously injured…the aircraft sustains damage or structural failure…the aircraft is missing or is completely inaccessible…". While an incident is defined as "an occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation", a serious incident is defined as "an incident involving circumstances indicating that there was a high probability of an accident …". Examples of relevant incidents are listed in this manual and it is further noted in the definition for serious incidents that "the difference between an accident and a serious incident lies only in the result" (International Civil Aviation Organization (ICAO), 2020a).

Note that the JACDEC event categories differ somewhat from those used by ICAO: rather than using the ICAO category of "accidents", JACDEC identifies those accidents where an aircraft was destroyed, or damaged beyond repair, as "Hull losses". Accidents not resulting in a hull loss are included in the category "Serious incidents", which also includes events that are not, by the ICAO definition, "accidents". At the time of our analysis in April 2021 the JACDEC database comprised 17,795 worldwide occurrences which comprised 4,885 events categorized by JACDEC as hull loss accidents, 7,220 as serious incidents and 5,690 as incidents (which included some accidents according to ICAO classification). It therefore provided the largest set of global aviation event data freely accessible for research that we were able to find. Access to this database can be purchased so that information about events can be downloaded from it.

[9] Further information on the details of ADREP and how an accident/incident is defined in aviation can be found in https://skybrary.aero/articles/icao-adrep

[10] https://www.jacdec.de/accident-incident-database/

[11] A hull loss defines an accident where an aircraft was destroyed or damaged beyond repair.

3.2.2 Event selection

Not all events within the database are appropriate for the study of flight crew role assignment. For events occurring during maneuvers on the ground (e.g. runway incursions, collision with other aircraft, vehicles, or obstacles on the taxiway or the ramp) the role assignment is usually fixed to be the PIC as PF, either as a result of the technical design of certain aircraft not providing any technical means for the SIC to taxi the aircraft (e.g. B737 aircraft), or by virtue of company regulation as most airlines in the world prohibit the SIC from controlling the aircraft on the ground even if the technical means for this are available.

Because our focus is on events for which the role assignment is interchangeable between the PIC and SIC, we therefore excluded those ground events not associated with takeoff or landing operations. We also excluded all events exclusively attributed to technical malfunctions or emergencies[12] as the primary accident factor in the database so that no obvious pilot actions were identified with either the cause or the outcome of the events. We also excluded all events in which more than a single aircraft was involved (e.g., for air traffic control related events such as loss of separation or other air proximity events) to avoid the complication of multiple determinations of role assignments for a single event. This left us with events in the database coded as runway excursions (RE), collisions with obstacles during take-off or landing (CTOL), abnormal runway contact (ARC), under- or overshoots (USOS), controlled flight into terrain (CFIT), loss of control inflight (LOC-I) and low altitude (LALT)[13]. After application of these exclusion criteria and restricting events to those in the period 2000-2020 we obtained records for 3,335 events, 405 of which were coded as incidents, 1,931 as serious incidents and 999 as hull losses, together accounting for 11,780 fatalities.

We then applied three further data exclusion criteria: firstly we excluded all military aircraft; secondly, to ensure that we only investigated events involving civil commercial aircraft operated by an airline flight crew consisting of at least two qualified pilots, we excluded all small aircraft

[12] JACDEC allows to filter and select events with technical malfunctions or inflight fires only as it uses the official ADREP acronym for technical aircraft malfunctions such as System Component Failures (SCF) - non-power plant (NP) and power plant (PP) and Non-Impact Fires (F-NI).

[13] According to the International Civil Aviation Organization (ICAO) the accident types of RE, CFIT and LOC-I represent the highest accident frequency and fatality risk in commercial aviation (International Civil Aviation Organization (ICAO), 2020c, p. 27).

(Maximum Take-off Weight < 15t, e.g. small turboprop or business jet aircraft) as some of these might also be operated by a single pilot or the type of operation may not be comparable to commercial airlines in terms of pilot qualification and training; thirdly we excluded aircraft requiring additional crew members such as navigators or radio operators to ensure comparability of events regarding task sharing and teamwork. This left a final sample of 2,293 events comprising 370 Incidents, 1,459 Serious Incidents and 464 hull losses which together accounted for 9,256 fatalities.

3.2.3 Event coding

Our analysis studied the relative frequency of events as a function of four factors:

(1) *Role Assignment* is a binary variable reflecting whether the PIC or SIC was the PF as gleaned from the context or investigation reports. We read all the investigation reports and event descriptions of the 2,293 events. Given the limitations of the information provided in the event reports (e.g., not always containing relevant information on the role assignment as it is still not a mandatory investigation requirement) we were able to make assessments of *role assignment* for 841 (36.6%) of the events. For those events when, during the flight, there was a planned or unplanned role change from the original role assignment (n=55) we determined the PF as the pilot whose control input was consequential for the event. E.g., if after a bounced landing by the SIC the PIC took over control and subsequently crashed the aircraft, we coded the PIC as PF. When the SIC took away control from the PIC it was coded as SIC as PF.

The aircraft in our sample of events have flight controls at both pilot stations though, normally, only the PF operates her/his controls. However, there were some cases of *dual input* (n=55) when both the PF and the PM were acting on their respective controls simultaneously. These were coded as PIC as the PF. Dual inputs can either be mutual, e.g., by both pilots pushing the controls such as the aircraft elevator or brakes in the same direction (n=33), or in opposition, e.g., by pilots pushing the controls in different directions (n=22), which is possible on most aircraft equipped with an electronic side stick as aircraft control.

(2) *Mode of Operation* is a binary variable reflecting whether the aircraft was in *Normal Operation* or *Non-Normal Operation* as defined by the aircraft's technical and flight status. *Non-*

Normal Operation was indicated when the aircraft was not technically airworthy or there was an aircraft related emergency (i.e., inflight smoke or fire). In the absence of any technical failure or aircraft related emergency the event was deemed to have occurred in *Normal Operation.* For the purposes of this study, we considered threats due to weather, terrain or time pressure, provided there was no aircraft related technical malfunction or emergency, as occurring in normal operation: they should always be safely manageable by a well-trained flight crew using given TEM-strategies. Although some aircraft operating manuals include certain flight maneuvers (such as windshear- or upset-recovery, terrain- or traffic avoidance or rejected take-off procedures) in their non-normal operation section these maneuvers are applicable regardless of whether the aircraft is technically airworthy or not. Accordingly, we coded events in which these maneuvers were used as *Non-normal* only when the aircraft was not technically airworthy or there was an aircraft related emergency (i.e., inflight smoke or fire). We were able to determine the *mode of operation* for 1,076 (46.9%) of the 2,293 events in our sample.

(3) *Teamwork Behavior* is a binary variable indicating whether or not “poor CRM” or “poor teamwork” was a contributory or causal factor in the event. This may be explicitly referred to in investigation reports but in some cases, when no such direct information or conclusion was provided in the report, but when, in the opinion of the first author, sufficient information included in the investigation report or event description clearly merited it, a judgment was made by the researcher that *Teamwork Behavior* was an issue in the event. Given the dyadic nature of the flight crew setup this included cases when mutual intervention was obviously missing or ineffective, but nevertheless was evidently realistically possible, e.g., when errors or deviation from standard operating procedures by one pilot occurred but were not trapped and mitigated by the other pilot although he/she had an option to do so. Notwithstanding such cases it should be noted that errors by one pilot not trapped and mitigated by the other pilot were not necessarily coded as a failure of *Teamwork behavior;* if, for example, there was insufficient time or opportunity for a mitigating response by the other pilot then poor CRM or poor teamwork would not be recorded. The researcher is an active airline pilot with experience as an airline safety manager, accident investigator, training captain and human factors facilitator. The reliability of these judgements was tested and confirmed by comparison with

judgments made by an independent expert on a subset of the judged cases (see details described below). We were able to determine the *teamwork behavior* for 834 (36.4%) of the 2,293 events in our sample.

(4) *Preventability* is a binary variable denoting whether or not there was a realistic opportunity for preventing the event by pilot behavior, either by an individual pilot or by the flight crew team. The concept of pilot-preventable events was derived from the healthcare domain. More than twenty years ago the American Institute of Medicine (IOM) issued a report entitled “To Err is human: building a safer health system” that revealed findings from research in patient safety establishing that thousands of Americans died in hospitals each year because of *preventable adverse events* (Kohn, Corrigan, & Donaldson, 2000).

Being a compilation of several individual studies preventable adverse events were therefore defined in several ways: one study by Andrews et al. (1997) presented in the IOM-report defined adverse events as situations in which “an inappropriate decision was made when, at the time, an appropriate alternative could have been chosen”. Other studies such as by Brennan et al. (1991) defined an adverse event “as an injury caused by medical management rather than by the underlying disease or condition of the patient” and included practitioner negligence as well. Such injuries were called *iatrogenic* meaning that they did not originate from illness, but from medical error by practitioners.

At first sight this might look comparable, in some respects, to the term *pilot error* often used in association with aviation events. However, the view of human errors, their origin and mitigation in high-risk-domains such as aviation or healthcare, has significantly evolved in recent years. Since the insights delivered by the research domain of resilience engineering (RE) it has been claimed that it is always necessary to look behind human error in order to understand and learn from the systemic context of events instead of using simplistic solutions such as labeling ‘pilot error’ as a cause for events (R.K. Dismukes, Berman, & Loukopoulos, 2007, p. 290; Woods, D. D., & Cook, 1999; Woods, Dekker, Cook, Johannesen, & Sarter, 2010).

While the motivation and legitimacy for accident and incident analyses in the aviation domain has always been focused on future prevention instead of apportioning blame or liability (International

Civil Aviation Organization (ICAO), 2020a, secs. 3–1), the focus on individual error by physicians instead of focusing on systemic issues was motivated in the healthcare domain, at least at the time of the studies presented in the IOM-report, by a culture influenced by liability claims against hospitals and a presumption that physicians could be expected to function without error (Brennan et al., 1991; Leape, 1994). By transferring the idea of preventable adverse events to aviation we certainly do not wish to re-introduce this outdated thinking on human error.

Nonetheless, introducing a distinction between preventable and non-preventable events based on practitioners' decision-making and their risk- and error-management might serve as an additional means to better capture and categorize the context of events so that the safety performance of a high-risk-domain, in this case aviation, and any possible gap towards a realistic vision of zero fatalities or even zero accidents can be assessed more comprehensively.

Preventability was determined from investigation reports; events were coded as pilot-preventable if the report explicitly indicated this - e.g., by stating "the pilots should have initiated a go-around" or the "accident could have been prevented". As with the coding of *Teamwork Behavior*, in cases when no such explicit information or conclusion was provided a judgment was nonetheless made by the first author that an event was pilot-preventable when information included in the investigation report or description of the event made this clear. Examples include cases when it was obvious that a more risk-averse option or a realistic option for error prevention or effective mutual intervention had been available to the flight crew. We were able to determine the *preventability* for 907 (39.6%) of the 2,293 events in our sample.

Complete listings of the downloaded events selected for each of the reported analyses are available online at OSF https://osf.io/h5aj8/files/osfstorage/64c69585c7ab290ca3d4df62.

3.2.4 Data coding reliability

To cross-check the reliability of the data coding assessments a sample of 32 events was assessed by an independent expert briefed as to the determinations that should be made according to the event coding detailed above. The independent expert is an active and experienced airline and 'check pilot' (senior examiner for Airbus and Boeing aircraft types). The expert's assessments for

Mode of operation, *Crew assignment* and *Preventability* were in complete (100%) agreement with the researchers' assessments. For *Teamwork Behavior* two events were rated differently resulting in high (93.8%) but somewhat less than perfect levels of agreement. Although the assessments of *Teamwork/Behavior* and *Preventability* may be critiqued as judgmentally determined, the high levels of inter-rater agreement support the validity of these assessments.

3.3 Results

3.3.1 Role assignment

Table 3-1 depicts the 841 events in our sample of 2,293 events for which we were able to determine the crew role assignment. Given the assumed equal distribution of flight sectors between the PIC and SIC, there is no reason to expect any difference in the frequency of events as a function of the two different possible role assignments - unless the crew role assignment itself influences the propensity for accidents and serious incidents. Nonetheless, plainly the two proportions of events are substantially different. Almost two and a half times as many events occurred when the PIC was acting as PF (n = 597, 71.0%) as when the SIC was acting on the controls (n = 244, 29.0%). A binomial test for equal proportions confirms that the events were not equally frequent for each role assignment: significantly more events occurred when the PIC was acting on the controls, $p < .001$.

Table 3-1: Frequencies (n) and Percentages (%) of Events and Fatalities by Role Assignment

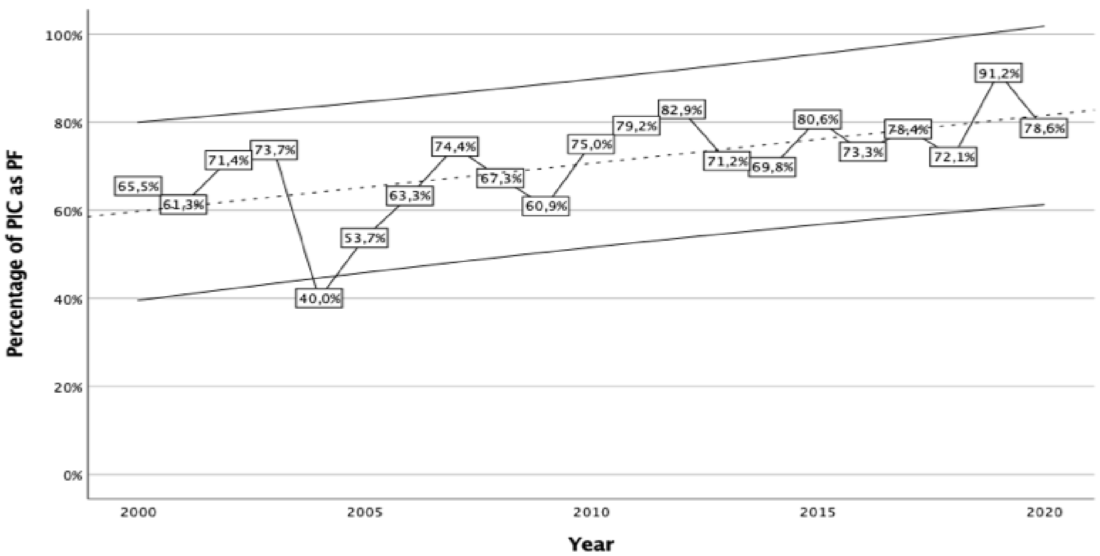
	Role Assignment											
	Events						Fatalities					
	PIC as PF		SIC as PF		TOTAL		PIC as PF		SIC as PF		TOTAL	
Event type	n	%	n	%	n	%	n	%	n	%	n	%
Hull losses	163	79.9	41	20.1	204	100	4078	76.7	1239	23.3	5317	100
Serious Incidents[a]	394	68.2	184	31.8	578	100	1	-	0	-	1	-
Incidents[a]	40	67.8	19	32.2	59	100	0	-	0	-	0	-
All events	597	71.0	244	29.0	841	100	4079	76.7	1239	23.3	5318	100

[a] Percentages of fatalities for serious incidents and incidents are not computed due to a lack of data.

Binomial tests confirm that this difference is also statistically significant for each event type depicted in table 3-1; significantly more hull losses, significantly more serious incidents and significantly more incidents occurred when the PIC was acting on the controls than when the SIC was acting on the controls (Hull losses: PIC as PF (n = 163, 79.9%), SIC as PF (n = 41, 20.1%), $p < 0.001$; Serious incidents: PIC as PF (n = 394, 68.2%), SIC as PF (n = 184, 31.8%), $p < 0.001$, Incidents: PIC as PF (n = 40, 67.8%), SIC as PF (n = 19, 32.2%), $p = 0.009$). Nevertheless, and indicating that more serious outcomes result when the PIC is PF, the association between the role assignment and the frequency of events is stronger for hull losses than for serious incidents ($\chi^2(1, N = 782) = 10.13$, $p = 0.001$).

To investigate whether the role assignment effect had changed over the 21-year period covered by our dataset we plotted the percentage of events when the PIC was acting as PF for each year over the period 2000-2020 (see Figure 3-1). Counter to the expectation that reforms to crew resource management and the pilot label change would reduce the role assignment effect, Kendall's tau revealed a significantly *increasing* monotonic trend in the annual proportion of events where the PIC was PF (n = 21) over the period 2000-2020 ($\tau_b = 0.46$, $p = .003$).

Figure 3-1: Percentages of the PIC as PF per year



Note: The dotted line depicts the regression fit line. The two solid lines depict the 95% confidence interval around that line.

Within the sample of 841 events for which we were able to determine the role assignment, 90 events (10.7%) were fatal, accounting for 5,318 fatalities; the other 751 events (89.3%) were non-fatal. Binomial tests show that significantly more fatalities result with the PIC as PF (n = 4,079) than with the SIC as PF (n = 1,239), $p < .001$, and that the PIC was acting as PF significantly more often in both event types (Fatal: PIC as PF (n = 72, 80.0%), SIC as PF (n = 18, 20.0%), $p < .001$; Non-Fatal: PIC as PF (n = 525, 69.9%), SIC as PF (n = 226, 30.1%), $p < .001$. The pattern of the PIC as PF is also significantly stronger for fatal than for non-fatal events, ($\chi^2(1, N = 841) = 3.98$, $p = 0.046$) consistent with the notion that more serious outcomes result when the PIC is PF. Given the strong manifestations of a crew role assignment effect on events, fatal events and fatalities, it is not surprising that Mann-Whitney U tests indicate that the number of fatalities *per event* (*M* = 6.3, *SD* = 27.6) differs significantly by role assignment for all events in the sample (PIC as PF = 6.8, SIC as PF = 5.1), z = -1.99, $p = .047$. However, there is no such difference in the number of fatalities per event (*M* = 59.1, *SD* = 63.6) for the smaller set of 90 fatal events (PIC as PF = 56.7, SIC as PF = 68.8), z = 0.06, $p = .956$.

We also investigated when *changes* of role assignment had been initiated, either by an explicitly announced change of role assignment or *de facto* by simultaneous input on the controls by both pilots (dual input). In aggregate a total of 110 (13.1%) of the 841 events for which we were able to determine the role assignment involved role changes; 94 of these (85.5%) were events where the SIC had originally been the PF at the controls. In half (55) of the 110 events there was an announced control change from one pilot to another. Consistent with the notion that at least some PICs judge it best that they, rather than the SIC, be at the controls in demanding situations (but inconsistent with the recommendation of Sexton (2004), the vast majority of these announced control changes involved the PIC taking control from the SIC (52, 94.5%) rather than vice-versa (3, 5.5%) - a difference that a binomial test reveals is unlikely to be due to chance ($p < .001$). For the other 55 of the 110 events there was a deviation from the prescribed division of tasks between the PF and PM such that both pilots gave input to the controls *simultaneously*: for 33 of these events both pilots were acting on their controls in the same direction (e.g. during braking on the runway during landing or inflight when deemed necessary to aggregate a control input) and in 22 events they were acting in opposition to each other, despite the fact that aircraft operating procedures do not allow contradictory control inputs by the pilots but require the PM to *officially* take over control by announcing “I have control”. For both types of dual control cases the SIC was originally assigned as PF in significantly more of these events: for the 33 events in which we detected input in the same direction the SIC was originally the PF in 25 (75.8%), $p = 0.005$; for the 22 events in which we detected contradictory control inputs the SIC was originally the PF in 17 (77.3%), $p = 0.017$.

Note that the presence of inflight role changes does not allow for the role assignment effect to be substantially attributed to changes of control such that the PIC spuriously more often appears to be the PF because of inflight role changes: even allowing for all of the 107 inflight role changes that resulted in the PIC being coded as PF and considering these as SIC as PF, there are still significantly more events with the PIC as PF than the SIC as PF (PIC as PF = 490; SIC as PF = 351, $p < .001$).

Finally, given that the logic of our inferences regarding the role assignment effect depends critically on the assumption that the two crew assignments (PIC as PF, SIC as PM and SIC as PF, PIC as PM) operate equally frequently, we exploited an opportunity to subject this assumption to empirical test. One way this might be evaluated is by looking at the distribution of crew assignments for events that are independent of any pilot behaviors – this should reflect the underlying distribution of crew assignments. For example, assuming that technical failures occur independently of crew role assignment, the relative frequencies of the two different crew assignments for a sample of events involving technical failures should reflect the actual distribution of crew assignments in the population. Recall however that, in compiling our dataset of events we deliberately excluded all events exclusively attributed to technical malfunctions where no pilot actions were identified with either the cause or the outcome of the event. Yet, one category of event that can be reasonably assumed to be unrelated to role assignment - and hence to be unaffected by any selection effects stemming from pilot behavior - is bird or other wildlife strikes.

Within our sample of 841 events for which we were able to determine the crew role assignment, only 2 events were recorded by JACDEC as involving bird or wildlife strikes, therefore we conducted a separate download of JACDEC events that involved bird or wildlife strikes (n = 421). However, only 38 of those events had investigation reports available so we additionally searched another event database (www.skybrary.aero) for bird or wildlife strike events over the same time period (2000-2020). As these kinds of events are only infrequently investigated in depth, we were able to determine the role assignment for only 30 of the total 61 events with a report available. Given the assumption that a bird or wildlife strike event is independent of pilot behavior we have no reason to hypothesize that they would be more prevalent with one role assignment than another - unless that role assignment was in fact more prevalent in practice. In short, the relative frequency of bird strikes for each crew assignment should reflect the relative frequency of each role assignment in practice.

When we investigated the role assignment in these 30 bird or wildlife strike events, we found that there were 16 events occurring with the SIC as PF and 14 with the PIC as PF. A binomial test showed no statistically significant difference between the two role assignments, $p = .856$. This confirms our assumption, consistent with airline practice of alternating crew role assignment, that each role assignment is indeed operated equally often in commercial aviation practice.

3.3.1.1 Role Assignment by geographic region

Our analyses of the role assignment effect are based on a global sample of events. Nonetheless the role assignment effect might not be a global phenomenon; for example, it might, conceivably, be restricted to some parts of the world. To investigate this issue and elicit possible geographical differences in the role effect we split the sample based on ICAO defined regions. ICAO has segmented the world into the following eight regions[14] (in alphabetical order): Africa-Indian Ocean (AFI), Asia and Middle East (MID / ASIA), Caribbean (CAR), European (EUR), North American (NAM), North Atlantic (NAT), Pacific (PAC) and South American (SAM). As the role effect might possibly vary as a function of possible influences stemming from different norms and cultures within different airlines around the world, we determined, for each of the 841 events, the location of the operator's (airline's) headquarters and sorted them to the relevant regions. For simplicity we diverted slightly from the original segregation of ICAO by dropping the NAT and PAC regions (the only affected headquarters (Iceland) was included in Europe) and merged the CAR and

[14] https://www.skybrary.aero/articles/icao-regions

SAM regions to a single SAM region. Additionally, we removed the southern part of the EUR Region, within which ICAO includes some of Africa's most northern countries, so that Europe only included the European continent and combined it with AFI so as to include the whole African continent. Table 3-2 exhibits the findings which confirm by means of binomial tests the presence of a statistically significant effect in all regions in the world, $p < .01$.

Table 3-2: Frequency of Events by Role Assignment and Geographic Region

	Role Assignment		
	PIC as PF	SIC as PF	TOTAL
Region	Events	Events	Events
Africa	41 (75.9%)	13 (24.1%)	54 (100%)
Asia and Middle East	204 (76.1%)	64 (23.9%)	268 (100%)
Europe	214 (66.9%)	106 (33.1%)	320 (100%)
North America	103 (65.6%)	54 (34.4%)	157 (100%)
South America and Caribbean	35 (83.3%)	7 (16.7%)	42 (100%)
Total	597 (71.0%)	244 (29.0%)	841 (100%)

3.3.2 Mode of Operation

As shown in table 3-3 the majority - 777 (72.2%) - of the 1,076 events for which we were able to determine the mode of operation (normal or non-normal) occurred during normal operation, meaning with technically airworthy aircraft and no emergency present; only 299 (27.8%) of the events occurred in the presence of any aircraft-related abnormality or emergency; a binomial test for equal proportions showed that this difference was statistically significant, $p < .001$. Another binomial test revealed that significantly more of the 6102 fatalities occurred in normal operation (4,181, 68.5%) than in non-normal operation (1,921, 31.5%), $p < .001$.

Table 3-3: Frequencies (n) and Percentages (%) of Events and Fatalities by Mode of Operation

Mode of Operation

	Events						Fatalities					
	Normal		Non-Normal		TOTAL		Normal		Non-Normal		TOTAL	
Event type	n	%	n	%	n	%	n	%	n	%	n	%
Hull losses	158	60.5	103	39.5	261	100	4179	68.5	1920	31.5	6099	100
Serious Inc.[a]	551	77.3	162	22.7	713	100	2	-	1	-	3	-
Incidents[a]	68	66.7	34	33.3	102	100	0	-	0	-	0	-
All events	777	71.0	299	29.0	1076	100	4181	76.7	1921	23.3	6102	100

[a]Percentages of fatalities for serious incidents and incidents are not computed due to a lack of data.

Recall however that in our selection of events as described in section 3.2.2 we excluded all events attributed solely to technical aircraft malfunctions and other emergencies such as onboard fires when we downloaded the set of events to analyze the role assignment effect. As a result, we were not able to determine how many of the events solely attributed to technical failures or emergencies as primary event causation were excluded. As these events would plainly all qualify as occurring in non-normal operation their exclusion will clearly affect our measure of the proportions of events occurring in normal and non-normal operation. Therefore, in order to estimate the proportions of events in normal and non-normal operation that would have resulted had we not excluded all events attributed solely to technical aircraft malfunctions and emergencies, we undertook analysis of a separate sample of events previously downloaded from the JACDEC database. In contrast to the sample used for our analyses this other dataset included all types of accidents and incidents over the period 1977 to 2019 and comprised 13,142 events. We then applied the same selection criteria which we had used to retrieve our sample of 2,293 events underlying the analyses presented in this paper. Accordingly, we excluded: events occurring during maneuvers on the ground; ground events not associated with takeoff or landing operations; all events in which more than a single aircraft was involved; all small aircraft (Maximum Take-off Weight < 15t); all military aircraft; events prior to the time period 2000-

2019. This resulted in a sample of 4,496 events of which only 530 (11.8%) events were solely attributed to technical failures or inflight fires. Assuming a similar proportion of events were excluded from our initial sample of 3,335 events (see 3.2.2) would imply it excluded 394 events and so, together with the 1,076 events for which we were able to determine the mode of operation, would have resulted in a total of 1,470 events with 777 (52.9%) occurring in normal operation and 693 (47.1%) occurring in non-normal operation. After allowing for the events excluded for being solely attributed to technical failures or inflight emergencies a binomial test shows that significantly more events occur in normal than in non-normal operation (p = .03).

It may also be noted that we were only able to establish mode of operation for 1,076 of the 2,293 total events. We have no way of estimating the proportions of the two modes of operation for the other 1,217 events - short of assuming it is the same as for those 1,076 events where we could identify the mode of operation. While we have no specific basis for either adopting or challenging it, that would, arguably, not be a safe assumption. Although one might expect technical failures and onboard emergencies to be routinely recorded in accounts of events whenever they occur, we have not treated the absence of information in event records as being indicative.

Although unlikely, assuming that *all* 1,217 of the 1,217 events for which we were unable to determine the mode of operation occurred in non-normal operation and combining those events with the 394 events that we estimate were excluded as events solely attributed to technical failures produces, from a total of 2,687 events, 1,910 (71.1%) in non-normal operation and 777 (28.9%) in normal operation. Hence, after making allowances for potential sampling errors on our analyzed set of events, it is possible that a minority of events occur in normal operation; nevertheless, the conclusion that operation with technically airworthy aircraft and in the absence of any onboard emergency is not without risk is inescapable.

3.3.2.1 Mode of operation and role assignment

We were able to determine both the mode of operation and the role assignment for 837 events (see table 3-4). The PIC was the PF in proportionately more events in both non-normal operation (76.3%) and normal operation (69.6%) but there was no statistically significant association between role assignment and mode of operation for all events (χ^2(1, N = 837) = 2.74, p = .098) or within any of the three types of event: Hull losses (χ^2(1, N = 203) = .99, p = .319); Serious incidents (χ^2 (1, N = 575) = 2.31, p = .128); Incidents (χ^2 (1, N = 59) = 2.16, p = .141).

Table 3-4: Frequencies (n) and Percentages (%) of Events by Mode of Operation, Role Assignment and Event type

	Mode of Operation											
	Normal Operation						Non-Normal Operation					
	PIC as PF		SIC as PF		TOTAL		PIC as PF		SIC as PF		TOTAL	
Event type	n	%	n	%	n	%	n	%	n	%	n	%
Hull losses	112	81.8	25	18.2	137	100	50	75.8	16	24.2	66	100
Serious Incidents	330	66.8	164	33.2	494	100	61	75.3	20	24.7	81	100
Incidents	32	64.0	18	36.0	50	100	8	88.9	1	11.1	9	100
All events	474	69.6	207	30.4	681	100	119	76.3	37	23.7	156	100

Given the method we adopted to determine the PF as the pilot whose control input was consequential for the event, the finding that the role-assignment effect did not vary with mode of operation could be viewed as somewhat surprising. If the longstanding recommendation in aviation cited earlier that, whenever a crew encounters a high workload situation it is best to have the SIC on the controls so that the PIC can devote their attention to the overall *big picture* (Jentsch et al., 1999; John B. Sexton, 2004) was widely implemented, it might be expected, given the non-routine nature of non-normal operation, that the proportion of events with the SIC as PF would be higher in non-normal operation than normal operation. Of course, complex and high workload situations may also arise in normal operation (e.g., due to weather, time pressure or demanding air traffic control clearances); moreover, some non-normal situations might be perceived as non-complex or easy to handle. Nonetheless, given the unambiguous indicators of non-normal operation, one might expect the crew to more frequently implement a change of the role-assignment in non-normal operation when the PIC was PF.

Accordingly, in order to investigate this further, in addition to the analysis of role changes reported in section 3.3.1 above, which comprised all events for which we were able to determine the role assignment, we also investigated changes of role assignment by mode of operation. Within the 782 cases for which we were able to determine both the mode of operation and whether or not there was an announced change of control, we found 633 events in normal operation of which 38 (6%) involved announced role changes, 36 (94.7%) from the SIC to the PIC and only 2 (5.3%) from the PIC to the SIC. Of the 149 events in non-normal operation 17 (11.4%) involved announced role changes; of those role changes 16 were from the SIC to the PIC and only 1 from the PIC to the SIC. If pilots were compliant with the Sexton (2004) recommendation one would expect to see more announced control changes from the PIC to the SIC. In fact, we found quite the opposite: nearly all announced control changes in both modes of operation were from the SIC to the PIC. These findings indicate that pilots refrain from adopting the recommendation, perhaps due to a lack of knowledge about the recommendation. The fact that the announced control changes are nearly all in the opposite direction to that recommended, and that there are proportionately more such control changes in non-normal operation than normal operation, suggests a lack of trust by PICs in the competencies of the SIC as PF or perhaps, as especially in non-normal operation, a feeling of responsibility or perceived social expectation in PICs given their role as the accountable pilot. Despite being numerically fewer there are proportionately more announced control changes in non-normal operation than normal operation ($\chi^2(1, N = 782) = 5.39$, $p = .02$).

3.3.3 Teamwork Behavior

We were able to determine coding of the teamwork behavior variable for 834 of the 2,293 events (see table 3-5). Binomial tests for equal proportions confirmed that the flight crew's teamwork behavior was a contributory factor in a significantly larger proportion of events - 730 (87.5%) - than in events showing no issues with flight crew's teamwork behavior - 104 (12.5%), $p < 0.001$. This same difference is evident in the same comparison for each of the three event types: Hull losses (192, 88.9% vs 24, 11.1%, $p < .001$); Serious incidents (495, 86.7% vs 76, 13.3%, $p < .001$); Incidents (43, 91.5% vs 4, 8.5%, $p < .001$).

Table 3-5: Frequencies (n) and Percentages (%) of Events and Fatalities by Teamwork Behavior

	Teamwork Behavior											
	Events						Fatalities					
	Issue		No Issue		TOTAL		Issue		No Issue		TOTAL	
Event type	n	%	n	%	n	%	n	%	n	%	n	%
Hull losses	192	88.9	24	11.1	216	100	5491	96.3	212	3.7	5703	100
Serious Incidents[a]	495	86.7	76	13.3	571	100	1	-	0	-	1	-
Incidents[a]	43	91.5	4	8.5	47	100	0	-	0	-	0	-
All events	730	87.5	104	12.5	834	100	5492	96.3	212	3.7	5704	100

[a]Percentages of fatalities for serious incidents and incidents are not computed due to a lack of data.

We were able to determine *both* teamwork behavior and role assignment for 779 of the 834 events (see table 3-6).

Table 3-6: Frequencies (n) and Percentages (%) of Events by Teamwork behavior, Role Assignment and Event type

	Teamwork Behavior											
	Issue						No Issue					
	PIC as PF		SIC as PF		TOTAL		PIC as PF		SIC as PF		TOTAL	
Event type	n	%	n	%	n	%	n	%	n	%	n	%
Hull losses	143	82.2	31	17.8	174	100	12	57.2	9	42.8	21	100
Serious Incidents	322	68.2	150	31.8	472	100	49	71.0	20	29.0	69	100
Incidents	26	66.7	13	33.3	39	100	3	75.0	1	25.0	4	100
All events	491	71.7	194	28.3	685	100	64	61.5	30	38.5	104	100

Somewhat at odds with the notion that teamwork is impaired when the PIC is PF, we found no evidence for an association between *role assignment* and *teamwork behavior* over all events (χ^2(1, N = 779) = .52, p = .47). Nevertheless, and although an analysis split by the event types also revealed no association between *role assignment* and *teamwork behavior* for either incidents (χ^2(1, N = 43) = .12, p = .74) or serious incidents (χ^2(1, N = 541) = .22, p = .64), there is indeed a significant association between *role assignment* and *teamwork behavior* for the more serious 195 events involving hull losses, χ^2 (1, N = 195) = 7.21, *p* = .007. This association is such that the unequal preponderance of the two role assignments (more events with the PIC as PF than the SIC as PF) is more extreme in events with a teamwork issue than the events where there was no teamwork issue. This finding is consistent with the notion that teamwork is impaired when the PIC is PF.

We were also able to determine both the teamwork behavior and mode of operation for 831 events. 678 (81.6%) of these were in normal operation and for the vast majority (646, 95.3%) of the 678 events in normal operation there were issues with the flight crews' teamwork behavior. By contrast, among the 153 events happening in non-normal operation, only just over half (82, 53.6%) of the events had issues with the flight crews' teamwork behavior. This significantly greater association of teamwork behavior as a contributory factor for events in normal operation (χ^2 (1, N = 831) = 199.77, $p < .001$). Although this might be taken as evidence that flight crew teamwork is better in response to a technical malfunction or emergency, this association might also be a result of a selection effect acting on the set of events. Events in normal operation may be more likely to be tagged as showing poor teamwork because they originated as a *consequence* of poor teamwork than events in non-normal operation where a technical failure or onboard emergency would likely be the primary origin of the event.

3.3.4 Preventability of Events

We were able to determine the preventability for 907 events (see table 3-7). Binomial tests for equal proportions confirmed that, across all occurrence types, significantly more events - 797 (87.9%) - were deemed pilot-preventable than not pilot-preventable - 110 (12.1%), $p < 0.001$. This same pattern was also confirmed for each of the three event types: Hull losses ($p < 0.001$); Serious incidents ($p < 0.001$); Incidents ($p < 0.001$). The vast majority of the 5715 fatalities (5501, 96.3%) are due to preventable events rather than the events deemed not preventable (214, 3.7%).

Table 3-7: Frequencies (n) and Percentages (%) of Events and Fatalities by Preventability

	Preventability											
	Events						Fatalities					
	Preventable		Not Prevent.		TOTAL		Preventable		Not Prevent.		TOTAL	
Event type	n	%	n	%	n	%	n	%	n	%	n	%
Hull losses	203	88.2	27	11.8	230	100	5500	96.3	212	3.7	5712	100
Serious Inc.[a]	538	87.5	77	12.5	615	100	1	-	2	-	3	-
Incidents[a]	56	90.3	6	9.7	62	100	0	-	0	-	0	-
All events	797	87.9	110	12.1	907	100	5501	96.3	214	3.7	5715	100

[a]Percentages of fatalities for serious incidents and incidents are not computed due to a lack of data.

We were able to determine both role assignment and preventability for 796 of the 837 events (see table 3-8).

Table 3-8: Frequencies (n) and Percentages (%) of Events by Preventability, Crew Assignment and Event type

	Preventability											
	Pilot-Preventable						Not Pilot Preventable					
	PIC as PF		SIC as PF		TOTAL		PIC as PF		SIC as PF		TOTAL	
Event type	n	%	n	%	n	%	n	%	n	%	n	%
Hull losses	149	83.2	30	16.8	179	100	9	47.4	10	52.6	19	100
Serious Incidents	342	68.4	158	31.6	500	100	33	68.8	15	31.2	48	100
Incidents	30	65.2	16	34.8	46	100	3	75.0	1	25.0	4	100
All events	521	71.9	204	28.1	725	100	45	63.4	26	36.6	71	100

Across all events we found no evidence of an association between role assignment and preventability ($\chi^2(1, N = 796) = 2.26, p = .132$). Nevertheless, and although an analysis split by the event types also revealed no association between role assignment and preventability for either serious incidents ($\chi^2(1, N = 548) = .002, p = .96$) or incidents ($\chi^2(1, N = 50) = .16, p = .692$), there is indeed a significant association between role assignment and preventability within hull losses ($\chi^2(1, N = 198)$

= 13.71, $p < .001$). Many more hull loss events judged pilot-preventable occurred with the PIC as PF (149) than with the SIC as PF (30), yet there was hardly any difference in the preponderance of the two crew assignments for those events judged not preventable by the flight crew (9 with PIC as PF; 10 with the SIC as PF). This pattern is consistent with the notion that preventability is impaired when the PIC is PF to the extent that *preventable* adverse events are more frequent when the PIC is PF.

The findings for *Preventability* are very similar to those for *Teamwork Behavior*: more events, and more events of each type, are both preventable and attributable to ineffective teamwork behavior; moreover, both *Preventability* and *Teamwork behavior* are similarly associated with more egregious outcomes and with the PIC as PF role assignment. However, despite their similarities, these factors are both conceptually and empirically distinguishable; we were able to determine both *Preventability* and *Teamwork behavior* for 830 events and identified 33 (4.0%) where *Preventability* and *Teamwork behavior* were dissociated. While only 2 (2.7%) of the 74 events judged not pilot-preventable nevertheless also involved inappropriate teamwork, 31 (4.1%) of the 756 events judged pilot-preventable showed no issue with flight crew teamwork. Those events included cases where an event was judged preventable by virtue of the fact that an individual error by one pilot was realistically avoidable (e.g., by better workload- or risk management), but the other pilot had no realistic opportunity to effectively intervene (e.g., due to a lack of time). Other cases included events in which the flight crew showed good teamwork by mutually agreeing on a decision, which turned out to be consequential for the event, but which, realistically, could have been taken differently given the context of the event.

Finally, we investigated whether there was an association between preventability and mode of operation. We found 905 events for which we were able to determine both preventability and mode of operation (see table 3-8). As might be envisaged for events that occur in the absence of any technical failure or aircraft related emergency, almost all (703, 98.5%) of the 714 events that occurred during normal operation were deemed preventable[15]; of the 191 events that occurred in non-normal operation

[15] Of the 11 events deemed non-preventable in normal operation 9 involved unforeseeable interventions from wildlife, water, humans or vehicles on the ground leading to contact during landing with people, wildlife or equipment (e.g., cows, a calf, owls, a car, a person). The other 2 events involved mistakes in aircraft operating procedures and aircraft loading.

a far smaller proportion were deemed pilot-preventable (93, 48.7%). A chi-squared test confirmed that preventability varied significantly as a function of mode of operation (χ^2(1, N = 905) = 352.3, $p <$ .001).

As shown in table 3-9 that pattern of association - greater preventability in normal operation than non-normal operation - is apparent for all three event types. Of the 52 incidents in normal operation 51 (98.1%) were deemed pilot-preventable and only 1 (1.9%) deemed not pilot-preventable, but of the 10 incidents occurring in non-normal operation 5 were deemed preventable and 5 not preventable (χ^2(1, N = 62) = 22.2, $p <$ .001). Of the 507 serious incidents happening in normal operation 499 (98.4%) were judged pilot-preventable and only 8 (1.6%) as not pilot-preventable, but of the 107 serious incidents happening in non-normal operation only 39 (36.4%) were deemed pilot-preventable and 68 (63.6%) were judged as not pilot-preventable (χ^2 (1, N = 614) = 312.9, $p <$ .001). For hull losses in normal operation 153 (98.7%) were pilot-preventable and only 2 (1.3%) were found to be not pilot-preventable, but of the 74 hull losses in non-normal operation 49 (66.2%) were deemed pilot-preventable and 25 (33.8%) not pilot-preventable (χ^2 (1, N = 229) = 50.9, $p <$ .001).

Table 3-9: Frequencies (n) and Percentages (%) of Events by Preventability, Mode of Operation and Event type

	Preventability											
	Pilot-Preventable						Not Pilot-Preventable					
	Normal Operation		Non-Normal Operation		TOTAL		Normal Operation		Non-Normal Operation		TOTAL	
Event type	n	%	n	%	n	%	n	%	n	%	n	%
Hull losses	153	75.8	49	24.2	202	100	2	7.4	25	92.6	27	100
Serious Incidents	499	92.8	39	7.2	538	100	8	10.5	68	89.5	76	100
Incidents	51	91.1	5	8.9	56	100	1	16.7	5	83.3	6	100
All events	703	88.3	93	11.7	796	100	11	10.1	98	89.9	109	100

3.4 Discussion

The events collated and analyzed here provide clear evidence of a systemic safety risk in civil commercial aviation. Although accident statistics confirm that the safety of air travel has improved over the years[16] our analysis indicates that the flight crew role assignment is strongly associated with the frequency of aviation accidents and safety critical incidents. Specifically, our analysis shows that, despite the convention that captains and co-pilots usually take it in turns by flight sector to be the PF or PM such that half of flight sectors feature the PIC as PF and half the SIC as PF, almost two and a half times as many events occurred when the PIC was acting on the controls. Four times as many events involving fatalities and more than three times as many fatalities occur when the PIC rather than the SIC is PF. The clear implication is that the crew role assignment is itself a factor influencing the propensity for accidents and serious incidents.

Furthermore, our research provides clear evidence that the association between flight crew role assignment and accident/incident frequency has persisted subsequent to the reforms introduced to address it; indeed, and counter to any expectation that these reforms might, over time, gradually improve the deleterious impact of role assignment on accidents and safety critical incidents, the data show a significantly *increasing* trend in the crew role assignment effect over time between the years 2000 and 2020. The crew assignment effect is also not a localized phenomenon; it is present in each of the five continental regions we identified where civil aviation operators are headquartered.

Despite training pilots in CRM for decades, introducing a label change from PNF to PM and launching industry initiatives on monitoring the flight crew team setting with the PIC as PF and with the SIC as PM is associated with more severe accident outcomes and fatalities than the team setting with the SIC as PF and the PIC as PM, a pattern which suggests that current aviation regulation and airline policies regarding flight crew role settings are ill-fated and dysfunctional and which threatens the industry's announced goal of zero fatalities by 2030 (International Civil Aviation Organization (ICAO), 2019a). As crew role assignment is mostly under the control of aircraft operators there is a

[16] The industry has been able to consistently decrease the fatal accident rate from around 3 per million flights in the 1960s to below 1 per million flights by 1990 and further below 0.5 per million flights from the year 2000 onwards (Airbus, 2023; Boeing, 2022; International Air Transport Association (IATA), 2022).

clear basis for mitigating the risk associated with this factor - a point to which we return in discussing the policy implications of our findings.

We also found that, even in the absence of any technical malfunction or emergency, the risk for harm in commercial aviation is substantial: within the sample of all the (1,076) events for which we were able to code *Mode of Operation* as normal or non-normal, more than twice as many events and more than twice as many fatalities occurred in normal operation - i.e., with technically airworthy aircraft and no emergency present - than in non-normal operation. Even after allowing for the events omitted from our sample that were exclusively attributed to technical failure as well as conceding the possibility that *all* the events for which we were unable to code the mode of operation occurred in non-normal operation, there was a substantial proportion of events occurring in normal operation. This finding suggests weaknesses in flight crew risk management when dealing with routine operational challenges, e.g., weather, time pressure or distraction, which is consistent with findings by EASA (2020, p. 28) who found that the most common underlying cause for accidents between 2015 and 2019 was flight crew's management of challenging circumstances created by technical failure or poor weather conditions. Further research on the distribution of all safety relevant events in aviation based on our proposed methodology for defining the context of events by *mode of operation* may help provide a better risk picture for the aviation industry.

Our evaluations of *Teamwork Behavior* further support this notion, with "poor CRM" or "poor teamwork" identified as a contributory factor in a large majority (95.3%) of the events occurring in normal operation while only just over half (53.6%) of the events in non-normal operation showed issues with teamwork. Although we were unable to detect an association between flight crew role assignment and the manifestation of problematic *Teamwork Behavior* across the whole set of events, there was just such a discernible relationship for the most serious events (hull losses): consistent with the notion that flight crew teamwork is impaired when the PIC is PF, failures in flight crew teamwork were significantly more prevalent for hull losses when the PIC was PF.

Our assessment of the preventability of events indicated that a large majority of the events (87.9%) – were deemed preventable by more risk-averse flying or decision-making by the flight crew. While slightly less than half of the events (48.7%) occurring in non-normal operation were preventable by the flight crew, almost all (98.5%) of the events in normal operation were determined to be preventable by the flight crew. Notably the vast majority of the fatalities (96.2%) were as a result of pilot-preventable events. As for the evidence of an association between flight crew *Role Assignment* and *Preventability* our finding was similar to that for the association between flight crew *Role Assignment* and *Teamwork Behavior:* across the whole set of events there was no association between *Role Assignment* and the *Preventability* of events. Nevertheless, there was a strong relationship between these factors for the most serious events (hull losses): almost four times as many hull loss events judged pilot-preventable occurred with the PIC as PF than with the SIC as PF.

The variation in the association of the role assignment effect by event type for both *Teamwork Behavior* and *Preventability* may reflect the influence of sampling characteristics of our limited sample of events. Note that the distribution of role assignments for both the *Teamwork Behavior* and *Preventability* variables are strongly skewed - the small numbers of events where Teamwork was *not* an issue and events were *not* preventable, together with the relatively few events where the SIC was PF, reduces the sensitivity of our analyses to probe the role assignment effect by event type for both *Teamwork Behavior* and *Preventability*. Note also that the number of *incidents* is relatively small. This doubtless reflects a feature of the reporting of events - incidents that don’t involve any damage, injuries or fatalities will, unlike accidents, be reported at the carriers’ discretion (Stamolampros, 2022). As a consequence, incidents are a category of events that will inevitably, to some extent at least, be under-reported and under-analyzed. In the JACDEC database 32% of events are coded as incidents (as we report above, 5,690 incidents out of a total of 17,795 events). Our multiple exclusion criteria, including the focus on events between 2000-2020, reduced the number of events to 2,293 of which only 370 (16%) were incidents. The availability of crew role assignment information further significantly reduced the number of incidents we were able to include in our analyses; role assignment was determinable for 841 events (37%) of the 2,293 events but only 59 (7%) of these were incidents.

The small number of incidents raises concerns that they may be under-represented in the database; certainly, given that not every incident result in an accident, one would expect more incidents than accidents. The small numbers of incidents obviously compromise the power of our statistical analyses; moreover, there is also a risk that any process of exclusion of incidents from the dataset will also produce non-representative samples. For example, any tendency by the PIC to under-report incidents where the PIC was the PF more often than when the SIC was PF would clearly undermine our analysis. While we have no way of knowing whether or not, and to what extent if any, this happened, such an effect would help account for our findings that the associations between flight crew *Role Assignment* and *Teamwork Behavior and* flight crew *Role Assignment* and *Preventability* were only evident for hull losses.

Our research approach may serve as an example for the aviation industry on how to better study commercial aviation's safety performance by including consideration of all kinds of events instead of only (fatal) accidents. We would also advocate that records of events be improved so that they are more comprehensive and include as many details as are available as standard. For example, and despite the evidence we present for its relevance, crew role assignment is not currently a standard feature of accident and incident reports. For all we know there may well be other features of events that currently go unrecorded that, if made available, would be revealed as pertinent. In the digital age there seems no reason why event reports could not link to all available data about for example all crew members detailed flying history. In epidemiological research developments in information technology and the development of digital databases have proved enlightening (Hripcsak et al., 2015; Zhang et al., 2017); there are similar opportunities in aviation pending reforms to the design of event reports and the curating of aviation event archives.

In contemplating the policy implications of our research it is worth noting that our findings on the significant influence of crew assignment are consistent with the conclusions of previous research on flight crew role assignment (Behrend & Dehais, 2020; Beveridge et al., 2018; Jentsch et al., 1999; National Transportation Safety Board (NTSB), 1994; Orlady, 1982; John B. Sexton, 2004) in indicating that having the PIC active on the controls is not the best option for accident prevention, may even impede effective flight crew teamwork and also suggest a particular route for reform as we outline below. Along with the crew assignment effect, other of our findings indicate that there is significant scope for improvement in aviation safety. Specifically, the findings that substantial proportions of events occur in the absence of any technical failure or aircraft related emergency, involve “poor CRM” or “poor teamwork” as a contributory factor and are judged pilot-preventable all point to the potential for reforms to mitigate these outcomes.

Given its evidently pernicious nature it is clearly important to establish what course of action could mitigate - and even entirely eliminate - the crew role assignment effect. We noted in our review of literature in the introduction that a number of different mechanisms have been proposed as underlying the effect, namely: (1) a greater cognitive workload on the PIC when the PIC is PF negatively impacting PIC decision-making; (2) differences in the relative expertise of the PIC and SIC (SICs are more likely to lose situational awareness due to a lack of experience); (3) differences in the relative status and authority of the PIC and SIC inhibiting the SIC as PM from communicating any observations or concerns. While the relative contribution of these three mechanisms remains to be established some reforms could potentially address all three possibilities. For example, one might assume that the deleterious influence of the crew role assignment effect could be tackled by relieving the PIC of the task of operating the controls by mandating the routine combination of *Command and Monitoring* assigning the PIC as PM on all flights. However careful evaluation of the impact of reforms is needed as any reform might potentially have unintended consequences; for example, if PICs never took the controls this might, over time, lead to a decline in their flying skills.

Given the repeated concerns raised about the quality of monitoring and intervention (Barshi & Bienefeld, 2018; Bienefeld & Grote, 2012; Civil Aviation Authority (CAA), 2013; R. Key Dismukes & Berman, 2010; Flight Safety Foundation (FSF), 2014, 2021; Foushee, 1984; Noort, 2020; Noort, Reader, & Gillespie, 2019, 2021b, 2021a; Perkins, Gosh, Vera, Aragon, & Hyland, 2022; R. L. Sumwalt & Morrison, 1997; R. L. Sumwalt et al., 2002) and its often-noted association with the crew assignment effect (Behrend & Dehais, 2020; Besco, 1995; Beveridge et al., 2018; Fischer & Orasanu, 2000; Jentsch et al., 1999; Limor & Borowsky, 2020; Milanovich, Driskell, Stout, & Salas, 1998; Orlady, 1982; Tarnow, 2000) there is a clear case to introduce measures to boost the efficacy and status of monitoring and intervention on aviation flight decks and indeed the FAA has recently introduced further guidance on how to train monitoring and intervention by the PM more effectively (Federal Aviation Administration (FAA), 2022). This initiative, which has advisory character only and is currently only targeted at aircraft operators in the US, may well have a positive effect, even globally, as airlines become aware of it, as, for the first time, it now clearly demands the training of every pilot, irrespective of rank or level of experience, in actively taking-over control when in the PM role and reacting appropriately when in the PF role (Federal Aviation Administration (FAA), 2022, secs. 3–11). Currently, existing regulations, e.g., in Europe (European Union Aviation Safety Agency (EASA), 2022, sec. 4), require teaching of practical intervention techniques such as taking over control for training captains as PM only, with the effect that such training is still not mandated except for those few captains who have a training role.

Interestingly, neither the FAA advisory circular nor the related NASA study on monitoring (Mumaw, Billman, & Feary, 2020) explains or acknowledges the inconsistency inherent in standard operating procedures: when using the auto-pilot these procedures require that the PF, in certain critical flight phases, must "guard and follow through"[17] the flight controls in order, in the event of auto-pilot malfunctions, to be able to immediately take-over manual control; and yet, when the PF is flying manually, the same guarding of controls by the PM, in the event of piloting errors by the PF, is not required. The potential benefits stemming from such guarding by the PM, e.g., for a quicker and more effective intervention by the PM during critical flight phases such as take-off, landing or go-arounds, would warrant further research to establish the effectiveness of such guarding and following through by the PM and its influence on the teamwork between PF and PM.

Moreover, these papers also do not reflect on the fact, mentioned above, that some states or operators still require that the PF be the PIC for certain complex or demanding operations despite the opposite scientific recommendation (Jentsch et al., 1999; Sexton, 2004). These requirements may even reinforce the pernicious fallacy that the safest role assignment is to have the PIC at the controls, which in turn might explain why we found that most changes of control involve PICs taking control from SICs rather than vice-versa. Such thinking might be instilled by a reliance on flight experience as the primary factor for pilot competency and a disregard of the implications for effective teamwork. However, our analysis shows that the policy for what is termed "captain-only" operation should be critically reviewed taking into account the paramount role of the PM for safe flight operation.

[17] Guarding or following through the controls means to have the hands and feet loosely on the controls but not physically acting on them, however being ready to do so immediately, if required.

Although it might be hoped that enhanced training of crew teamwork - and monitoring and intervention in particular - would alleviate the crew assignment effect, the evidence presented here does not encourage the view that more assiduous crew teamwork could resolve the issue. Firstly, cognitive overload of the PIC when PF is unlikely to be reduced by more efficient teamwork and secondly, despite efforts to improve CRM training, the crew assignment effect has grown over the twenty-one-year period that we studied. Some consideration of the organization of the distribution of responsibilities by the flight crew is plainly called for.

One might well question the suitability of the hierarchical design of the current flight crew team setting which allows that only one pilot is PIC-rated, meaning that only one pilot is fully trained and assessed in leadership, judgment and decision-making. Currently the qualification and training requirements for SICs (Co-pilots) are generally lower, demanding less knowledge, less experience and respectively less training, especially in leadership, judgment and decision-making, in comparison to the PIC-role (International Air Transport Association (IATA), 2020). An alternative scheme requiring both pilots in the PF and PM role to be trained to the same standard in all aspects including leadership, judgment and decision-making, and so be PIC-rated, should mitigate pernicious status hierarchy effects but also enable flight crews to regularly switch roles and at the same time ensure that the PM-role was always occupied by the PIC ensuring the required currency for all pilots in both functional roles. Both the roles (PF and PM) and the command (PIC and SIC) could be alternated on each flight leg.

A teamwork method that moves in this direction has already been designed, and even incorporated in existing aviation legislation, known as *PIC under Supervision* (PICuS) that allows the SIC to routinely perform the duties of the PIC albeit under the supervision of the PIC (European Union Aviation Safety Agency (EASA), 2022, para. FCL.035). This method is used during training in order to introduce co-pilots to command responsibilities and further their development to PIC status. Given that both crew members were PIC rated there would be some value in investigating the efficacy of this method for more safely distributing the leadership and decision-making tasks among the crew with both functional roles (PF/PM) being routinely alternated by every flight leg. Moreover, further evolution of the label from the passive term *Pilot Monitoring* (PM) to the more active term *Pilot Supervising* (PS) might better transmit the notion that monitoring also requires effective intervention.

3.5 Conclusion

The analyses presented here show clear evidence of predictable variation in aviation risks that indicate strong potential for introducing reforms to improve safety in aviation. In contrast to the aviation industry's current focus on flight crew training in teamwork, our analyses suggest that the underlying teamwork role settings are dysfunctional and require reform. In particular, while current standard practice for crew role assignment and human factor and simulator training programs assume that the regular combination of command and control (PIC as PF) is safe and acceptable, our analyses indicate that this assumption is fatally wrong.

Identifying and implementing effective reforms will of course require careful further research. Continuing calls for improved CRM training may address ineffective monitoring and detrimental status hierarchy effects (cf. Federal Aviation Administration (FAA), 2022; Noort et al., 2021b; Perkins et al., 2022). Nevertheless, we submit that there is a clear case for considering a structural redesign of the relative status of flight crew and their roles. In the same way that prevention is better than cure, a new crew assignment design - one that eliminated status hierarchy effects and unburdened the pilot in command from the concurrent task of operating the aircraft controls - could obviate the need for an uncertain search for ways to inculcate actions to counter the deleterious behaviors prompted by the current arrangements.

Our research has also revealed that there are opportunities for the aviation industry to better learn from data gained from safety relevant events by routinely including the analysis of factors such as the role assignment and the mode of operation in investigation reports and by building a single global and freely accessible database allowing comprehensive research.

4 Study 2: Associations with the role assignment effect

4.1 Introduction

The discussion of the results found in Study 1 delivered several proposals for policy change in aviation and implications for further research. However, as any policy change in aviation requires at least participation of regulatory bodies and aircraft operators, which is out of the scope of this thesis, this research project instead further concentrates on eliciting the underlying reasons for the role effect found by the analysis of the field data.

In our review of literature regarding the role effect we noted that Beveridge (2018) proposed a number of different mechanisms as underlying the effect, namely: a greater cognitive workload on the PIC when the PIC is PF negatively impacting PIC decision-making; differences in the relative expertise of the PIC and SIC (SICs are more likely to lose situational awareness due to a lack of experience); differences in the relative status and authority of the PIC and SIC inhibiting the SIC as PM from communicating any observations or concerns.

The current role setting within the flight deck team with one pilot in the rank of a captain and one pilot in the rank of a co-pilot creates a status difference between the pilots on a flight deck, also known as the cross- or trans-cockpit authority gradient, which according to Edwards (1975), as cited in Hawkins (1987, p. 35), should be neither too steep nor too flat to enable optimum teamwork. This means that PICs should apply the appropriate style of leadership while SICs should apply the appropriate style of followership enabling effective teamwork.

The relationship of leadership and followership, thus the hierarchical structure of societies, was subject of research by Hofstede (1980) who investigated the influence of culture on people's values and behavior. He developed a cultural dimensions theory based on five different dimensions of which one was power distance (PD) describing how humans in societies accept hierarchical structures. Subsequently, Merritt (2000) investigated if cultural influences as proposed by Hofstede would replicate within the pilot community. She used the associated power distance index (PDI) invented by Hofstede to investigate cultural influences on pilots' attitude towards their cockpit management behaviors. According to Hofstede's website[18] the PDI is defined as follows: "Hofstede's Power distance Index measures the extent to which the less powerful members of organizations and institutions (like the family) accept and expect that power is distributed unequally. This represents inequality (more versus less), but defined from below, not from above. It suggests that a society's level of inequality is endorsed by the followers as much as by the leaders." It is based on three items: percentage who choose consultative leadership as their ideal leadership style, percentage who choose autocratic or directive leadership as the typical leadership style, and mean response to "how often subordinates are afraid to express disagreement". For example, Hofstede's PDI value for Great Britain and Germany is 35, for the USA it is 40, for Brazil it is 69 and for West Africa it is 77. The highest value is derived from Malaysia with 104 and the lowest with 11 from Austria.

Merritt (2000) found generally higher PDI scores among the 19 investigated pilot nationalities than calculated from the formulae used by Hofstede meaning that within the pilot community "subordinates were more afraid to disagree with their superiors than in Hofstede's data". She concluded that those higher PDI scores reflect the given context by the status hierarchy on the flight deck defined by a more autocratic or directive leadership than in the other occupational groups investigated by Hofstede. She further concludes that "the study confirms that the effects of national culture can be seen over and above the professional pilot culture, and that one-size-fits-all training is not appropriate."

According to the aviation knowledge repository Skybrary[19] "Modern globally accepted crew resource management (CRM), team resource management (TRM) and Human Factors training programmes provide leaders with the tools to invite feedback, ideas and challenges to their own decisions and performance - without becoming defensive and critical. These same programmes encourage junior team members to challenge others with confidence, including senior members, openly, assertively and early to help reduce risk. Both of these aspects may run counterintuitively to various cultural norms - national, racial, religious, tribal etc. In many cultures deference is often given

[18] http://clearlycultural.com/geert-hofstede-cultural-dimensions/power-distance-index/

[19] https://skybrary.aero/articles/authority-gradients; the article also includes several examples of accidents and serious incidents in which the authority gradient was a causal or contributing factor

to age, rank, seniority, role, caste etc and, if brought into the workplace, this can create ineffective use of team, crew and group resources. It is therefore important for safety critical workers to undertake cultural diversity awareness training, and for organisations to adopt effective strategies to reduce associated risks."

However, given the fact that we found differences in the global distribution of the role assignment effect (see 3.3.1.1) it could be assumed that, despite the existence of such trainings, there is indeed an association between culture and the role assignment effect. Based on our results on the global distribution showing that in countries with relatively lower PDIs (Europe and USA) the proportion of events with the role setting of PIC as PF is lower than in countries with higher PDIs (Asia, Africa or South America) we hypothesized that a higher PDI will be associated with the role setting with the PIC as PF in incidents and accidents (H1).

However, a possible reluctance of the SIC to speak-up, termed by Bienefeld & Grote (2012) as raising *safety voice*, or even a reluctance of the PIC to accept intervention from the SIC, termed by Noort et al. (2021a) as *safety listening*, may not only result from cultural influence. It is possible that a large difference in flight experience, or even merely a large difference in age, between the PIC and the SIC may increase the barrier for effective intervention by the SIC or the ability of the PIC to accept intervention as this may exacerbate the perceived status difference and have a negative influence on the cross-cockpit authority gradient on the flight deck. We therefore hypothesized that pilots' ages (H2) or their flight experience (H3) will be associated with the role assignment effect.

4.2 Data and Analysis

The same dataset of events from JACDEC for the period 2000-2020, as described in Study 1, was also used for the analysis in this study. Data on pilot demographics were collated from the official investigation reports or the JACDEC events descriptions for the subsample of N = 841 events in which we were able to determine the role assignment. The dataset including the PDI information is available online at OSF: https://osf.io/m6qhp/?view_only=8da65c046d5541e3a4290fc9220c4a44

Given the binary character of the role assignment variable and the different scales used for the other variables we used binary logistic regression and Pearson's correlation analyses. As for the data analysis of study 1 we used SPSS Version 28 in this study.

During the information acquisition regarding the PDI and the demographic information of the pilots we discovered that due to the frequent incompleteness of either the official investigation reports or the JACDEC event descriptions (see 3.2.3) we were not able to determine all required demographic information for every event. A limiting factor for information gathering was the incompleteness of requirements given by the ICAO Accident and Incident Investigation Manual (Annex 13) requiring that final reports contain the following information only: age, validity of licenses, ratings, mandatory checks, flying experience (total and on type) and relevant information on duty time (International Civil Aviation Organization (ICAO), 2020a). Although this information should be recorded for all flight crew members, we often found that only the PIC details were given and sometimes not even then completely which led to different base rates for our analyses as shown in table 4-1. For this reason, we were also not able to determine the PDI values for the nationality of individual pilots in the events.

Nevertheless, we found an alternative means to measure a possible influence of culture on the role assignment effect. We used the PDI of the country where the operator’s base is located (likely to be the same as the nationality of the majority of pilots working for that operator) as a means to assess for any cultural influence associated with the role assignment effect. As we were able to determine this PDI value for nearly all events in our sample we altered our first hypothesis. We now hypothesized that a higher operator’s base PDI will be associated with the role setting with the PIC as PF (H1).

4.3 Results

Table 4-1 gives an overview of the pilot demographics which we were able to extract from the investigation and event reports in regard to pilots’ demographics. By paired samples t-tests we found, as expected, that there are significant differences in the dataset between the PICs and SICs mean age as well as their total flight experience and their on-type flight experience. For the tested events PICs are significantly older (*M* = 47.86 years; *SD* = 9.44) than SICs (*M* = 35.23; *SD* = 8.94) years, t (174) = 15.02, $p < .001$. The PICs in the tested events were also more experienced than the SICs. While PICs in the tested events had on average 11,397 total flight hours of experience[20], which is a very high number of flight hours reflecting approximately 15-20 years of average work experience as a pilot, SICs had about 4,185 total flight hours, t (208) = 16.62, $p < .001$. The difference in means of PIC and SIC age is 12.63 years and the differences in means of PIC and SIC total flight experience is 7,212 flying hours. The on-type flight experience between PIC and SIC also differed significantly. The PICs in the tested events had on average 4,202 hours of flight experience on the type of aircraft involved and the SICs 1,474, t (202) = 12.34, $p < .001$.

Table 4-1: PDI and Pilot demographics across events and correlation with role assignment

				Correlation with Role Assignment		
	N	M	SD	*r*	*df*	*p*
Role Assignment	841	1.29	.45	1.00	839	-
Operator’s base PDI	785	54.71	20.08	-.15	783	<.001
PIC Age	194	47.62	9.27	.04	192	.625
SIC Age	176	35.19	8.93	.19	174	.014
Difference in age	175	12.63	11.12	-.07	173	.339
PIC Total Flight Hours	231	11,129.73	5,737.51	-.05	229	.426
SIC Total Flight Hours	210	4,188.83	4,213.14	.00	208	.985
Difference in total hours	209	7,212.65	6,274.76	-.02	207	.810
PIC on-type experience	222	4,110.94	3,069.35	-.08	220	.245
SIC on-type experience	204	1,474,02	1,536.33	-.15	202	.038
Difference in on-type hours	203	2,728.20	3,149.98	.00	201	.959

[20] The differences of means between the paired samples t-test and those cited in table 4-1 stem from different N used for calculations. This is due to the fact that relevant information such as age, total and specific flight experience was not given for both the PIC and SIC for all events.

The bivariate correlation analysis of role assignment with the PDI and the pilots' demographics revealed an association with the operator's base PDI, *r* (783) = -.15, *p* <.001, the SIC age, *r* (174) = .19, *p* = .014, and with the SIC on-type experience, *r* (202) = -.15, *p* = .038. To assess, in combination with all three significant predictor variables the strength of the relationship of the PDI, the SIC age and SIC on-type flight experience with the dependent variable *role assignment*, a multiple binary logistic regression analysis was conducted (see table 4-2). Due to high numeric values used for the variables representing pilots' flight experience (in hours) leading to very small S.E. we converted the raw data to Z-scores for these variables in the analysis. We found that the predictor of SIC age and the PIC on-type flight hours contributed to the model.

Table 4-2: Multiple binary logistic regression of operator's base PDI and pilot demographics with role assignment

	Dependent Variable: Role Assignment					
Coefficients	B	S.E.	Wald	df	p	Exp (B)
(Constant)	-6.336	2.748	5.317	1	.021	.002
Operator's base PDI	-.014	.015	.876	1	.349	.986
PIC Age	.009	.047	.041	1	.840	1.009
SIC Age	.122	.045	7.245	1	.007	1.130
PIC Total Flight Hours (Z-scores)	.173	.391	.196	1	.658	1.189
SIC Total Flight Hours (Z-scores)	-.473	.402	1.385	1	.239	.623
PIC Hours on Type (Z-scores)	-.700	.337	4.312	1	.038	.497
SIC Hours on Type (Z-scores)	-.381	.367	1.077	1	.299	.683
Remarks: N = 144; R^2 = 0.122; Stand. R^2 = 0.225; $\chi^2(7, 144) = 18.72$; *p* = 0.009						

Although the operator's base PDI was significantly negatively correlated with the role assignment as predicted by our hypothesis, the regression analysis revealed that, when controlling for the pilot demographics this effect was eliminated. Therefore, we have to retain the null hypothesis that there is no evidence for an association of PDI and role assignment. It would have been interesting to test the data for any association of the PDI values for the country of origin of individual pilots with the role assignment however, due to missing or incomplete information in the event reports and descriptions, we were regrettably not able to code the national PDI values according to the nationalities of the individual pilots. Possible further research in this area of interest could try to elicit the individual pilot PDIs and measure their association with the role assignment effect.

However, the regression analysis confirms that the age of the SIC is significantly associated with the role assignment (H2); as hypothesized the role assignment effect increases as SIC age decreases. A t-test on the absolute chronological ages of the SICs show that the SICs are significantly younger when the PIC is flying (M = 34.49, SD = 8.80) than when the SIC is flying (M = 39.07, SD = 8.79), t (174) = -2.49, p = .014. This finding is consistent with the theory that the status hierarchy between pilots contributes to the role assignment effect such that monitoring is less effective when SICs are monitoring - and is greater when SICs are younger - either because younger SICs are less willing – or able – to “speak up” than older SICs or because PICs ignore intervention from younger SICs more often than from older SICs.

We additionally found the PIC on-type experience now being associated with the role assignment showing that a higher on-type experience is associated with the role setting with the PIC as PF. This finding further supports our theory that differences in (perceived) status hierarchy are associated with the role assignment effect (H3) either because SICs are reluctant to speak-up, perhaps trusting in the more experienced PIC, or because the more experienced PIC defends any criticism with the argument of higher experience, or both.

4.4 Discussion

To determine the underlying reasons for the role assignment effect we tested several factors related to pilot demographics as well as an additional cultural factor derived from the country, in which the aircraft operator (the airline) being involved in the event has its base, for their association with the variable *role assignment*. We hypothesized that a higher operator’s base PDI, reflecting a more hierarchy-oriented culture, is associated with the role setting with the PIC as PF (H1). Regarding the suspected influence of the status hierarchy on the flight deck, we hypothesized that age (H2) or a pilots' flight experience (H3) will be associated with the role assignment effect. We finally found that only the age of the SIC and the on-type experience of the PIC was significantly associated with the role assignment however in the direction as predicted by the theory that status hierarchy effects are underlying the role assignment effect; the younger the SIC and the more experienced the PIC was on the type of aircraft the larger the role assignment effect. The fact that, for accidents and incidents, younger SICs are more often associated with the role setting of the PIC as PF suggests that either PICs more often ignore concerns raised by younger SICs, or younger SICs are less willing or able to speak up and intervene. Thus, our data indicates that monitoring is less effective with younger SIC.

This finding is remarkable if we remember the fact - highlighted in the introduction of the thesis - that, ever since its instigation in the 1980s, CRM training was focused on correcting behavioral deficits primed by status hierarchy effects such as a lack of assertiveness by junior Co-Pilots and authoritarian behavior by the pilot in command (PIC) of the flight (see 2.1). Therefore, the associations of SIC age and the on-type experience of the PIC with the role assignment effect highlight that even modern CRM training does not effectively mitigate the risk of ineffective monitoring and intervention arising with junior SIC deployed in the monitoring role.

That the role assignment effect becomes weaker with higher SIC ages suggests that either monitoring by older SIC is more effective plausibly because PICs have more 'respect' for the voice of an older SIC, or because older SICs are more assertive due to more life or flight experience - or both. On the other hand, this result may even provoke another interpretation regarding the intervention capability of the PIC. The weaking effect of increasing age on the role assignment can also be interpreted in a way that there are more incidents and accidents in our dataset with older SIC as PF. Although we had no way in this study to elaborate the theory of cognitive load or even the influence of natural cognitive decline underlying the role assignment effect, it could be assumed that when older SIC as PF produce situations requiring interventions by the PIC as PM, then the PIC are less effective PMs highlighting that formal intervention training, both within simulator- as well as within classroom CRM-training, should incorporate not only the SIC but the PIC as well. This would also cover yet another possible explanation for the weaking of the role assignment effect with increasing age, which is an increased desire for harmony on the flight deck fostered by on overemphasis on positive team climate in CRM-trainings. Bienefeld & Grote (2012) reported that “even captains indicated that sometimes they chose to remain silent in order to keep everybody happy”. They quoted a captain saying, “I should probably have said something or taken over, but our CRM was good, we had a good team spirit and I just didn’t want to be the bad guy”. Such a possible negative side effect of CRM-trainings could have more impact in similar-aged crews or when the SIC is even older than the PIC as it may have in crews with another age distribution. The desire for group harmony in combination with the age effect may hamper the PIC from being an effective PM more than if being crewed with a younger SIC when the difference in age further supports the authority of the PIC role. In any case the aviation industry should consider ways to empower the role of the PM and the SIC making it invulnerable to any age effect so that pilots are always willing to give and to accept interventions irrespectively of rank, age or experience.

This is especially important because the differences in flight experience and age between PIC and SIC which we found in our analysis requires specific consideration as the age and experience distribution which we found in our sample showing higher ages and experiences of the PIC than for the SIC may not be representative for all airlines. If there is a difference in flight experience or age between the PIC and SIC, depends widely on the structure of the individual airline. It is not uncommon that SICs are older or have more total experience or more experience on the aircraft type than the PICs. This may be related to different career paths of pilots, e.g., within airlines operating different fleets. SICs may elect to refrain from changing from short-haul aircraft to long-haul aircraft or to refrain from taking opportunities for upgrading to PIC for personal reasons, e.g., family or commuting related. Thereby it can happen that senior SICs on a short-haul fleet are crewed together with junior PICs, e.g., when these junior PICs did their upgrading training on the SIC’s fleet after having flown on long-haul aircraft as SIC. Another opportunity which may lead to the SIC being older or having more experience than the PIC might be cases when airlines allow external junior PIC to enter (permanently or seasonally), e.g., during times of expanding their fleet. Nevertheless, airlines or certain fleets within airlines might have to consider the age and experience distribution of their pilots to customize their focus in CRM-training content respectively. On top of that our findings also highlight that airline policies regarding the roles of the PM and the SIC should be critically assessed if those roles description and standard operating procedures for these roles are sufficiently empowered to actively intervene, irrespectively of rank, age or experience.

A way to further mitigate the role assignment effect and eliminate negative effects by the status hierarchy is to promote the recommendation by Sexton, et al. (2004) that the PIC should be in the PM role especially during complex and high workload situations. In our previous study (study 1) we found that pilots refrain from adopting the recommendation as there were nearly no control changes from the PIC to the SIC, perhaps due to a lack of knowledge about the recommendation (see 3.3.2.1). Our results in the current study suggest that there might be a lack of trust by PICs especially in the competencies of younger SIC as PF.

Although the regression analysis found that the effect of culture on the role assignment was eliminated when controlled by the SIC age and the PIC on-type experience this does not mean that there is no effect by culture at all on the role assignment effect. If the industry follows our recommendation from study 1 to make the role assignment and more pilot demographic information mandatory for data collection during incident and accident investigation, then further research might be able to better establish results regarding an association of culture and the role assignment effect.

4.5 Conclusion

Our analysis of the possible influences of pilot demographics and culture on the role assignment effect found evidence that support the theory, highlighted by previous research, that the status hierarchy on the flight deck is an underlying factor for the role assignment effect. Given the history and intent of CRM-training our research results clearly point to deficiencies in scope and content of PM and SIC training and possibly to airline policies regarding the roles of the PM and SIC as well.

5 Background for further research regarding the role assignment effect

The research in studies 1 and 2 used field data from civil commercial aviation in the period 2000-2020 to analyze the influence of flight crew role assignment on the frequency of accidents and incidents. The analysis revealed that having the PIC as PF actively on the controls can have a pernicious effect on the safety of a flight and is not the best option for accident prevention in commercial aviation. Although similar findings have been raised before by Jentsch et al. (1999) or Palmer et al. (1995) our analysis reveals that the measures to mitigate the effect, such as human factor training for pilots, a label change of the role of the pilot not acting on the controls and further industry initiatives to promote active monitoring, were evidently not effective as our research also found an increasing trend of the role assignment effect over the investigated period. Further analysis revealed that the role effect is significantly associated with the age of the SIC which not only supports the theory that status hierarchy effects may be underlying the role effect but also that PICs seem to be vulnerable in regard to effective intervention when being crewed with elder SICs. We discussed possible countermeasures against the role effect such as a policy change regarding the flight crew team setting in commercial aviation and formal intervention training for SIC and PIC.

However, the results from our field data analysis suggest that especially in normal operation not only the teamwork, but also the risk management of commercial flight crews is often dysfunctional. On top of the findings regarding the role assignment effect we found that most (72.2%) of the accidents and incidents, and also most (68.5%) of the fatalities, were happening in normal operation meaning with technically fully airworthy aircraft and no aircraft related emergency present. Furthermore, nearly all (98.4%) of these events were deemed pilot preventable. Similar conclusions have also been drawn by other safety research as well. The European Aviation Safety Agency (EASA) found that the most common underlying causes for accidents in the years 2015-2019 were associated with the flight crew’s management of challenging circumstances created by technical failures or poor weather conditions (European Union Aviation Safety Agency (EASA), 2020, p. 28). And, similar to our analysis, safety research by safety experts from the International Air Transport Association (IATA) found that in the period 2012-2016 aircraft malfunctions contributed to only 25% of all accidents and in the period 2016-2020 to only 31% of accidents (IATA, 2016; International Air Transport Association (IATA), 2021). These findings offer further potential for research because, in principle, nearly all flight related threats or hazards can, in normal operation, be safely managed and even anticipated by a well-trained flight crew (see explanation further below).

Since the introduction of TEM about twenty years ago flight crews have been provided with a tool and should be trained in a method of operational risk management which enables them to practice foresight and anticipate threats that emerge from various influences affecting their flight. Figure 5-1 shows a flight and threat awareness tool used in practice which was built upon the concept of TEM and is presented on a single foldable page which includes all relevant information and foreseeable threats and pressures related to a typical commercial airliner's flight. The tool uses the principle of a *reverse risk assessment* starting with the desired end state (e.g., reaching cruise flight or diverting to an alternate field) and then looking backward for the relevant threats, a methodology which better prevents rushing and overlooking relevant hazards and risks when using the tool. Thereby environmental influences such as weather or traffic, organizational influences such as time-pressure and other individual influences such as fatigue or proficiency are well anticipatable in advance - even before a flights' departure. With the exception of technical malfunctions or other aircraft related emergencies (e.g., an onboard fire) it is possible for flight crews to gain complete awareness about all the relevant threats possibly affecting their flight even before starting it. Possible changes or even uncertainties regarding some factors such as the runway direction for departure or the expected approach can be considered even before the flight and catered for so that those uncertainties can always be safely managed, and their associated risks successfully mitigated in practice. Accordingly, the main benefit of TEM lies in its potential to enhance predictability in daily aviation operation of frontline practitioners. However, despite a high level of standardization and regulation in aviation the view that the aviation system is highly predictable is evidently not commonly shared among safety researchers or other industry stakeholders.

Figure 5-1: Flight and Threat Awareness Tool (FAT)

DEPARTURE THREAT / HAZARD ANALYSIS

CLIMB & CRUISE							
☐ PANEL / TRIM / CPDLC / FMS-WIND / SPD ☐ FIR / WX / TURBUL / FMS / CRZ-BRIEFING			STEP CLB/DES ☐ N/A	☐ OFP DATA / ACARS / FUEL CH. / PAX ANN. ☐ MEAL / NAP / SCHED / NXT OFP / ATL / LTS			APP PREP AT:
TRANS. ALT ☐ *5000 / 6000*	CLB-WX JET CAT MW TSCB TCU ICE	CLB-TFC/PERF OPPOS. DESC. SLOW CLIMB	INITIAL CRZ TFC / SPD LIM. EARLY TOC	CRZ-WX JET CAT MW TSCB TCU ICE	ENR-RESTRIC. ALT WX / OPS ENR NOTAM	ENR-EMERG. MORA>10000 DD/ESC-PRCD	CRZ-TIME EET ≤ 60min EARLY TOD
SPECIALS							
CHANGE	WX-RADAR	WIPER	MGN < 200m	EARLY A/P	NO LNAV	DEP-FREQ.	RCF SPEC.
EOSID & RETURN / T/O-ALTN							
EFP-DESIGN EARLY TURN EARLY STOP	EFP-WX WX-DEV REQ. NO VIS-RTN	EO-ON-SID TERRAIN CRIT. CONFLICT. TFC	T/O ALT ☐ N/A	RTN/ALT APP ☐ ILS	RTN/ALT-LDA ≤ 2500m MGN < 200m	RTN *A.TOW* ☐ OVER-WT LDG ≠ DEP	RTN/ALT-WX NO VIS. RTN DETER. TREND
1. DME / ALT ☐ N/A	1. TURN L R	1. TRACK ☐ N/A	EOAA TURNS?	1. SPD-LIMIT ☐ N/A	TGT/PTN ALT	EO HOLD ☐ N/A	INBD/TURNS?
SID							
1. DME / ALT ☐ N/A	1. TURN L R	1. TRACK ☐ N/A	Vref40+70	1. SPD-LIMIT ☐ N/A	1. STOP ALT	1. SID CNSTR. ☐ N/A	ABLE? ☐
SID-DESIGN EARLY TURN EARLY STOP	SID-WX WX DEV REQ TURBULENCE	SID-TFC LOW SPACING VFR / BIRDS	SID-NAV RNP / P-RNAV RAW DATA	SID-NOTES BALL NOTES BOXED ITEMS	1. MRVA/MSA ☐ H.MSA	PDG ☐ 3,3%	ABLE? ☐
TAKE-OFF & TAXI							
T/O FLAPS 1 5 10 15 25	T/O START 180°/ L/U<90° STATIC / R.UP	T/O ROLL CROSSW.-T/O REQ.VIS > 400	TOPERF N1 < 85 / > 95 V1<125 / >150	T/O SPECIALS Δ v1/r > 4 kts NEAR EGT LIM.	T/O PROCED. NADP-1 / SPEC ANTI-ICE ON	T/O BLEEDS NO ENG BLD UN-PRESSUR.	TOPERF CAL. W/S TOPERF TMPO/SP. DTA
SEL. TO-RWY	INTERSECT. ☐ N/A	TORA ☐ >2500m	RWY-STATUS WET / DAMP SLIPP. / CONT.	RCC/CONTAM 5 4 3 < 3 WTR / SN / ICE	RWY-DIMENS. SLOPE ≥ 0,5% WIDTH ≠ 45m	RWY-SURFACE UNEV/ROUGH ARREST. GEAR	RWY SPECIALS NO RCLL EMAS AVAIL.
EXP.TX-OUT	OTHER TFC?	P/B RLS/CHK N E S W	DE-ICING RMTE DE-ICE H.O.T. CRITIC.	TAXI-RTE RWY-X /CONG. BACKTRACK	TAXI-HAZARD HOTSPOTS SIGNAGE/ WIP	TAXI-SPECIAL NEAR M.TOF BLEED/FLAPS	TAXI-TIME SHORT / LONG T/O-Q / INBDS
WEATHER & HUMAN FACTORS							
WIND-DIRCT VARIABLE SHIFTING	WIND-SPD MEAN > 15 GUSTS > 10	WIND-COMP CROSS *LIMIT?* TAIL *LIMIT?*	WIND-ALOFT CROSS *1.HDG?* TAIL *LIMIT?*	WIND-PHEN. WIND-SHEAR OROGR TURB.	TEMP / D.PT ≤ 10° > 25° SP ≤ 2° T.INV	COLD-WX FZ / ICING SN/ICE RMVL	ATIS D-ATIS? ☐ N/A
TREND*360°*☐ DETERIORAT. INCOM. WX	CONVECTIVE TS/CB EMBD? TCU / THERM	PRECIPITAT. RA / DZ / SH SN / SG / GR/S	SPECIAL WX SA / VA / FC SPACE WX	CLOUDS ANY ≤ 1000' CEIL ≤ MSA	VISIBILITY ≤ 5000m BR / HZ / FG	SUN-POS. BLINDING DARKNESS	SR / SS: ☐ N/A
FATIGUE T.S.A. > 10 SPS LVL > 2	FITNESS UNWELL / ILL CREW FATIG.	TIME PRESSURE IDLE / DISTRCT	DISCIPLINE WORK ERR > 2 EMOTIONAL	ROUTINE A/P USED > 3 DUTY-DAY > 3	WORK-ATM. BURDENED TOO GOOD	PF LOW PROFIC. PIC / SPORTY	PM LOW PROFIC. LOW ASSERT.
A/C-GW LOW / HEAVY NEAR LIMIT	A/C-VARIANT UNFAMILIAR DIFFERENCES	A/C-DIFFER. 1 FMC ONLY NO IAN / NPS	A/C-FAILURES MEL-OPS NEW FAULTS	A/C-SPECIALS ACARS INOP EX-MAINT.	TIRES/BRAKES CUTS / SPOTS WEAR < 3mm	TYPE OF FLT FERRY / POSIT. TRNG / CHECK	RNP-CHECK A/C CHCK ☐ RAIM CHCK ☐
AIRPORT & TIME							
DEP-AIRPORT CAT: B C UNFAMILIAR	RUNWAYS SINGLE ONLY PARAL / X-ING	TORA / R.LDA T ≤ 2500m RTN-L <2500m	FACILITIES NO ILS/ NO 3D NO ATIS/ MRC	RESTRICTIONS NCF / HO / HJ RCFF < 7 / PCN	ENVIRONMNT TERR CRITICAL SEA / LAKE	ELEV H.ELEV ☐ < 200'	H.MSA ☐ < 3000'
ATC-SAFETY CHALLENG. NO RDR / "E"	ATC-QUALITY POOR / 1-FRQ CONGESTED	ATC-SPECIALS HIRO / MROT RCF / SH.COM	LOCAL PHEN. WIND / WX LAND/SEA EFF.	NOISE RESTR. NADP1 / SPEC. APU LIM:	TRAFFIC VFR / BIRDS PEAK / HUB	SPECIALS AOI RELEVANT CCI RELEVANT	NOTAM NOTAM RELEV. TEMPO-CHRTS
DEP / T-ALTN ☐ NIL	NOTAM/INFO	DEP SPECIFICS ☐ NIL	EOBT / TOBT	TSAT FPET? ☐ N/A	SCHEDULE DELAYED / FDT EET ≥ PL.BT	DEP-LIMITS DEP-NCF/ RTD DEST-NCF/RTA	RTA NCF / FDT ☐ N/A
			CTOT ☐ NIL		T/A RESTRICT LATE CR. ARR SEC.S. / IMMI.	T/A-LIMITS BRAKE-HEAT A/C CHANGE	STA UTC:

©LTB FLIGHT AWARENESS TOOL (FAT)_version_14.06.2024

ARRIVAL THREAT / HAZARD ANALYSIS

OPTIMUM DIV-ALTN							
SEL-DEST-ALT	EXP. APP	LDTA 30/40 2/3 ☐ ≤DEST	REAL. EET OFP?	DIV ALT MFA?	OFP MINDIV	SAFE MINDIV ☐ OFP	LOW T/D FUEL
ALT-AIRPORT UNFAMILIAR CAT: B C	ALT-RESTRICT. NCF / HO / HJ RCFF < 7	ALT-LDA < 2500m MGN < 200m	ALT-FACILITIES NO ILS / 3D NO ATIS / MRC	ALT-APP WX LIMITED EO-G/A LIMIT	ALT-SPECIALS NOTAM RELEV. HOLD. EXPECT.	ALT-SPECIALS PARK. LIMITED HOTAC / OPS	ALT-SPECIALS MASS DIVERS. MIN. FUEL ARR
SPECIALS							
CHANGE	WX-RADAR	WIPER	MGN < 200m	REVERSE	NO LNAV	ATC-SPEEDS	RCF SPEC.
MISSED APPROACH & DIVERSION							
M/A-DESIGN EARLY TURN EARLY STOP	M/A-TRAFFIC VFR / BIRDS TFC (OPP/PRLL)	M/A-SPECIALS WX CRITICAL GRAD/BLK.LDG	DIV-WX TS/CB TCU ICE STRONG HWC	DIV-ROUTE NO DIR. / TERR SUA / VFR	1. MRVA/MSA ☐ H.MSA'	ADD. G/A-FUEL	OPT. TO STAY SINGLE RWY WX-LIMITED
1. DME / ALT ☐ N/A	1. TURN GRAD? L R	1. TRACK ☐ N/A	Vref40 L/S-LW?	1. SPD-LIMIT ☐ N/A	1. STOP ALT	G/A HOLD ☐ N/A	INBD/TURNS?
LANDING & TAXI-IN							
POS APU-LIM.?	OPT. EXIT L R	EXP. TAXI-IN	TAXI-HAZARDS HOTSPOTS SIGNAGE / WIP	TAXI-RTE RWY-X-ING BACKTRACK	TAXI-IN-TIME SHORT / LONG STOPS / RTA	TWY / APRON SMALL / SLIPP. CONGESTED	POSITION OCCUPIED SLIPPERY
SEL. LDG-RWY	LDA DISPL.THR ☐ >2500m	LDTA 30/40 2/3 ☐ N/A	RWY-STATUS WET / DAMP SLIPP. / CONT.	RCC/CONTAM. 5 4 3 < 3 WTR / SN / ICE	RWY-DIMENS. SLOPE ≥ 0,5% WIDTH ≠ 45m	RWY-SURFACE UNEV./ ROUGH ARREST. GEAR	RWY SPECIALS NO RCLL EMAS AVAIL.
DESCENT & APPROACH							
ALS / RLS NO FULL ALS NO TDZL / RCLL	VIS-ILLUSIONS TOO HIGH BLACKHOLE	LDG-TFC LATE LDG-CLR TIGHT SPACING	LDG-SPECIALS TURBULENCE WAKES / GUSTS	TDZ TPL CHK ☐ SHORT / DARK LOW DENSITY	T/D-WIND CWC LIMIT? TWC LIMIT?	T/D-SPECIALS LATE PWR CUT AUTOLAND	BRAKING FULL REVERSE MAX MANUAL
1.CONFIG CH. ☐ D12	G/P-INTERCPT < 3000' > NO GP / VISUAL	APP-G/P > 3° < EARLY GEAR	FIN-SPECIFICS TWC / CWC FMC ≠ IAC	MIN-SPECIFICS REQ.VIS > 550 CTC / VDP REQ	APP-AIDS NO T/D DME NO PAPI ≠ G/P	APP-TERRAIN RA ≠ BARO OROGR. SPEC.	APP-SPECIALS BOXED ITEMS OFFSET / CRVD
DES-PROFILE EARLY / STEP HIGH SPD DES	DES-TFC SLOW / BELOW OPP.CLB / PEAK	DES-WX JET CAT MW TSCB TCU ICE	DES-COND. TURBUL / WXR CA EARLY SEAT	DES-PATH TWC / BAD ATC STEEP PROFILE	STAR CNSTRTS ALT CONSTRTS SPD CONSTRTS	ARR-DELAY HOLD. / RMVL FULL TRANSIT.	TRANS. LVL ☐ *60 / 70*
WEATHER & HUMAN FACTORS							
WIND-DIRCT VARIABLE SHIFTING	WIND-SPD MEAN > 15 GUSTS > 10	WIND-COMP CROSS *LIMIT?* TAIL *LIMIT?*	WIND-ALOFT CROSS *F.HDG?* TAIL *LIMIT?*	WIND-PHEN. WIND-SHEAR OROGR TURB.	TEMP / D.PT ≤ 10° > 25° SP ≤ 2° T.INV	COLD-WX FZ / ICING SN/ICE RMVL	ATIS D-ATIS? ☐ N/A
TREND *360°* ☐ DETERIORAT. INCOM. WX	CONVECTIVE TS/CB EMBD? TCU / THERM	PRECIPITAT. RA / DZ / SH SN / SG / GR/S	SPECIAL WX SA / VA / FC SPACE WX	CLOUDS ANY ≤ 1000' CEIL ≤ MSA	VISIBILITY ≤ 5000m BR / HZ / FG	SUN-POS. BLINDING DARKNESS	SR / SS: ☐ N/A
FATIGUE T.S.A. > 10 SPS LVL > 2	FITNESS UNWELL / ILL CREW FATIGUE	TIME PRESSURE IDLE / DISTRCT	DISCIPLINE WORK ERR > 2 EMOTIONAL	ROUTINE A/P USED > 3 DUTY-DAY > 3	WORK-ATMOS. BURDENED TOO GOOD	PF LOW PROFIC. PIC / SPORTY	PM LOW PROFIC. LOW ASSERT.
A/C-GW LOW / HEAVY NEAR LIMIT	A/C-VARIANT UNFAMILIAR DIFFERENCES	A/C-DIFFER. 1 FMC ONLY NO IAN / NPS	A/C-FAILURES MEL-OPS PROC NEW FAULTS	A/C-SPECIALS ACARS INOP EX-MAINT.	TIRES/BRAKES CUTS / SPOTS WEAR < 3mm	TYPE OF FLT FERRY / POSIT. TRNG / CHECK	RNP-CHECK A/C CHCK ☐ RAIM CHCK ☐
AIRPORT & TIME							
DEP-AIRPORT CAT: B C UNFAMILIAR	RUNWAYS SINGLE ONLY PARAL / X-ING	LDA / N.TORA L ≤ 2500m N.-T/O <2500m	FACILITIES NO ILS/ NO 3D NO ATIS/ MRC	RESTRICTIONS NCF / HO / HJ RCFF < 7 / PCN	ENVIRONMNT TERR CRITICAL SEA / LAKE	ELEV H.ELEV ☐ < 200'	H.MSA ☐ < 3000'
ATC-SAFETY CHALLENG. NO RDR / "E"	ATC-QUALITY POOR / 1-FRQ CONGESTED	ATC-SPECIALS HIRO / MROT RCF / SH.COM	LOCAL PHEN. WIND / WX LAND/SEA EFF.	NOISE RESTR. CDO / SPEC. APU LIM:	TRAFFIC VFR / BIRDS PEAK / HUB	SPECIALS AOI RELEVANT CCI RELEVANT	NOTAM NOTAM RELEV. TEMPO-CHRTS
DEST / ALTNs ☐ NIL	NOTAM/INFO	PAX SPECIALS? ☐ NIL	SCHEDULE DELAYED / FDT A/C SCHEDULE	DEST-LIMITS RTA / DBC DEST-NCF/RTA	CREW TRAVEL PROCEED. AFT IMMIGR./CUST	NXT BOARD. ☐ N/A	RTA NCF / FDT ☐ N/A
			T/A SPECIALS CREW CHANGE A/C CHANGE	NEXT T/A NO REFUEL SHORT T/A	NEXT T/A TRANSIT PAX ASU / SP.EQPM	NXT STD ☐ N/A	STA UTC:

According to Bouarfa et al. (2013) the aviation industry is an example of a complex socio-technical system "with interactions between a variety of facilities, users, technical systems, human resources, rules, and procedures". In line with other researchers (Hollnagel, 2010, 2020; Nemeth, 2012) they argue that aviation is even a complex adaptive system in which safety is primarily an emergent property. These authors postulate that linear causality models such as the "swiss cheese model" promoted by Reason (1997) meaning that accidents happen due to "corresponding holes in the layers of defenses, barriers and safeguards" build into the system, fail to explain why safety relevant events happen because processes in such systems are so tightly coupled, thereby being unpredictable, and resources are generally limited forcing practitioners to adapt their behavior to accomplish their missions.

However, this view lacks the perspective that the processes in the commercial aviation system are indeed highly predictable, at least in normal operation and for a flight crew. Although it is true that practitioners in high-risk-environments need the ability to safely adapt to expected and unexpected pressures and disturbances during both routine and non-routine operation, the model of a complex adaptive system does not recognize that especially flight crews always have, in normal operation, the ability to anticipate common threats and have also always the option for a more risk-averse decision-making, meaning that they always have a more safer option available as the following examples show.

Just as in an everyday activity such as car driving when drivers can always elect to adapt their driving behavior to be more cautious or even to stop their car, flight crews have similar options in daily operation as long as the aircraft is airworthy, and no aircraft related emergency exists. Given the legal power and authority of the role of the PIC, being primarily and personally responsible for the safe operation of the aircraft, flight crews can always increase their safety margins or even stop working if necessary (Cadieux, 2014, p. 141). In practice, this means for example that flight crews should not take procedural shortcuts to achieve an on-time departure but take the necessary time for flight preparation before departure by accepting delay, or during an approach they can always deny challenging ATC clearances and request more descent mileage to enable a stabilized approach and landing. While flight crews have those options available in normal operation, aircraft malfunctions or emergencies might lead to complex situations which are characterized by limited resources in regard to time and fuel so that in non-normal operation flight crews might require a more flexible thinking and behavior to safely cope with such situations. In more general terms used by those advocating that aviation is rather an intractable system, i.e., (Hollnagel, 2009), flight crews have in normal operation always the option to trade-off efficiency for thoroughness (TETO) while it may be necessary in non-normal operation to trade-off thoroughness for efficiency (ETTO).

An explanation of the aviation system which better incorporates the bi-modal view of normal and non-normal operation is provided by Stogsdill & Ulfvengren (2017) who labeled the aviation system as a Highly Complicated and Occasionally Complex (HCOC) system based on the CYNEFIN[21] framework presented by Kurtz & Snowden (2003). This framework characterizes a

[21] Cynefin, pronounced kuh-nev-in, is a Welsh word that signifies the multiple, intertwined factors in our environment and our experience that influence us (how we think, interpret and act) in ways we can never fully understand. https://thecynefin.co/about-us/about-cynefin-framework/

system based on the following four domains: simple (best practice based), complicated (expert knowledge required), complex (emergent properties present), chaotic (improvisation needed). While situations or events in the complex and chaotic domain are defined as unordered, thereby usually not predictable, those in the simple and complicated domain are ordered and thereby usually predictable.

This model better matches with the distinction of aircraft operation in the modes of normal and non-normal operation. While flight crews may find themselves in situations defined or perceived as complex or in situations for which no regulation or SOP exist, both in non-normal and normal operation, the resources as well as the options to de-complex such situations and thereby transfer immediately back into the complicated or even simple domain, are always given in normal operation but may be significantly limited in non-normal operation. Therefore, we propose to the aviation industry to consider implementing the bi-modal view of normal and non-normal operation as it may better facilitate the identification and mitigation of safety hotspots in aviation. For example, it could be a first step if aircraft manufacturers and aircraft operators (airlines), instead of using the wording *normal* and *non-normal* for certain flight maneuvers (e.g., rejected take-off, windshear- or terrain avoidance maneuvers) which are equally applicable in normal and non-normal operation according our proposed distinction rather as *non-routine* and all previously named normal maneuvers as *routine* in their aircraft related documentation. This could help the aviation industry to improve safety performance by better defining the context of flight operation leading eventually to better training flight crews in effective risk-management and teamwork.

Although our field data analysis has revealed that flight crews' teamwork and risk-management is obviously dysfunctional too often, it would be inappropriate to accept those failures simply as human error. It might be easy to promote that human errors are assumed to contribute to 60-80% of all aviation accidents (Wiegmann & Shappell, 2003), but this only describes the symptoms and not the underlying disease of the aviation system. Fortunately, by insights from the research discipline of resilience engineering the view on human error has evolved leading to an enhanced awareness for the need to look behind the label *human error* and to understand the context of events and the local rationality practitioners are facing in their daily work (Woods et al., 2010). In commercial aviation this context is always influenced by business considerations such as on-time-performance or cost savings (e.g., fuel) leading to pressures on the sharp end. Leveson (2004), when introducing a new accident analysis method termed Systems-Theoretic Accident Model and Processes (STAMP) model, builds this model among other pillars upon previous conclusions from other researchers: Woods (2000) argued that "production pressures may lead to accidents by eroding planned defenses thereby facilitating a drift toward failure" and Rasmussen (1997) even argued that "major accidents are often caused not by a coincidence of independent failures but instead reflect a systematic migration of organizational behavior to the boundaries of safe behavior under pressure toward cost-effectiveness in an aggressive, competitive environment". Commercial pressures are also listed as possible risk factors for unstable approaches (International Air Transport Association (IATA), 2016). By interviewing Alaskan commercial pilots Bearman, Paletz, & Orasanu (2009) found that goal seduction originating from business and monetary pressures led the pilots to take unnecessary risks in flight operation. Bearman, et al report that "a number of theories of human error make use of a medical metaphor, arguing that resident pathogens exist in a system and can lead to errors and accidents given a particular set of circumstances."

Based on our findings from the field data research that elicited dysfunctional team-settings, ineffective intervention methods and unsafe risk-management of flight crews especially in normal operation we follow up this picture and theorize that the combination of any salient goal (e.g., on-time performance, cost avoidance, noise abatement or other operational restrictions) in combination with risky flying or decision-making and/or missing or ineffective intervention represents an operational syndrome[22] making the aviation system prone to serious safety relevant events (see figure 5-2).

[22] Definition of Syndrome, e.g., in the healthcare domain: A set of symptoms or conditions that occur together and suggest the presence of a certain disease or an increased chance of developing the disease, e.g., the metabolic syndrome in which one of the elements alone might not lead to an event but only the combination of them. (U.S. National Cancer Institute – Dictionary of Cancer Terms)

Figure 5-2: Operational Syndrome

The second part of this thesis will now present our research aiming to elicit the underlying reason for our findings in the analysis of the field data, thus the suspected syndrome. In fact, it could be assumed that CRM/TEM as practical tools and their training would be sufficient measures to ensure effective teamwork and safe risk-management of pilots. However, our analyses suggest that this is not the fact, at least for those airlines and pilots being involved in the analyzed events. We therefore suggest looking for reasons why these tools and their training obviously have the potential to fail in delivering the expected output.

Although CRM/TEM training may have negative side effects, e.g., possibly on the intervention behavior of PICs as discussed in study 2 (see chapter 4), it is hard to imagine that such training being focused on human factors and accident prevention would fail completely or even make things worse. Instead, it can be assumed that raising topics such as negative effects by status hierarchy, the importance of assertiveness by juniors, the fostering of effective communication, the need for team-oriented leadership and many more in such trainings should even facilitate the application of effective intervention in practice. But the mere fact that we even found the role assignment effect being still present and even with an increasing trend in the period 2000-2020 let us assume that there might be inherent obstacles making it hard for pilots to transfer CRM/TEM training content into their daily practice.

Given the fact that the work on a commercial airliner's flight deck is mostly governed by airline's policies and standard operating procedures it would have been interesting to examine those policies and procedures for inherent obstacles for effective intervention and safe decision-making thereby facilitating the presence of the role assignment effect. For example, some airlines might have restricted the right for a go-around call by the SIC or have only very basic or even no role description for the SIC or PM thereby probably hampering pilots in these roles to carry out their monitoring function properly. Unfortunately, most airlines which were contacted during the research were not willing to disclose their operations manual content so that we were not able to pursue this research approach further.

However, those norms may not be the only variable influencing pilots' safety relevant behavior. According to the theory of planned behavior (TPB) developed by Ajzen (1991) the human behavior may be influenced not only by subjective norms, reflecting pilots' interpretation of policies and procedures like those described above, but also by people's attitudes and their perceived behavioral control as shown in figure 5-3.

Figure 5-3: Theory of planned behavior

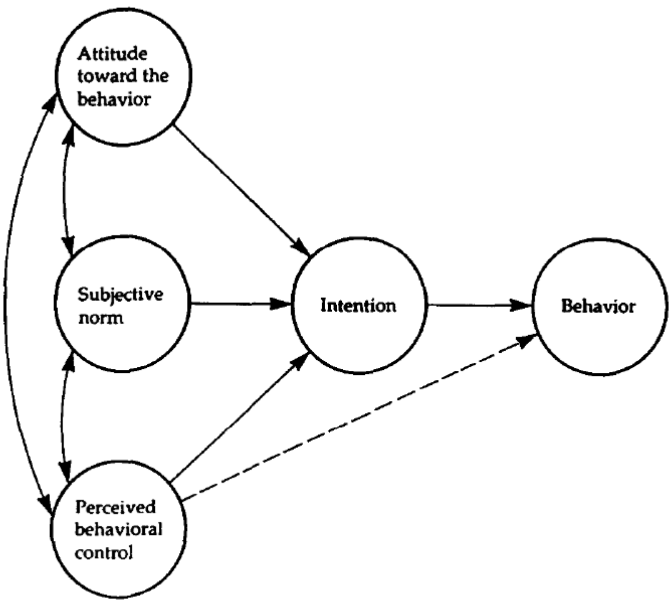


FIG. 1. Theory of planned behavior.

In line with TPB, which will be introduced in detail later in chapter 6, we therefore propose to probe pilots' experience in practice and their attitudes, especially towards effective intervention and safe decision-making as well as their roles of the PIC/SIC and PF/PM, to investigate the underlying reasons for the operational syndrome including the role assignment effect and risky decision-making. The focus on pilots' attitudes might be useful not only because it concentrates on the practitioners directly but also because the work environment on aviation flight decks has basically not changed for decades unlike many parts of the aviation system in recent years. There was an intensified systemic focus on safety at the organizational level of the aviation production process as outlined above leading to regulatory changes such as the global introduction of safety management systems (SMS) starting in 2009. This involved not only an improved focus on safety culture, safety reporting, more detailed safety auditing, but also improved policies and standard operating procedures and the requirement for aviation organizations to proactively manage safety such as any other business function, too (International Civil Aviation Organization (ICAO), 2018).

However, these positive initiatives may also have a blurring effect because they might cover up latent system deficiencies such as unhealthy attitudes within the aviation system towards pilots' roles because there are several factors related to the work environment on the flight deck which have not changed even since the beginning of commercial aviation. First, pilots' basic education is still mostly license- instead of graduation-based and is focused more on training of technical skills instead of training non-technical skills. Second, the leadership and team structure in aircraft cockpits has not changed at all. It is still common that the regulatory requirements for pilots in the role of the SIC are lower than for the role of the PIC and, despite scientific warnings in the 1990s as outlined before, PIC are still allowed to routinely act as PF. Third, pilots' role descriptions still incorporate the requirement for pilots to take into account business considerations such as fuel cost or flight schedules which may lead to operational pressures at the front end. As pilots will remain the most important role for the prevention of accidents and incidents in aviation, even if controlling an aircraft in a single pilot configuration or remotely, research concentrating on pilots' attitudes towards their role in the industry as well as towards their flight deck roles might be helpful to find solutions for effective incident and accident prevention.

6 Survey of pilots' attitudes, experience, and behavior of choice

6.1 Construction of the survey instrument

6.1.1 Introduction

Our field data analysis revealed that the risk management and teamwork of flight crews do not always function as intended, even in routine flight operation. The results from study 1 (field data analysis) and study 2 (analysis of pilot demographics) support findings from previous research (Bienefeld & Grote, 2012; R. L. Helmreich, 2006; Milanovich et al., 1998; Perkins et al., 2022; Tarnow, 2000) suggesting that the relative status hierarchy on the flight deck negatively influences the safety performance in commercial aviation. Furthermore, we found that most events and most fatalities happen in normal operation, meaning with technically airworthy aircraft and no emergency present. A logical next step in research will be to determine why these patterns exist. Given that we found these results despite the fact that there has been human factor training for pilots for more than four decades, we envisage that there might be latent problems in commercial aviation stemming from pilots' attitudes towards their roles on the flight deck, preventing this training from becoming effective.

This notion was already instilled during the author's research for a master's thesis in 2012 *(Accident prevention in practice - the development of a practical tool for enhancing situational and operational awareness of cockpit-crews)*[23]. This master's thesis particularly highlighted the influence of flight crew decision-making, teamwork, and situation awareness in normal operation, however without providing empirical evidence regarding the distribution of events based on the mode of operation. Given the fact that the aviation system does not provide a global and comprehensive single repository of safety relevant events that is freely accessible and usable for statistical research as noted before (see 3.2.1) we were not able to complete a field data analysis as the intended first step of the research until discovering the JACDEC database in 2017. However, as outlined above, prior to the discovery and analysis of these data, the literature review in chapter 2 regarding decision-making and

[23] A copy of the master thesis can be found at OSF: https://osf.io/ye5vb/?view_only=69eb31f9e1eb4810a7f54bc0d1d23c1b

teamwork on the flight deck had already revealed issues with status hierarchy, role assignment and training of pilots in human factors. Furthermore, that review of literature on aviation incidents and accidents had already provided a sense that technical malfunctions and emergencies were not the main driver of accidents in aviation as outlined by Wiegmann & Shappell (2003, p. 10). Subsequent to the literature reviews, to further progress the research in order to achieve better understanding of flight crew teamwork and decision-making, we decided to use online surveys of pilots in order to study why status hierarchy and issues with ineffective monitoring and intervention were obviously still prevailing in aviation, despite the introduction of human factor training for pilots.

Given the fact that the aircraft used for transportation of passengers and cargo are still crewed by human pilots and the common life cycle of today's commercial aircraft, conservatively assumed to last for twenty years (Howe, Kolios, & Brennan, 2013), it is very likely that the practice of using a dyadic flight crew team - and thereby the discovered role assignment effect - will continue in the coming years - even in the face of technological evolution and a trend towards more autonomous or reduced crew operation, at least for a large portion of the worldwide fleet of commercial airliners.

Therefore, the safety relevant teamwork and decision-making of the dyadic flight crew consisting of a Pilot-in-Command (PIC), also known as Captain, and a Second-In-Command (SIC), also known as Co-Pilot, will continue to be crucial elements contributing to the overall safety performance of the aviation system. As outlined before, early research on the influence of the flight crew's teamwork and decision-making on the safe outcome of flights started in the 1970s and led to the introduction of mandatory human factor training termed crew resource management (CRM) training for pilots (Cooper et al., 1980; R. L. Helmreich, 2006; International Civil Aviation Organization (ICAO), 1998). One of the basic intentions of CRM training was to positively influence pilots' cockpit management behavior, especially their style of leadership and decision-making. Today, those behaviors are specifically allocated to the two pilot competencies of *Leadership and Teamwork* and *Problem Solving and Decision-Making* (see chapter 2.2).

To determine pilots' attitudes towards their cockpit management behavior Helmreich (1984) invented an 11-item cockpit management attitude questionnaire (CMAQ) and found evidence of significantly diverging attitudes on cockpit management between PIC and SIC, especially in regard to intervention, leading him to the conclusion “that there is not complete acceptance of the idea of coordinated activity and decision making in the cockpit”. In turn these findings highlighted the need for promoting CRM-training for pilots as originally demanded by the NTSB in 1979[24]. Following the investigation of an accident in 1978 the NTSB recommended to the FAA: “Issue an operations bulletin to all air carrier operations inspectors directing them to urge their assigned operators to ensure that their flightcrews are indoctrinated in principles of flightdeck resource management, with particular emphasis on the merits of participative management for captains and assertiveness training for other cockpit crewmembers.”

Further research by Gregorich, Helmreich, & Wilhelm (1990) to elicit the effectiveness of the introduced CRM training focused on the attitudes of pilots towards optimum cockpit management before and after such training. Although Gregorich et al.’s research also found significant influence of certain personality traits on pilots’ cockpit management behavior they focused on pilots’ attitudes because, unlike personality traits, they assumed attitudes to be “less resistant to change and therefore may be altered through appropriate intervention” for which they deemed CRM-training an appropriate means (Gregorich et al., 1990, p. 682). Based on the CMAQ developed by Helmreich they used further essential attitudes relevant to optimum teamwork and finally created a 25-item scale as shown in table 6-1 to assess pilots’ attitudes both before and after receiving CRM-training. This research found that CRM training was successful regarding communication and leadership behavior. They also found that CRM courses were considered helpful by most of the participating pilots. Nevertheless, the researchers also observed a “boomerang effect” meaning that some participants, obviously those who showed poor cockpit management attitudes, were rather resistant to the course content, which highlighted possible limitations of CRM-training (R. L. Helmreich, Chidester, Foushee, Gregorich, & Wilhelm, 1990). To determine the long-term efficiency of CRM-training and lasting behavioral changes over time they suggested using the CMAQ on a regular basis. However, we are only aware of the CMAQ being used, in an adapted format, in other high-risk-environments such as the medical domain (J. B. Sexton et al., 2006).

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[24] NTSB-Aviation Accident Report 79-7, https://www.ntsb.gov/investigations/AccidentReports/Reports/AAR7907.pdf

Table 6-1: The 25 statements used in the CMAQ designed by Gregorich, Helmreich, & Wilhelm (1990)

1) Crew members should avoid disagreeing with others because conflicts create tension and reduce crew effectiveness.
2) Crew members should feel obligated to mention their own psychological stress or physical problems to other flight crew personnel before or during a flight.
3) It is important to avoid negative comments about the procedures and techniques of other crew members.
4) Captains should not dictate flight procedures to their first officers.
5) Casual, social conversation in the cockpit during periods of low workload can improve crew coordination.
6) Each crew member should monitor other crew members for signs of stress or fatigue and should discuss the situation with the crew member.
7) Good communications and crew coordination are as important as technical proficiency for the safety of flight.
8) Pilots should be aware of and sensitive to the personal problems of other crew members.
9) The captain should take control and fly the aircraft in emergency and nonstandard situations.
10) The pilot flying the aircraft should verbalize plans for procedures or maneuvers and should be sure that the information is understood and acknowledged by the other crew members.
11) Crew members should not question the decisions or actions of the captain except when they threaten the safety of the flight.
12) Crew members should alert others to their actual or potential work overloads.
13) Even when fatigued, I perform effectively during critical flight maneuvers.
14) Captains should encourage crew members to question procedures during normal flight operations and emergencies.
15) There are no circumstances (except total incapacitation) where the first officer should assume command of the aircraft.
16) A debriefing and critique of procedures and decisions after each flight is an important part of developing and maintaining effective crew coordination.
17) My performance is not adversely affected by working with an inexperienced or less capable crew member.
18) Overall, successful flight deck management is primarily a function of the captain's flying proficiency.
19) Training is one of the captain's most important responsibilities.
20) Because individuals function less effectively under high stress, good crew coordination is more important in emergency and abnormal situations.
21) The pre-flight crew briefing is important for safety and for effective crew management.
22) Effective crew coordination requires crew members to take into account the personalities of other crew members.
23) The captain's responsibilities include coordination of cabin crew activities.
24) A truly professional crew member can leave personal problems behind when flying the line.
25) My decision making ability is as good in emergencies as in routine flying situations.

We therefore considered if the CMAQ would be a useful means for our research to elicit the origin of the role assignment effect and the prevalence of safety relevant events in normal operation. Although we found that the CMAQ contained some items related to status hierarchy or intervention (items 1, 3, 4, 14, 15) it only contained one item eliciting pilots' risk-management and decision-making in normal operation (item 25). Given the long period of human factor training for pilots (> 40 years) and given the changes as well as the initiatives regarding the role of the Pilot Monitoring (PM) in the last twenty years (see 3.1) it could be argued that most of the CMAQ items represent general knowledge of today's CRM-training only and are therefore not helpful for gaining new insights on pilots' attitudes towards their roles on the flight deck and within the aviation system. Nevertheless, we took the CMAQ items as a useful starting point to invent a new questionnaire which, more specifically and in greater depth elicited those attitudes.

Although Boag-Hodgson, Duong, & Bagley (2022) reported a direct relationship between safety attitudes and safety behavior, previous research has found that attitude-behavior-consistency is not always found (Gross & Niman, 1975; Yuan, Sun, Zuo, & Chen, 2023). This attitude-behavior-gap is a well-known limiting factor for research methods using self-reported survey data. Early research by Ajzen & Fishbein (1977) on the relation between attitude and behavior critically discussed the assumptions required to find a reliable relation between both. They proposed that "to predict behavior from attitude, the investigator has to ensure high correspondence between at least the target and action elements of the measures he employs.". From their research on the relations of attitude and behavior they concluded that, in order to explain a social phenomenon, in our case the role assignment effect, the measurement of attitude requires a high correspondence between attitudinal and behavioral entities. To follow this advice, we decided to expand the scope of the survey and additionally included specific intervention and decision-making scenarios in the survey thereby simulating common situations in daily operation which correspond to pilots' attitudes towards the role of the SIC and PM to better estimate flight crews' behavior in practice and to correlate this with their attitudes.

Moreover, given the fact that we did our surveys before we were able to complete a comprehensive field data analysis, we decided to also include questions regarding pilots' experience with teamwork, their dealing with commercial and business pressures, and other safety relevant behavior, i.e., their SOP adherence in daily practice and training, to assess the safety related work reality of pilots to the best possible means. Although the scope of the survey became rather large by this method, we decided that the benefit of getting the chance to analyze pilots' experience in practice (study 3), their attitudes (study 4), their choices in the intervention scenarios (study 5) and decision-scenario (study 6) from one single sample outweighed the risk of reduced responses, e.g., by response fatigue.

The enlarged survey setup also provided us with the opportunity to focus on another, yet unexplored, dimension of the psychology behind safety relevant events in commercial aviation - the influence of pilots' occupational identity or self-concept. According to Burns (1979, p. 272) the self-concept can have significant influence on a person's behavior and attitudes. In the medical domain Arthur (1992) reports about various approaches to measure the self-concept of nurse referring also to his own master thesis in which he developed an instrument to measure the multi-dimensional construct of professional self-concept of nurses. This sparked the idea that similar can be done for pilots as well. The idea that the professional self-concept of pilots may have safety critical impact was supported by the experience of the author during both routine work and training with pilot colleagues, that the acceptance of CRM-training content and the orientation towards safety seemed not to be homogeneous among the pilot workforces. Similar to the findings of Helmreich et al. (1990) mentioned above that not all participants of CRM-trainings were willing to accept its content, the experience from practice with pilot colleagues suggested the assumption that the individual safety relevant behavior was dependent on individual understanding and attitude towards the job of a pilot within the aviation system. Those who appeared more open and interested in human factors appeared more safety and teamwork oriented and worked more disciplined according to Standard Operating Procedures (SOP) while those being focused on flying or operating the aircraft appeared less safety and more business oriented instead. The CMAQ item No. 7 (Good communications and crew coordination are as important as technical proficiency for the safety of flight.), which deals with pilots' orientation towards their Non-Technical Skills (NOTECHS), provided a foundation to operationalize this professional self-concept of pilots.

Given the changes introduced to the pilots' profession by evolution of cockpit technology and safety research over the last decades we assume that the NOTECHS orientation might play a significant role in constructing pilots' professional self-concept. On the one hand these changes stemmed from new aircraft and cockpit design introduced in the 1980s, using prominently more sophisticated computer and fly-by-wire technology in many new aircraft, and also from a shift in pilot training over the recent years from focusing purely on technical skills towards integrating and focusing more on non-technical skills and required competencies, especially in regard to teamwork and monitoring and intervention (see 2.2). We therefore wanted to test the hypothesis that pilots' NOTECHS orientation predicts their attitudes towards safety relevant decision-making and teamwork (H1).

On the other hand, the increase of complexity in the aviation system over the last decades by more sophisticated aircraft and more condensed air traffic had the effect that the operation of aircraft has become more and more streamlined and standardized by more operational limitations and strict SOP. This fact combined with learnings from many incidents and accidents also led to a higher degree of automated flight and less individual freedom for pilots to hand-fly and self-determine how to operate the aircraft. However, this might run counter to pilots' intrinsic motivation for having selected the job of a pilot. In their study on occupational identity and occupational fantasies of furloughed airline pilots Fraher & Gabriel (2014) found in pilots' narratives that "A crucial element of these narratives, and one whose ramifications have not been adequately recognized in the past, is their connection to a specific childhood dream, an image of themselves flying in the skies, free and uninhibited." Depending on how prominent and important such thinking is for the basic value system of individual pilots regarding their job we assume that it may influence their self-image as a pilot, whether they view themselves more as a safety or risk-manager whose focus is to manage the safety performance of their flight, or more as an aircraft or system operator whose main focus is on flying and operating the aircraft.

For example, in subsequent study by Fraher (2019) she describes pilots as 'quasi-professional experts' because their job does not exactly fit in traditional distinctions of sociologists who use the subgroups of *occupations*, e.g. for craftsmen and manual workers, and *professions*, e.g. for doctors and lawyers, “whose practice is highly specialized through advanced education and enforced by professional communities with ethical norms such as physicians’ Hippocratic Oath and lawyers’ bar association.”. Since 2009 there has been a global requirement for airlines to implement Safety Management Systems (SMS) which also incorporate the requirement for an overarching and guiding safety policy for the whole organization (International Civil Aviation Organization (ICAO), 2018). However, there is still no comparable oath binding pilots or other aviation stakeholders such as Air Traffic Controllers (ATCOs) individually to core safety values in safety relevant decision-making and teamwork, such as the need to always apply a risk-averse safety relevant decision-making and aircraft operation *(colloquially speaking: a conservative or defensive instead of a sporty or risky style of aircraft operation)* or to raise and accept mutual intervention. We therefore hypothesized that the extent to which pilots view themselves as a safety or risk-manager will also predict their attitudes towards safety relevant decision-making and teamwork (H2).

Within their theory of self-process and role behavior Horrocks & Jackson (1972) elaborated that “a value or set of values assumes a guidance function when an action decision must be made” (p. 70) and that “As compared with attitudes, values are more fundamental…” (p. 78). Other research on the differentiation of beliefs, attitudes and values such as by Rokeach (1968) also defines values as having a guiding function for developing attitudes. While an attitude is seen as “an organization of several beliefs focused on a specific object (physical or social, concrete or abstract) or situation, predisposing one to respond in some preferential manners … a value, unlike an attitude, is a standard or yardstick to guide actions, attitudes, comparison, evaluations and justification of self and others.” (pp.159/160). It is of course also possible to claim that values are simply higher level (more encompassing) attitudes so that also attitudes directly influence behavior similarly as it was attributed to values. In their work on the psychology of attitudes and attitude change Maio, Haddock, & Verplanken (2019) highlight that attitudes can be significant predictors of behavior. However, they point out that this association depends on a number of factors such as the domain and situation in which the attitude and behavior is measured, the personality or even the function of the attitude. This view is also in line with Ajzen’s theory of planned behavior mentioned before. In his book on attitudes, personality and behavior Ajzen (2005) further outlines that the three determinants leading to people's intention to perform a behavior are themselves influenced by behavioral, normative and control beliefs and those can additionally be moderated by further background factors such as personal, demographic or environmental factors, e.g., personality traits, self-esteem, age, gender, stress, etc. Furthermore, not all factors, beliefs or determinants govern people's intention always to the same extent as there may still be variation. Additionally, intent does not automatically mean that the intended action is actually performed. "According to the theory of planned behavior, performance of a behavior is a joint function of intentions and perceived behavioral control" (Ajzen, 1991). The influence of perceived behavioral control, a concept similar to self-efficacy, which incorporates the extent to which a person believes to have the required resources and opportunities, or in other words the amount of perceived difficulty to perform the intended behavior, is expressed by the dashed line in figure 5-3.

We therefore aimed to incorporate questions into our studies probing pilots' capability to effectively intervene as SIC or PM and probing their beliefs regarding the hierarchical and functional roles on the flight deck. For the purpose of our research, we additionally adopt the view that the basic understanding of a pilot's role as a pilot in regard to their main function in the aviation system and their affinity to the human factor elements of their job may well act as basic values or beliefs and inform the underlying set of values or beliefs influencing pilots' attitudes towards their decision-making and teamwork on the flight deck. As these values or beliefs may be also influenced by other stakeholders in the aviation system, such as the aviation regulatory bodies or an airline's management, who provide the legal and operational framework for aircraft operation and pilot training, we intend to also approach those stakeholders to elicit their view on the role of pilots in the aviation system. Moreover, given our holistic research approach to cover the entire frontline team responsible for the safe operation of an aircraft (see section 1.2) we also plan to include the views of Air Traffic Controllers (ATCOs) on pilots' safety relevant decision-making and teamwork.

6.1.2 Method

6.1.2.1 General

By adopting the basic idea of the CMAQ and expanding it to include not only pilots' attitudes, but their experience from practice and practical decision-making scenarios as well we developed an Aviation Safety Questionnaire (ASQ) targeted not only at pilots, but other aviation stakeholders as well. To serve our initial research objective to better understand flight crew teamwork and decision-making in commercial aviation we first - in 2017 - developed a pilot study targeted only at flight crews in a single European airline followed - in 2020 - by a global safety survey named as 'joint aviation safety survey' surveying all relevant stakeholders. In the following text we describe the survey structure and present the purpose of the selected items per section. Due to the large scope of the survey (including 127 items) we report the results separately for different sections of the survey. A detailed reasoning for the items used in each section follows before each individual results section further below.

6.1.2.2 Survey design and structure

Both surveys[25] were divided into five parts. Part 1 contained a short initial demographic section and questions regarding pilots' professional self-concept. After selecting which aviation branch (civil or military) the respondents belong to and which role they have in aviation (pilot, ATCO, management, regulator) the demographic questions started, for the pilots, with 5 questions on their rank and crewing experience as a flight crew member followed by 3 questions on their gender, age and country of citizenship. Part 2 contained 7 questions regarding pilots' orientation towards human factors, their training and knowledge about this topic, and included a question on pilots' NOTECHS - orientation. A further 3 questions dealt with pilots' experience with feedback and CRM behavior of training and check pilots in practice. Parts 3 and 4 were the main body of the survey and were identified within the survey as Part A covering "Monitoring and Intervention" and Part B covering "Aeronautical Decision-Making".

[25] Ethics approval codes: 2017: PSYETH (R/L) 16/17 130; 2020: ETH 1920-1414

Part 3 on monitoring and intervention started with 8 questions on pilots' experience with hard interventions in practice such as taking-over control or commanding a go-around and 3 questions on their experience with CRM-behavior in practice and on their experience with training of intervention. These were followed by 6 questions on pilots' experience in the role of the Pilot Monitoring (PM) and Pilot Flying (PF), 8 questions regarding pilots' attitude towards the role of the PM and PF and 6 questions regarding their perceived reluctance to intervene. The next task in this part was to make choices in a hypothetical intervention scenario derived from practice in which respondents were asked to select how the SIC should behave depending on the reactions of the PIC. Depending on the selected choices this scenario required up to 6 responses. The intervention scenario was followed by 5 questions targeted at those pilots in the role of the SIC to elicit their experience in the SIC role and 3 questions probing whether they had any reluctance to intervene. For all pilots independent of their rank this section also contained 7 questions measuring their attitude towards the role of the SIC and a further 6 questions regarding specific competencies of the SIC such as taxiing the aircraft or taking command training which concluded part 3 of the survey.

Part 4 on pilots' safety relevant decision-making started with two decision-making scenarios depicting situations familiar to pilots containing 3 questions in total. The first scenario for half of the respondents required a decision on how much fuel to take for a flight depending on specific fuel price information; for the other half of the respondents elicited a decision on making pushback for departure depending on given time information. The second scenario dealt with a problem regarding aircraft delay and was framed analogously to the Asian disease problem used by Tversky & Kahneman (1981). As in that study, half of the respondents saw the outcomes framed in terms of gains and the other half of the respondents saw the outcomes framed in terms of losses.

Part 4 continued with 6 questions eliciting the orientation of the respondents with respect to the relative priority they gave to safety or business when they had to make choices that traded off these two dimensions. One question probed pilots' attitude towards deviations from Standard Operating Procedures (SOP) and another question measured pilots' self-view as a safety-risk-manager. The next section in part 4 elicited pilots' attitude towards conservatism in practice by asking respondents 8 questions specific to certain situations in aircraft operation, some being related with

ATCO interaction. The final section of part 4 contained 10 questions probing pilots' experience of decision-making in practice and 6 questions regarding their experience with SOP discipline and conservative aircraft operation.

The survey concluded with a final demographic section (part 5) containing 16 questions asking for participants' professional history, their work experience and information on the airline they are currently working for. Thereby the survey contained in total a minimum of 127 items for each respondent who was a pilot. As completed by airline management the survey contained 20 items only; for ATCO management the survey presented only 15 items and for the regulators the survey presented 44 items. For the latter three groups of respondents, items from the ASQ for pilots were selected and partly adapted which elicited attitudes towards pilots' (respectively ATCOs') safety relevant decision-making and attitudes towards the role of the SIC. The survey for ATCOs was built similarly to the pilot ASQ, but adapted to the tasks of ATCOs, and contained in total 56 items.

6.1.2.3 Measures

The ASQ required different response scales for the different research items. For the items eliciting pilots' attitudes we mainly used 5-point Likert scales ranging from 1 = Disagree strongly to 5 = Agree strongly. For those items probing pilots' experience, for the intervention as well as decision-making scenarios, the scales were dependent on the questions and could consist of a simple Yes or No choice, a 5-point Likert scale (e.g., 1 = always unlikely to 5 = always likely) or specified individual choices. For some items such as the NOTECHS-orientation, the self-view as safety or risk manager or experience with CRM-behavior in practice the respondents could select proportional values indicating the extent of their agreement (0-100%).

In addition to selected demographic variables (e.g., flight experience, age, etc.) the two variables informing the pilots' professional self-concept were used as independent variables: the self-image (whether pilots tended to view themselves as aircraft operator/system manager or safety/risk managers) and their NOTECHS-orientation (how important they perceived non-technical skills for their job). The dependent variables were ASQ results on the relevant scales and further individual items depending on the dimension. We used student's t-tests to test for between-groups differences in the responses of pilots in the rank of a captain (PIC) and pilots in the rank of a co-pilot (SIC), including appropriate Bonferroni corrections when testing differences in means on single items instead of scales. Furthermore, we used one-way ANOVAs including appropriate Post-hoc-tests (Bonferroni or Games-Howell) when testing for differences in means between more than two groups (e.g., pilots, ATCOs, management and regulators). Pearson's correlation analyses and multiple regressions were used to test the data for associations among specific items or scales. The surveys were administered through Qualtrics and for the statistical analysis we used SPSS 28. The survey data was checked for the assumptions required for parametric statistics using Shapiro-Wilk-tests for normality and Levene's test for homogeneity of variance.

6.1.2.4 Participants

In 2017 we conducted a study of pilots employed in a single airline targeting flight crews only. Invitations to complete the survey were distributed using the airline's internal pilot email list. In total 120 (23.4%) out of the 513 pilots at the airline participated in the survey which ran from May to July 2017. The survey was fully completed by only 73 pilots (61% of those attempting the survey). However, we considered any progress beyond the initial demographic section (survey progress of minimum 23% of items) as producing valid responses, which led, after excluding 15 respondents who had not completed the survey this far and 1 respondent having used the Qualtrics off-line app function but who failed to upload the data, to a final sample size of N = 104 pilots (42 PIC (40.0%), 62 SIC (60%)).

In May 2020 we launched a second online survey which was open to respondents until December of 2020. This survey targeted frontline staff such as pilots and air traffic controllers (ATCOs) as well as airline management and regulatory personnel. The invitation to participate in the survey together with the online link to the survey was distributed by means of a global safety information provider with a daily email service (www.fsinfo.org), airline pilots' associations and by some airlines advertising the survey link to their pilots. We collected in total 403 responses of which 295 were from pilots and 45 from their management, 33 from ATCOs and 8 from their management and 22 from regulators and related organizations.

Of the 295 pilots 216 (73.2%) fully completed the survey. After excluding 35 responses not progressing further than the initial demographic section (survey progress of 6% or more) as well as responses from 2 military, 6 helicopter and 7 student pilots as well as 4 responses with continuous extreme outliers we ended up with a final sample consisting of N = 241 civil aviation pilots flying commercial fixed wing aircraft (159 PIC (66%), 82 SIC (34%)). Unfortunately, the number of valid responses from the other groups was very low (ATCOs: N = 18, ATCO Management: N = 4, Airline Management: N = 34, Regulators: N = 20) so that we decided not to independently analyze those groups but to include relevant findings from them within the analyses of the surveys taken by the pilots.

Given the fact that the 2020 global survey was not advertised to the pilots of the airline where the 2017 pilot survey was conducted and also due to the fact that there was no major change in aviation procedures or training in between the period of 2017 to 2020 we decided to merge both surveys for our analysis leading to a sample size of N = 345 pilots (201 PIC (58.3%), 144 SIC (41.7%)). The survey structure and contents of both surveys were identical, except that the intervention scenarios were placed after the initial demographics section before the human factors' orientation. Additionally, based on feedback by respondents on the pilot survey in 2017 some items were slightly modified in wording. These changes are highlighted throughout the respective results section below. Where an inverted coding was required during merging both surveys this is also highlighted in the respective results section. The dataset for the merged surveys is available online at OSF: https://osf.io/6wguc/?view_only=084ef146c25a4b4ea5e472415a51c502

6.2 Results

6.2.1 Pilots' Demographics

The merged survey sample contained responses from both the 2017 survey in a single airline and the 2020 global survey. Table 6-2 provides a breakdown of the respondents' demographics. While nearly all the respondents in the 2017 survey were Germans, the 2020 survey was taken by pilots with origins from all five continents. Therefore, in the merged survey again most (54.3%) of the respondents were German, followed by pilots from the US (14.5%), from the UK (7.8%), from Austria (2.3%), from the Netherlands (2.0%), from Belgium (1.7%), from Canada, Colombia, India, Ireland and Mexico (each 1.2%), from Italy, Malaysia, New Zealand, Switzerland (each .9%), from Australia, Brazil, Denmark, Norway (each .6%) and from Bahamas, Croatia, Cyprus, Egypt, Japan, Lebanon, Nigeria, Saudi Arabia, Singapore, South Africa, Sweden, Tunisia, Turkey and UAE (each .3%). The remainder of the respondents (1.2%) did not want to disclose their country of origin. A large proportion (37%) of the pilots were employed with airlines in Germany, some (26%) pilots with airlines in the US, 10% in the UAE, 6% in the UK and 13% were employed in other countries and 8% did not disclose the base of their airline.

The distribution of gender was similar in both surveys. The 2017 survey was taken mostly (91%) by male and 9% female participants and the 2020 survey was also taken mostly (95%) by male and 5% of female participants leading in the merged sample to more male (93.3%) than female respondents (6.7%). The proportions of female participants reflect the proportion of female pilots in the aviation industry which is estimated at just over 5% according to the International Society of Women Airline Pilots[26]. The mean age (45) and mean total flight experience (11,026 flight hours) on medium and large aircraft reflect that the survey was taken mostly by very experienced pilots of which more than a third (40%) had wide body aircraft experience and thereby experience in flying long range. A quarter of them (24.9%) were pilots holding a training or check-rating. Only a few (11.6%) of the respondents had a military flying background. More than a third (36.8%) of the respondents worked for low cost or leisure airlines, nearly a third (28.7%) worked for a major network carrier and some (8.7%) working for cargo only airlines. Only very few (3.2%) were working in the business aviation sector. The remainder of respondents (22.6%) did not disclose by which kind of operator they were employed. The mixture of respondents in terms of their employment and the nearly equal proportions of PIC (58.3%) and SIC (41.7%) throughout the dataset provide a good foundation for reflecting the global commercial aviation pilot community.

[26] https://isa21.org/media/

Table 6-2: Demographic Breakdown of Participants

Demographic	**N = 345**	
	Frequency / Value	**%**
Sex		
Male	322	93.3
Female	23	6.7
Age		
Mean (years)	45	-
Rank		
Captain (PIC)	201	58.3
Co-Pilot (SIC)	144	41.7
Additional Function as Trainer	86	24.9
Total Flight experience (> 5.7to MTOW)		
Mean (hours)	11026	-
Year of pilot education		
Mean (year)	1998	-
Professional history and experience		
University degree	120	34.8
Sport flying experience prior to job	109	31.6
Business aviation flying experience	64	18.6
Military flying experience	40	11.6
Wide-body - experience	138	40.0
Side-Stick-experience	84	24.3
Aircraft operator (airline) information		
Mean fleet size (number of aircraft)	176	-
Legacy / Network Carrier	99	28.7
Low Cost / Leisure / Charter Carrier	127	36.8
Business / Corporate Airline	11	3.2
Cargo only Carrier	30	8.7
Other / No information	78	22.6

6.2.2 Dimensions and subscales of the ASQ

The ASQ was designed to capture the dimensions of pilots’ professional self-concept as described above as well as their experience with safety relevant decision-making and teamwork in practice and training. Furthermore, it should elicit pilots’ attitudes towards safety relevant decision-making and towards monitoring and intervention including their attitudes towards the roles of the PM and SIC. For this purpose, different scales were derived for each dimension using a combination of sensemaking from a flight operations perspective and taking into account results from factor analyses. The scale descriptive statistics and reliabilities are shown in table 6-3.

However, not all scales achieved a Cronbach's alpha coefficient of .8 as recommended by Clark & Watson (1995) and some scales even fell below the acceptable level of .7 as given by Nunally & Bernstein (1978). Given the fact that it was simply not feasible for some items to be altered or exchanged (e.g., those describing missing/ineffective intervention or the perceived freedom for safe decision-making) we accepted a Cronbach's alpha down below .6 to a value of .5 being aware that making inferences dependent on these scales should only be done carefully. Applying different methods for assessing the scale reliability using methods such as determining ‘omega’ or ‘greatest lower bound’ as proposed by Peters (2014) revealed the same weaknesses for the relevant scales so that we finally sticked to reporting Cronbach’s alpha.

Table 6-3 also includes selected single items relevant for the respective dimension. Information on the remaining survey items will be added in the respective results sections. The results of the intervention scenarios will be presented as a separate chapter (see 6.5) as well as the decision-scenarios will be shown as a separate chapter (see 6.6). Thereafter a summarizing discussion and concluding chapter of the thesis will follow (see 7.2).

Table 6-3: Descriptive Statistics and Reliabilities of the ASQ and Subscales

Dimensions and subscales	M	SD	α	Items
Pilots' Self-Concept / Occupational Identity				
Pilots' self-image as a safety/risk manager (%)	57.76	19.40	-	1
Pilots' NOTECHS orientation (%)	45.23	16.57	-	1
Human Factor orientation (aggregate of the above) (%)	50.98	13.35	-	2
Experience with safety relevant behavior				
Pilots' experience with safe behavior (%)	78.36	16.40	.81	4
Pilots' experience with CRM behavior (%)	42.84	17.47	.75	6
Pilots' perceived freedom for safe decision-making	3.87	.74	.53	4
Pilots' perceived difference by mode of operation	3.90	1.24	-	1
Experience with Monitoring and Intervention				
Pilots' experience in the PM role	3.10	.74	.62	6
SIC's experience with intervention	2.77	.87	.71	4
*Hard Intervention (control take-over) provided	1.70	.90	.73	2
*Hard Intervention (control take-over) received	1.25	.31	-	1
*Experience with missing/ineffective intervention	1.64	.53	.53	4
Attitude towards safety relevant decision-making				
Pilots' attitude towards SOP deviations	2.80	1.29	.68	2
Pilots' attitude towards conservatism in practice	2.18	.60	.62	5
Pilots' attitude towards safety/business considerations	3.36	.70	.60	5
Attitude towards Monitoring and Intervention				
Pilots' attitude towards the role of the SIC	4.10	.65	.60	5
Pilots' attitude towards the SIC / PM as supervisor	2.33	1.13	.70	2
Pilots' attitude towards a low authority of the PM	3.84	1.23	-	1
Pilots' attitude towards a high autonomy of the PF	2.96	1.34	-	1
PM's reluctance to take away control	2.81	1.42	-	1
Pilots' reluctance to intervene in a 2-Captain crew	2.73	1.30	.86	2
SIC's reluctance to intervene	2.73	1.07	.82	3

* Scales with an asterisk have a range from 1 = NO and 2 = YES. All other scales, except those showing a proportion (%) are based on 5-Point-Likert-Scales ranging from 1 = Disagree strongly to 5 = Agree strongly.

6.2.3 Pilots' Professional Self-Concept

Based on the reasoning mentioned in the introduction, we wanted to test the hypothesis that pilots' NOTECHS orientation as well as their self-image as a safety/risk-manager, which we adopted as basic values or beliefs making up pilots' professional self-concept, predict their attitudes towards safety and teamwork. Before doing so we first report about the results on the individual items capturing the self-image and the NOTECHS orientation.

6.2.4 Pilots' self-image as a safety/risk-manager

To elicit pilots' self-image, we asked them the following single question: "How much would you characterize the job of a pilot as being a safety/risk-manager relative to being an aircraft operator/system manager?" They should state the proportion of being a Safety/Risk Manager ranging from 0 to 100%. This question was also used for the ATCOs, the management and the regulators, however adapted to ask ATCOs for their own self-image as ATCOs and the management and regulators on how they view the role of the pilots. A one-way ANOVA was conducted to compare the means between the four groups of respondents and Games-Howell as post hoc test due to unequal variances in the responses. There was a significant difference view of the pilot role among the four groups, F (3, 326) = 15.09, $p < .001$. We found that pilots (M = 57.76, SD = 19.4) and ATCOs (M = 68.29, SD = 18.73), with no significant difference between these two groups, p = .15, see themselves slightly more as a safety/risk manager rather than as aircraft operators or system managers.

However, regulators view the pilots even more as safety/risk-managers than the pilots see themselves as such (M = 70.60, SD = 12.13), p = .006, and also airline managers see pilots significantly more as a safety- or risk-manager (M = 78.50, SD = 12.02) than the pilots themselves do so, $p < .001$. The difference in view between pilots and regulators, respectively airline management, is interesting as it might highlight a gap between blunt and sharp end of the aviation system in regard to the expectation of what the main duty of pilots is.

The nearly equal distribution of pilots' view between safety/risk management and aircraft/system operation might just reflect their daily work, being equally responsible for both, the technical operation of the aircraft and the safety relevant decision-making at the same time. However, since it can be assumed that both non-pilot groups know the work environment and the tasks pilots have to do along a flight very well, the focus of the regulators and airline managers (the blunt end) on the safety- and risk-management component might highlight that either the technical component of flying is underrated by them or their expectation regarding safety is higher than feasible for pilots in daily operation.

6.2.5 Pilots' NOTECHS orientation

To elicit pilots' NOTECHS-orientation we asked the survey participants the following question, which is basically an adaptation of the original CMAQ question No.7 (Good communications and crew coordination are as important as technical proficiency for the safety of flight.): "To become a professional pilot requires, amongst other things, training of skills. This includes technical skills (e.g., stick & rudder, procedural skills, etc.) as well as non-technical skills (e.g., decision-making, teamwork, communication skills, etc.). If you were responsible for the design of pilot's initial training/education today, of how much non-technical skills training in relation to technical skills training should today's professional pilot training consist? (the higher the percentage-value the more non-technical skills training you would demand)". They should state the proportion of NOTECHS-training ranging from 0 to 100%. This question was also used for the ATCOs, however it was adapted to ask ATCOs for their own NOTECHS-orientation.

We found that pilots rate NOTECHS-training as less important than training on how to technically operate the aircraft (M = 45.23, SD = 16.57). A one-way ANOVA showed that there was no significant difference in the responses on this item between pilots, ATCOs (M = 47.60, SD = 15.96) and regulators (M = 48.47, SD = 21.18). This question was not presented to the management respondents. That we did not find higher agreement on the importance of NOTECHS training might be related to the generally lower amount of NOTECHS training in pilot and ATCO education in comparison to their technical skills training. Before the introduction of the Competency Based Training and Assessment (CBTA) approach of the industry as mentioned before (see 2.2) the topics of non-technical skills and human factors were not the central element of the curriculum of initial education and training of pilots and ATCOs but an add-on only. CBTA changed this concept to better entangle non-technical skills and human factors with the technical skills by integrating all relevant skills in each of the nine competencies as described before. However, in the dataset used for the analysis nearly all (95.5%) of the participating pilots had completed their initial pilot education before 2016, the year when CBTA was first introduced, so that they could not take advantage of this new concept when gaining their pilot license.

6.2.6 Pilots' Human Factor orientation

Given the fact that important elements of risk-management such as situation awareness or decision-making are also core NOTECHS-elements we unsurprisingly found that pilots' NOTECHS orientation and their self-view as a safety- or risk manager are significantly correlated, r (245) = .17, p = .006. This finding suggests that the more NOTECHS-oriented the pilots are the more they seem to see themselves as safety- or risk-managers. Due to this result we decided to combine both items and create an aggregate variable out of both items' means and named it "human factor orientation". We will also use this aggregate variable to assess if there are any associations of pilots' self-concept with the scales used to elicit pilots' experience in practice and their attitudes towards safety relevant decision-making and teamwork. A one-way ANOVA with Bonferroni corrections was conducted, F (2, 276) = 4.77, p = .009, revealing that pilots (M = 50.98, SD = 13.35) and ATCOs (M = 56.82, SD = 11.37) seem to be equally human factor orientated, p = .243, but regulators (M = 60.33, SD = 13.48) seem to have a more human factor oriented occupational picture of the pilots than the pilots themselves, p = 0.26.

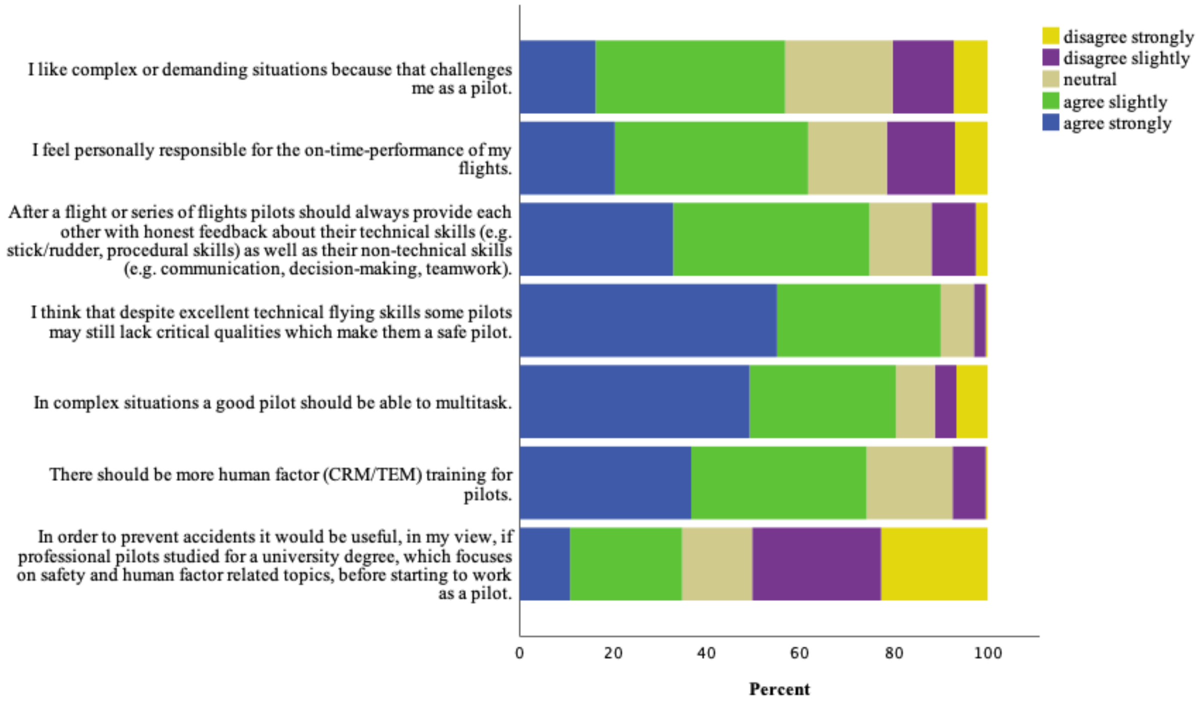
6.2.7 Additional items related to pilots' professional self-concept

To elicit pilots' professional self-concept, we had presented participants with further items regarding NOTECHS which did not fit in any scale. However, they provide some insights in pilots' view on complexity and the status of NOTECHS and its training. Results on these items are presented in table 6-5 and figure 6-2 below. From the results it becomes apparent that most pilots seem to be challenge seekers and feel personally responsible for business factors such as on-time-performance. Regarding the latter, the data from the airline management survey shows that management supports this kind of thinking by their pilots (*M* = 3.50, *SD* = 1.31). As shown by a one-way ANOVA equally as the pilots, also ATCOs (*M* = 4.15, *SD* = 1.29) and regulators (*M* = 4.53, *SD* = .84) seem to assume multitasking as a normal approach to deal with complex situations although research has shown that multitasking is a myth and that complex situations should rather be de-complexed instead of being handled using multitasking (Loukopoulos, Dismukes, & Barshi, 2009). Both groups also feel equally personally responsible for the on-time-performance, respectively the capacity management of their sector (*M* = 3.59, *SD* = 1.37). Although most pilots, as well as equally the ATCOs (*M* = 2.81, *SD* = 1.39), do not endorse the idea of requiring a university degree with safety or human factors contents, most of the pilots welcome more human factor training and support the idea that good technical skills alone do not necessarily make a safe pilot.

Table 6-4: Additional items related to pilots' professional self-concept

Average agreement with the following items				
Scale (1 = strongly disagree, 5 = strongly agree)	N	M	SD	Agree (%)
1. I like complex or demanding situations because that challenges me as a pilot.	222	3.45	1.13	56.7
2. I feel personally responsible for the on-time-performance of my flights.	172	3.53	1.17	61.6
3. After a flight or series of flights pilots should always provide each other with honest feedback about their technical as well their non-technical skills.	317	3.93	1.03	74.8
4. I think that despite excellent technical flying skills some pilots may still lack critical qualities which make them a safe pilot.	240	4.42	.77	90.0
5. In complex situations a good pilot should be able to multitask.	240	4.12	1.16	80.5
6. There should be more human factor training.	240	4.03	.94	74.2
7. In order to prevent accidents, it would be useful, in my view, if professional pilots studied for a university degree which focuses on safety and human factor related topics before starting to work as a pilot.	334	2.72	1.34	34.8

Figure 6-1: Additional items related to pilots' professional self-concept



6.2.8 Pilots' professional self-concept and pilot demographics

Based on the results on the pilot demographics in the field data research (study 1 and 2) we wanted to see how these results are associated with pilots' human factor orientation, the aggregate of the two variables we used to operationalize pilots' professional self-concept (Self-view and NOTECHS-orientation). In study 2 we found that especially higher aged, high experienced PIC and younger aged, low experienced SIC were involved in the events and that the role assignment effect is associated with lower ages of the SIC and higher on-type flight experience of the PIC.

We therefore wanted to check for associations between pilots' human factor orientation with those demographics we deemed relevant. Therefore, we used the following variables for this analysis and for further analyses as well: pilots' rank, age, gender, flight experience, work experience (trainer or no trainer, university degree, prior sport flying, business or military experience), and their type of aircraft flown (sidestick, wide-body experience).

A simple bivariate correlation analysis found that it seems that higher aged pilots tend to view themselves more as safety/risk managers than younger pilots, r (262) = .18, p = .004. As expected, this pattern was also consistent regarding pilots' total flight experience, r (242) = .14, p = .032, and qualification as training or check pilot, r (203) = .16, p = .020, as well as regarding pilots' rank showing that lower ranking crew members tend to view themselves more as an aircraft operator than as a safety/risk manager, r (262) = -.18, p = .003. A self-view of being a safety/risk manager was also positively correlated with having wide body and side stick experience, both r (242) = .23, $p < .001$, and with the fleet size of the airline, r (260) = .20, p = .001. More flight experience was positively correlated also with pilots' NOTECHS-orientation, r (243) = .13, p = .045. Sport flying experience prior to professional pilot education was negatively correlated with pilots' NOTECHS orientation, r (243) = .20, p = .002. However, a multiple linear regression using the relevant pilot demographics and the aggregate variable of pilots' human factor orientation, revealed that only prior sport flying experience significantly contributed to the model, p = .012, suggesting that this activity may lead to less human factor orientation of pilots. This negative correlation of previous experience with sport flying and NOTECHS orientation could be explained by the low focus on and low content of human factor training for gaining a license in general aviation, e.g., for gliders or single engine piston aircraft, at least during in the times when most of the participants of the survey started their professional pilot education.

Although all other demographics did not significantly contribute to the model the results from the bivariate correlation analysis may at least - having the possibility for an inflation in type one error in mind - point to some associations which are plausible, at least from an operational perspective. First, the possible negative association of rank and human factor orientation may well reflect current practices in aviation which allocate the risk-management and safety relevant decision-making mostly to the role of the PIC. Especially pilots with low flight experience, which is in our dataset naturally significantly correlated with low age, r (243) = .77, $p < .001$, could therefore first tend to focus on getting to grips with operating the aircraft instead of focusing on risk-management and safety relevant decision-making. This might lead more to a self-view of being an aircraft operator than a safety/risk manager among pilots in the role of the SIC which could also be a hint for how to explain the lower monitoring and intervention performance of younger and probably less-experienced SICs and an explanation for the correlation of flight experience with NOTECHS orientation, too. Second, the correlation of sidestick and wide-body experience with pilots' self-view could be explained by the aircraft design and type of operation. In contrast to aircraft with traditional control wheels those with a sidestick often have higher automated systems being more restrictive to manual system operation and manual flight which may, by design, shift the focus of pilots' work to safety and risk-management. Given the fact that wide-body aircraft are mostly used for long-range operation characterized by a rather long portion of cruise and automatic flight and most often only one take-off and one landing for the active flight crew might also shift the focus of pilot's work to safety and risk-management.

6.2.9 Pilots' human factor knowledge

To elicit the knowledge of pilots regarding human factors we asked them to indicate whether they are familiar with certain topics or not. In the 2017 survey we used a list of 10 items which was increased to 18 items in the 2020 survey as shown in table 6-6. Based on feedback on the pilot survey in 2017 we also reversed the way of presenting the items. While we asked in the 2017 to indicate which item pilots are familiar with, we asked in the 2020 survey which item pilots are not familiar with to facilitate a faster response to the items assuming that pilots know most of the items. When merging the two surveys we therefore inverted the coding of the 2017 results. Furthermore, we positioned this question differently in the global 2020 survey. While in the 2017 survey we asked for this at the end of the survey we shifted the question to the beginning combined with the professional self-concept questions. We found that human factor topics such as confirmation, conformity and continuation bias and resilience (all above 80%) seem to be known throughout the pilot community while specific terms used in the safety management and system safety domain such as ETTO/TETO[27] and ALARP are not well known. The knowledge of the above biases might not only stem from pilots' human factor training but from their frequent use in accident and incident reports. However, important to mention is that the actual human factor knowledge throughout the whole pilot community might be significantly lower than indicated by the survey results. Firstly, the participation in this survey already requires a certain affinity to safety and human factors which seems not to be given by all pilots

[27] ALARP = As low as reasonably practicable, a term used in safety risk management (refer to ICAO, 2018); ETTO / TETO: Efficiency Thoroughness Trade-Off / Thoroughness Efficiency Trade-Off, a term used in safety management and system safety domain (refer to Hollnagel (2009))

otherwise the participation rate to this survey would have been significantly higher. Secondly, the question design cannot rule out that pilots pretend familiarity with a topic even though they might have only heard about it instead of being trained therein. Furthermore, the relative lack of knowledge on system safety and safety management specific terms might indicate that front end staff is not sufficiently trained and embedded in airlines' safety management systems.

Table 6-5: Number and percentage of pilots indicating that their human factors knowledge

Human Factor / Safety topic	**N = 280 (100.0%)**
ALARP-Principle	112 (40.0%)
Anchoring Bias	159 (56.8%)
Confirmation Bias	234 (83.6%)
Conformity Bias	226 (80.7%)
Continuation Bias	227 (81.1%)
Framing Effect Bias*	179 (63.9%)
ETTO / TETO	79 (28.2%)
Loss Aversion Bias	160 (57.1%)
Preference Reversal	165 (58.9%)
Primacy-Recency-Effect Bias	152 (54.3%)
Operational Resilience	237 (84.6%)
Naturalistic Decision-Making*	196 (70.0%)
Nudging*	176 (62.9%)
Practical Drift*	196 (70.0%)
Psychological Priming*	180 (64.3%)
Psychological Safety*	208 (74.3%)
Resilience Engineering*	186 (66.4%)
The Weighting Function*	147 (52.5%)

Items with an Asterix were only shown in the 2020 survey.

6.2.10 Summary of key findings regarding pilots' professional self-concept

- Pilots see themselves slightly more as a safety/risk manager rather than as aircraft operators/system managers.
- Regulators and Airline Management see pilots significantly more as safety/risk managers than pilots see themselves as such
- Pilots see NOTECHS-training as less important than technical skills training. Pilots having done sport flying prior to their professional pilot education seem to be significantly less human factor oriented.
- The more NOTECHS-oriented the pilots are the more they see themselves as safety/risk-managers.
- Both frontline operators appear to be challenge-seekers. Multi-tasking is viewed by both groups as an appropriate means to deal with complex and dynamic situations. Both groups do not prefer an in-depth human factor education before their job.

6.3 Study 3: Pilots' safety relevant experience in practice and training

6.3.1 Pilots' experience with safe behavior in practice

The surveys incorporated questions regarding pilots' experience with safety relevant behavior and teamwork in practice and training as we did not have the field data analysis available yet at the time when we ran the surveys. As shown in table 6-7 pilots report that they view about three quarters (80%) of their colleagues being good role models for procedure adherence and risk-averse decision-making. At first sight, these results might suggest that working discipline in commercial aviation flight decks is rather high.

However, the given proportions, although being survey- and self-reported data only, show that there seems to be not only a gap between work-as-imagined (pilots who adhere to all SOPs = 100%) and work-as-done (reported proportion $M = 78.36$, $SD = 16.40$) but also a gap between the optimum and actual risk-taking by pilots. A multiple linear regression showed no significant influence of the relevant pilot demographics with their experience with safe behavior in practice.

In the survey we explicitly asked for pilots' experience in normal operation, meaning flights without any aircraft malfunction or emergency. But only those non-normal situations or emergencies might possibly warrant a deviation from given SOP or a riskier decision-making to eventually achieve a higher level of safety. Although the reasons behind these gaps such as a lack of discipline, commercial pressure or inadequate procedure design are not reported, the mere fact that pilots do not report near 100% SOP adherence or conservatism in normal operation, even not when working with their training- and check pilots, should give reason for concern in a safety critical industry like commercial aviation.

Another concern for the industry might be that our data shows significant differences in views of PICs and SICs in this regard. A student's t-test with a Bonferroni corrected alpha-level of .0125 revealed that PICs ($M = 84.39$, $SD = 14.00$) rate their SICs significantly higher in SOP adherence than the SICs rate their PICs ($M = 73.46$, $SD = 16.36$), $t(214) = 5.32$, $p < .001$. This not only reflects a probable shift of self- and public pictures in PICs but also signals that SICs are more subject to possible situations requiring intervention than PICs are.

Table 6-6: Percentage of pilots' showing safe behavior in practice and training

	N	M	SD
Scale average	-	78.36	16.40
1. What percentage of the Line-Pilots that you fly with are, in your view, good role models for a disciplined adherence to rules and procedures?	218	79.23	16.08
2. What percentage of the Line-Pilots that you fly with are, in your view, good role models for conservative/risk-averse flying or decision-making?	218	78.72	16.45
3. What percentage of your Training/Check-Pilots are, in your view, good role models for a disciplined adherence to rules and procedures?	104	79.35	21.59
4. What percentage of your Training/Check-Pilots are, in your view, good role models for conservative/risk-averse flying or decision-making?	104	80.80	22.15

6.3.1.1 Pilots' professional self-concept and their experience with safe behavior in practice

There was no significant correlation with pilots' human factor orientation and their experience with safe behavior in practice, r (228) = .05, p = .495.

6.3.1.2 Summary of key findings regarding pilots' experience with safe behaviors

- High, but less than expected level of positive experience with SOP discipline, even with training/check pilots
- PICs are rated significantly lower in safe behavior by the SICs than vice versa.

6.3.2 Pilots' experience with CRM in practice and training

On top of pilots' experience with SOP discipline and safety relevant decision-making we also asked them about their experience with teamwork in practice and training. Like our findings with safe decision-making in practice we also found that teamwork, although mostly rated positive, shows a gap to an optimum level as well, especially regarding teamwork with training- and check pilots (see table 6-8). The responses show that pilots, without significant difference between PIC and SIC, perceive only about three quarter (72.1%) of their line pilot colleagues as role models for good CRM and only slightly more than half (62.4%) of their training- and check pilots.

Especially the finding on the training and check pilots is striking because they should be role models for good CRM per se given their role in the aviation system to train and check pilots in their safety relevant behavior on the flight deck. Additionally, line pilots perceive only a few proportions (30.8%) of their training and check pilots as experts in human factors. We therefore checked again the responses given regarding pilots' human factor knowledge (see table 6-6), but a bivariate correlation analysis only found that line pilots report to know more often than training pilots about the ALARP principle, r (196) = .14, p = .050, and training pilots more often than line pilots report to know the topic of continuation bias, r (196) = -.15, p = .033, and the topic of primacy-recency-bias, r (196) = -.25, p < .001. These results do obviously not explain why line pilots rate their training pilots so low on human factor expertise, especially as those results are zero-order correlations only. However, one possible explanation could be that the level of pilots' satisfaction with their trainers' CRM behavior will certainly be influenced by the nature of these work experiences as they often happen in a training or check environment when line-pilots are assessed by the training- or check pilots on their performance. Nevertheless, the low rating of training- and check pilots on their CRM behavior could be a signal to the aviation industry to critically challenge the behavior of those who in fact should be role models in the industry.

Striking are also the findings on the feedback culture and perceived intervention capability of SICs. Despite training pilots in CRM for decades and thereby promoting feedback among flight crew members the data shows that this option is barely used in practice. Pilots report that they experience only very few (17.5%) of their colleagues asking them for feedback on their non-technical skills and just a quarter (23.3%) asking for feedback on their technical skills. While there are no significantly different responses between PIC and SIC regarding NOTECHS feedback, we found that the requests for feedback on technical skills is experienced more often by PIC (M = 27.92, SD = 26.11) than by SIC (M = 16.60, SD = 18.33), t (305) = 4.48, p <.001. Given the fact that a multiple linear regression of this specific item with the relevant pilot demographics additionally found that higher aged, p = .022, (and also mildly significantly higher experienced pilots, p = .063, with age and flight experience being two variables certainly being highly intercorrelated in our dataset (age: Variance Inflation Factor (VIF) = 3.65, total flight experience: VIF = 2.68)), reported a higher proportion of technical feedback requests might suggest that feedback is probably not given on a routine basis but is especially requested by junior pilots. Although this may be normal behavior for novices to further improve their performance, this pattern might show that the intention of CRM training to promote and highlight the value of feedback irrespectively of age or experience seems not to have the desired effect.

One of the reasons why pilots might refrain especially from giving NOTECHS-feedback could be a missing template which supports formulating this kind of feedback. When we asked participants if they find it easier to feedback technical errors (e.g., flight profile or procedure deviations) than to feedback non-technical errors (e.g., errors in decision-making, teamwork, communication) more than half (63.1%) of the responding pilots agreed to this statement, without any significant difference between PIC and SIC. While technical feedback might be easier for pilots due to the availability of observable parameters (e.g., speed or altitude deviations) the non-technical feedback requires a more qualitative and subjective description of the observed behavior. Therefore, it might be possible that the expected promotion of the new ICAO CBTA competencies might serve as a feedback tool supporting line pilots to mutually provide each other even non-technical feedback and thereby helping to improve the feedback culture within the pilot community.

Table 6-7: Pilots' positive experience with CRM in practice and training

	N	M	SD
Scale average	-	42.84	17.47
1. What percentage of the Line-Pilots that you fly with are, in your view, good role models in practicing effective crew resource management?	264	72.11	21.58
2. What percentage of the pilots that you fly with request feedback about their non-technical skills (e.g., decision-making, teamwork, communication) after a flight?	309	17.45	21.32
3. What percentage of the pilots that you fly with request feedback about their technical skills after (e.g., flying or procedural skills) after a flight?	309	23.34	23.90
4. What percentage of the Copilots in your company do you attribute the ability to intervene effectively in the flying or safety relevant decision-making of a PIC in practice?	264	65.30	25.48
5. What percentage of your training/check pilots are, in your view, experts in human factors?	148	30.79	25.60
6. What percentage of your training/check pilots are, in your view, good role models in practicing effective crew resource management?	140	62.35	26.69

6.3.2.1 Pilots' professional self-concept and their experience with CRM in practice and training

There was no significant correlation with pilots' human factor orientation and their experience with CRM in practice and training, r (245) = .06, p = .360.

6.3.2.2 Summary of key findings regarding pilots' experience with CRM

- ➢ Lower than expected CRM-role model behavior in practice, especially by Training- and Check pilots
- ➢ Very low frequency of feedback use in practice - no healthy feedback culture despite CRM-training - CBTA might help to improve this

6.3.3 Pilots' freedom for safe decision-making

To elicit if there is any perceived influence of commercial pressures on pilots' safety relevant behavior in practice, we additionally asked questions regarding their perceived freedom for safe decision-making in practice. The data in table 6-9 and figure 6-3 show that most (82.0%) pilots feel free to increase their safety margins by taking discretionary extra fuel and most (82.5%) report that they feel free to accept delays if necessary. A multiple linear regression with the relevant pilot demographics showed that elder pilots perceived more freedom for safe decision-making than younger pilots, $p = .024$, and those having wide-body experience perceived less freedom for safe decision-making, $p = .013$. While the influence of age might highlight a certain serenity in dealing with operational pressure on safety relevant decision-making, the negative influence of wide-body experience could be related to influences by the individual company safety culture of the airlines where the respondent is currently or was formerly employed.

However, given the fact that this scale had the lowest Cronbach's alpha (.53) we decided to additionally analyze the items of this scale individually. To cater for a possible type 1 error inflation, we used Bonferroni correction by setting the alpha level to .01. We found that SICs ($M = 3.94$, $SD = 1.08$) significantly less than PICs ($M = 4.46$, $SD = .86$) perceive the freedom to prevent hasted work before off-block, $t\ (156) = 3.74$, $p < .001$. A Cohen's d of .95 shows a large effect size. This difference might reflect that not all SICs may feel sufficiently empowered to intervene and take the time needed to perform safety relevant work calmly and deliberately if they feel pressured by time constraints, either due to their general lower status in comparison to PICs or due to a leadership behavior of PICs which does not take into account the necessity to adapt their pace of work and tasks in dynamic situations to the team member who requires more time.

By means of a multiple linear regression with the relevant pilot demographics we found that elder pilots seem to perceive more freedom to reject time pressure, $p = .036$, and that wide-body experience was negatively correlated with the perceived freedom to reject time-pressure, $p = .046$. We also found that prior business aviation experience was also negatively correlated with the perceived freedom to reject time-pressure, $p = .005$, which might further support the notion that an airline's safety culture might have influence on pilots' perceived freedom for safe decision-making. However, this could be mitigated by clear safety policies stating and highlighting that the airline management supports accepting or making delays for safety reasons and by a further focus on this issue in pilot training and checking so that pilots gain higher marks for safe decision-making including making or accepting delays for safety reasons.

6.3.4 The influence of business considerations

The influence of operational pressures by schedule or other business factors is also revealed by other items with no significant differences in responses between PICs and SICs: While only slightly more than half (64.5%) of the pilots endorse that they perceive safety being the primary goal of their airline (item 4), slightly less than half (46.4%) endorse that they perceive careful flying and decision-making being supported by the airline (item 3) and even more than half (68.9%) of the pilots admit that their risk-averse decision-making in normal operation may be hampered by business considerations (item 5). While a multiple linear regression with the relevant pilot demographics showed that there were no significant associations with items 4 (safety is the primary focus) and 5 (differences between normal and non-normal operation), the regression with item 3 (airline expectation) shows the respective results of the scale for age, $p = .027$, and wide-body experience, $p = .028$.

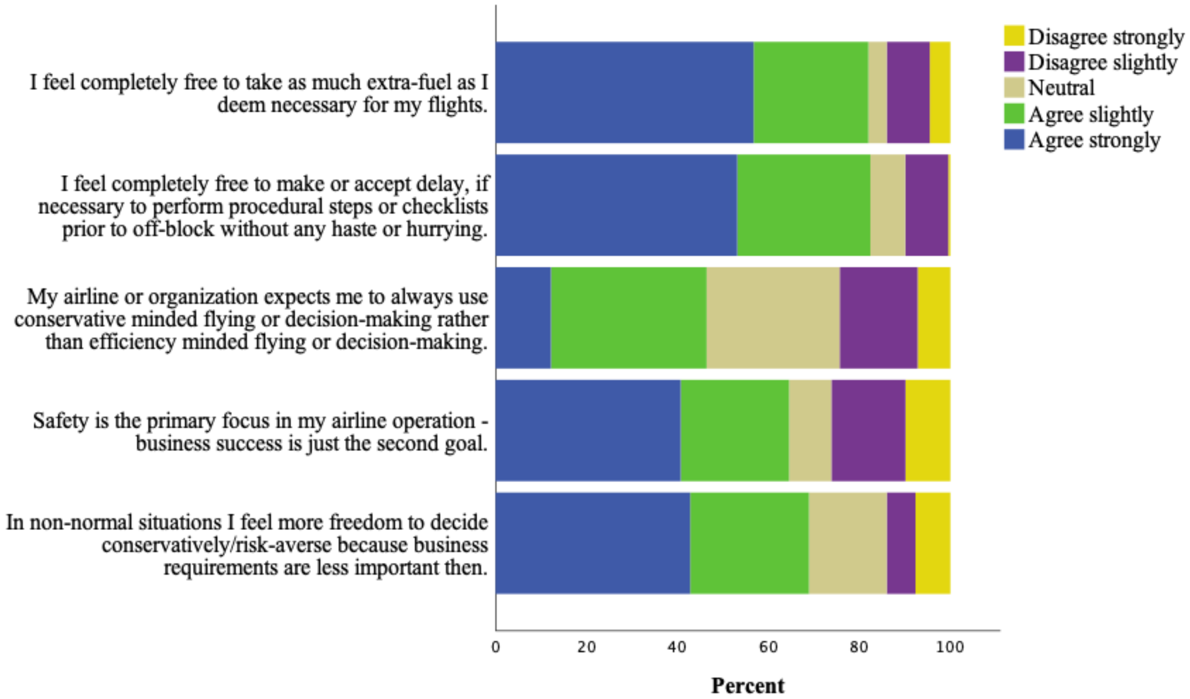
Furthermore, the influence of time or schedule pressures and its different impact depending on the pilot’s role became evident also when we asked participants the single item: “What percentage of the line-pilots that they fly with let themselves, in your view, be rushed by the goal to avoid or catch-up delay?” While we found that PICs endorsed this for only approximately a third of the SICs they fly with ($M = 34.68$, $SD = 26.04$), this was endorsed by the SICs for nearly a half of the PIC they fly with ($M = 44.81$, $SD = 25.04$), $t\,(214) = -2.92$, $p = .004$, which marks a significant difference, despite the Bonferroni corrected alpha level, and might show that especially PICs, despite allegedly feeling the freedom to reject time pressure, eventually do not really practice it. This in turn might underpin the need for positive company safety cultures in aviation including a strong and active management support in providing the whole pilot workforce with the freedom to reject time and other business pressures in favor for safety considerations.

Table 6-8: Pilot's perceived freedom for safe decision-making

Average agreement with the following items				
Scale 1 = disagree strongly, 5 = agree strongly	N	M	SD	Agree (%)
Scale average	-	3.87	.75	-
1. I feel completely free to take as much extra-fuel as I deem necessary for my flights.	222	4.20	1.17	82.0
2. I feel completely free to make or accept delay, if necessary, to perform procedural steps or checklists prior to off-block without any haste or hurrying.	222	4.25	.98	82.5
3. My airline or organization expects me to always use conservative minded flying or decision-making rather than efficiency minded flying or decision-making.	222	3.27	1.11	46.4
4. Safety is the primary focus in my airline operation – business success is just the second goal.	172	3.69	1.40	64.5
5. In non-normal situations I feel more freedom to decide conservatively/risk-averse because business requirements are less important then.	222	3.90	1.24	68.9

Item 5 is an additional item and does not belong to the scale.

Figure 6-2: Pilot's perceived freedom for safe decision-making



6.3.4.1 Pilots' professional self-concept and their perceived freedom for safe decision-making

There was no significant correlation of pilots' human factor orientation with the scale of pilots perceived freedom for safe decision-making (items 1 -4), r (219) = -.03, p = .697, and also not with the single item asking for the difference between the use of conservatism in normal and in non-normal operation (item5), r (219) = .08, p = .216.

Nevertheless, the data provided some interesting further results which might, despite being zero-order correlations only, serve as a nudge for further research in the field of pilot decision-making. Although we did not find any significant correlations with the professional self-concept of pilots and their view on airline's expectations (items 3 and 4), there is a possibility that pilots endorsing more that they feel less freedom by business consideration in normal operation (item 5) also more often like complex or demanding situations, r (220) = .15, p = .023, and also feel personally responsible for the on-time-performance of their flights, r (170) = .16, p = .035. These findings could suggest that business requirements such as on-time-performance may not only be perceived as a restriction for risk-averse decision-making in normal operation but also that those pilots thinking that they are responsible for the on-time-performance and those that are prone to challenge seeking might even feel pressured by business considerations thereby making it harder for them to take safe decisions. Furthermore, a one-way ANOVA found that the responses given by pilots on the item asking for the primary goal of an airline (item 4) did not significantly differ from the responses given on this item by airline management, regulators and ATCOs which might suggest a common understanding throughout the commercial aviation industry that safety seems obviously not to be the primary goal for all involved. Regarding what their organizations (Air Navigation Service Providers) expect from them, ATCOs (M = 2.53, SD = 1.23) even endorse significantly less than pilots (M = 3.27, SD = 1.11), t (235) = 2.64, p = .009, that their organization expects them to always use conservative minded controlling and decision-making. The ATCOs (M = 3.06, SD = 1.60) even significantly less than the pilots (M = 4.20, SD = 1.17) report that they feel free to take extra safety margins, t (17) = 2.89, p = .010, which could additionally highlight a potential safety issue in the air traffic system.

6.3.4.2 Summary of key findings regarding pilots' perceived freedom for safe decision-making

- Most pilots report that they feel free to take additional margins for safety
- SICs' observation on PIC behavior under time pressure suggests that PICs let themselves be negatively influenced by time pressure more than they admit
- Only slightly more than half of the pilots endorse that safety is their airline's primary goal and even less than half endorse that their airline expects them to use a conservative approach to flying and safety relevant decision-making.
- No significant difference in views throughout all stakeholders reveal that safety might not consistently be seen as the primary goal in commercial aviation.
- Two thirds of the pilots report that they might feel hampered by business considerations in their safety relevant decision-making in normal operation.
- ATCOs responses could highlight a potential safety issue in the air traffic system by negative influence of business considerations.

6.3.5 Pilots' experience in the role of the PM

As outlined in the introduction the aviation industry has already put a large emphasis on the role of the pilot monitoring (PM) to prevent incidents and accidents. To assess if those measures aimed to reduce negative effects by the hierarchy on the flight deck between PIC and SIC and to lower possible barriers for the PM to speak up were successful, we created items shown in table 6-10 and figure 6-4 stemming from actual flight operations which reflect the status of the PM role. We hypothesized that if the measures were successful, we should neither find more agreement than disagreement with the items nor should we find significant differences in responses by PIC and SIC.

However, a Wilcoxon-Signed-Rank test on the items with hypothetical medians of 2 (disagree slightly) and 1 (disagree strongly) revealed that the medians for all six items were significantly higher, $p < .05$. We found that more than half (54.4%) of the pilots admit that the work atmosphere or the personality of the other pilots influences their intervention behavior, and even more than half (64.6%) admit that they experience that hierarchy still influences the effectiveness of interventions as well.

Even nearly half of the pilots (47.3%) admit that they experience their colleague reacting annoyed when being challenged. This might be one of the reasons why more than half (60.7%) of the pilots admit that they do not intervene as long as they subjectively judge a situation as safe. Interestingly and in contrast to the previous item only few (19.7%) pilots report that they would be reluctant to intervene if necessary. The finding that more than a third (41.7%) of the pilots admit that they prepare less in the role of the PM than in the PF role may not only suggests a lower status of the PM role in relation to the PF role but also reflect that the duty of the PM may be perceived by pilots to require less effort than that of the PF role.

Moreover, a comparison of means between responses of PIC and SIC using student's t-tests with a Bonferroni corrected alpha level of .0083 revealed that, except for the two items describing possible barriers for intervention by status hierarchy (item 3 on the authority gradient between PIC and SIC and item 4 on the perceived hierarchy between PF and PM), the responses between PIC and SIC differed significantly. The PICs (M = 2.91, SD = 1.42) significantly less than SICs (M = 3.61, SD = 1.13) endorse that the PM should take into account the work atmosphere or the personality of the other pilot, t (288) = -4.75, p < .001. And as PM the PICs usually prepare a departure or approach more intensely (M = 2.57, SD = 1.33) than SICs do (M = 3.30, SD = 1.12), t (276) = -5.07, p < .001. The SICs (M = 2.66, SD = 1.07) significantly more often admit than the PICs (M = 1.98, SD = 1.10) that they are reluctant to intervene in the flying or decision-making of the PF, t (199) = -4.21, p < .001, and that they also significantly more often (M = 3.59, SD = .99) accept deviations from SOP than PICs do (M = 3.13, SD = 1.23), t (280) = -3.51, p < .001.

A multiple linear regression with the scale on pilots' experience in the PM-role revealed that only pilots' wide-body experience significantly contributed to the model, p = .034, showing that more wide-body experience is associated with better experience in the PM-role. This could either point to better teamwork-behavior of wide-body aircraft crews, e.g., influenced by the kind of route network characterized by operating mainly to major airports, often with single leg flying only, combined with less demanding approaches and less operational pressures than often present in narrow body aircraft operation. On the other hand, this finding could also be related to the cockpit and procedure design of wide body aircraft (e.g., A330, B777) supporting especially the status of SIC in the PM role more than on narrow body aircraft (e.g., A320, B737), e.g., by allowing the SIC to taxi the aircraft or being more engaged inflight management by the cockpit and aircraft system design than on narrow body aircraft.

We also asked participants agreeing to being reluctant to intervene (item 5) to specify the reasons justifying the reluctance. The following answers were collected (in order of the number of choices used):

38x - I do not want to intervene too early (No nitpicking)
34x - I want to give the PF a chance to correct her/his flying
17x - I do not want to risk our work atmosphere
3x - I do not feel sufficiently empowered to intervene
3x - Other reasons:
- 1x - I don't want to upset their thought process
- 1x - I want to observe how it unravels
- 1x - Sometimes, they do not give the chance. They have the attitude that they are more experienced and know it all, so I will have nothing extra to add.

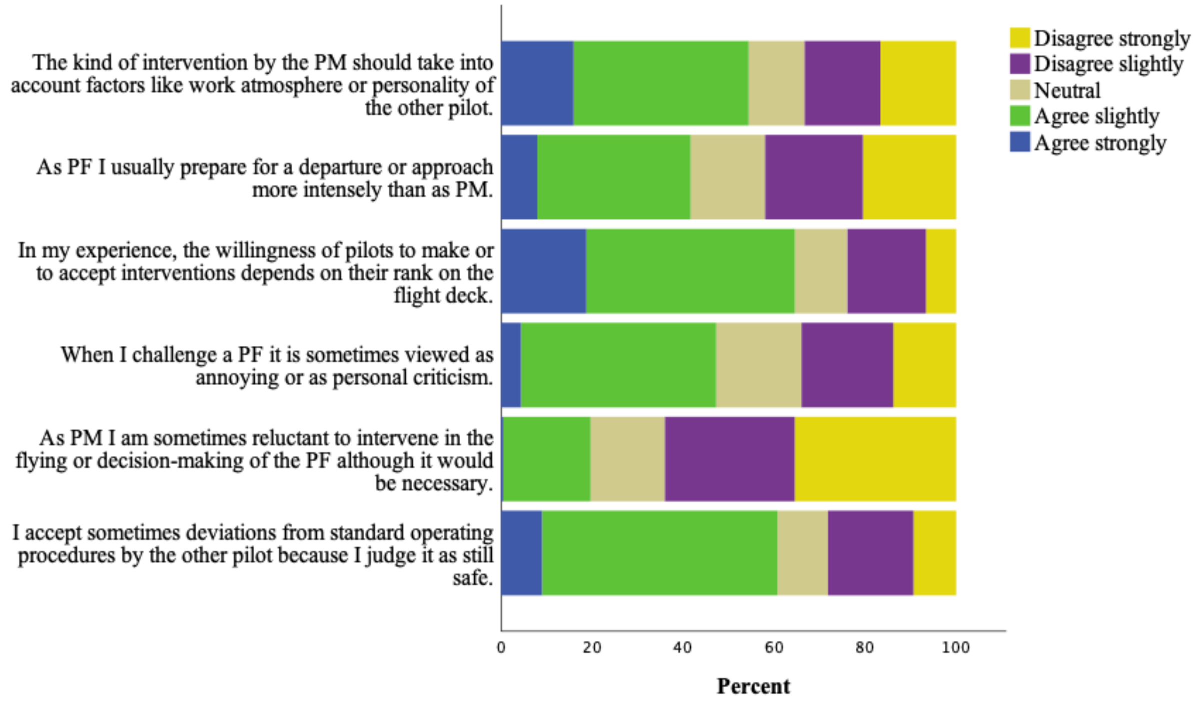
These responses clearly reveal that there are several barriers in practice hampering the effectiveness of the PM role. Overall, these findings suggest that the role of the PM has not yet reached the required status for effective accident prevention – despite training pilots in CRM.

Table 6-9: Pilots' negative experience in the PM-role

Average agreement with the following items				
Scale 1 = disagree strongly, 5 = agree strongly	N	M	SD	Agree (%)
Scale average	-	3.10	.74	-
1. The kind of intervention by the PM should take into account factors like work atmosphere or personality of the other pilot.	294	3.20	1.35	54.4
2. As PF I usually prepare for a departure or approach more intensely than as PM.	288	2.87	1.30	41.7
3. In my experience, the willingness of pilots to make or to accept intervention depends on their rank on the flight deck.	288	3.53	1.17	64.6
4. When I challenge a PF it is sometimes viewed as annoying or as personal criticism.	203	3.04	1.17	47.3

5. As PM I am sometimes reluctant to intervene in the flying or decision-making of the PF although it would be necessary.	203	2.21	1.14	19.7
6. I accept sometimes deviations from standard operating procedures by the other pilot because I judge it as still safe.	288	3.32	1.16	60.7

Figure 6-3: Pilots' negative experience in the PM-role



6.3.5.1 *Pilots' professional self-concept and their negative experience in the role of the PM*

We found that pilots' human factor orientation and their experience in the PM-role were negatively correlated, r (245) = -.14, p = .029. This could either mean that the more pilots are human factor oriented the less negative experience they make when in the PM-role, maybe because their human factor affinity helps them to more effectively fill this role. Or this could also mean that a positive experience in the PM-role positively influences pilots' self-concept to be more human factor oriented.

6.3.6 Pilots' experience with intervention in ATC

As one of the duties of the PM is the communication with ATC, we also asked participants about their experience regarding intervention in challenging ATC clearances. This intervention becomes necessary, e.g., by using the wording "unable", if ATC issues clearances which are not reasonable or which pilots or the aircraft are not capable of (CANSO, 2014). Frequent examples from practice are shortcuts given by ATC during approach which leave the aircraft too high and fast to maintain a safe descent path or an ATC clearance to enter a runway for take-off although the spacing to the incoming landing is too close. Therefore, we asked participants to disagree or agree to the statement "I am sometimes reluctant to deny challenging ATC-clearances even when I feel pressed by those clearances". We found that most (68.8%) of the 253 respondents disagreed with the statement while only less than a third (19%) agreed and the rest were neutral. However, again the data shows that SICs (M = 2.47, SD = 1.09) feel significantly more reluctance than PICs (M = 1.89, SD = 1.15), t (249) = -4.02, p < .001.

The reasons for this reluctance were as follows (in order of the number of choices used):

23x - I do not want to interfere with ATC's traffic planning

9x - It is my job as a pilot to comply with ATC clearances

3x - I feel pushed by my cockpit colleague

2x - I fear to get in trouble with my airline if I deny clearances too often

Among the 10 additional reasons given under the category "other reasons" were:

- Fear for being send by ATC to a "penalty box"
- Seeing no risk or appreciating the challenge
- In less optimal ATC regions a denial might deteriorate the situation for everybody

These findings suggest that the treatment of the safety issue of monitoring and intervention should not only incorporate the intervention behavior among the flight crew but also the intervention behavior towards ATC. The industry could consider joint pilot/ATCO training to better understand each one's perspective to ensure that safety is not compromised by undue risk taking either by pilots or ATCOs.

6.3.6.1 Pilots' professional self-concept and their experience with intervention in ATC

There was no significant correlation of pilots' experience with intervention in ATC with their professional self-concept in our data, r (245) = -.10, p = .115.

6.3.6.2 Summary of key findings regarding pilots' experience in the role of the PM

- Considerations on status hierarchy, work atmosphere and personality of the other pilots is perceived as a barrier for effective intervention by more than half of the pilots when in the PM role; however, this is perceived more by SICs than PICs.
- Nearly half of the pilots, irrespectively of rank, report that they experience the PF reacting annoyed when being challenged.
- Frequent reasons for being reluctant to speak up are: avoid nitpicking, giving the pilot a chance to correct, not risking work atmosphere
- SICs are more reluctant to intervene than PICs
- About one third of the pilots report being reluctant to intervene in ATC clearances as they mostly do not want to interfere with ATC's traffic planning

6.3.7 SICs' experience with intervention

Negative effects by the status hierarchy on the flight deck such as authoritarian behavior of the PIC or lack of assertiveness of the SIC were the drivers initially sparking the development of CRM-training in the 1980s (R. L. Helmreich, 2006). Now, more than three decades later we wanted to determine if the industry's endeavors were successful in eliminating those negative effects. However, on top of our results from the field data analysis also our survey data as shown in table 6-11 and in figure 6-5 reveals that negative effects by status hierarchy and that barriers for effective intervention by SICs are still present in today's commercial aviation.

More than half (54.6%) of the pilots reported that they have experienced status hierarchy creating safety relevant issues during flight. There was no significant difference between responses by PICs and SICs on this single item. As this item was openly framed in terms of being not restricted to a certain time period for which respondents had to recollect their experience it can be assumed that PICs also reflected on their time as SIC when answering this question. While it can be seen as a positive sign that only few SIC (15.5%) report about experience of not being involved in safety relevant decision-making, the fact that obviously situations still exist today in which PICs react annoyed to, as reported by more than half (54.5%) of the SIC, or do not take the concerns of the SICs seriously and even decide to override these concerns, as reported by nearly a third (30.0%) of the SIC which should be an alarming signal to the industry. A multiple regression with the relevant pilot demographics showed that only prior wide-body experience contributed to the model, $p = .015$.

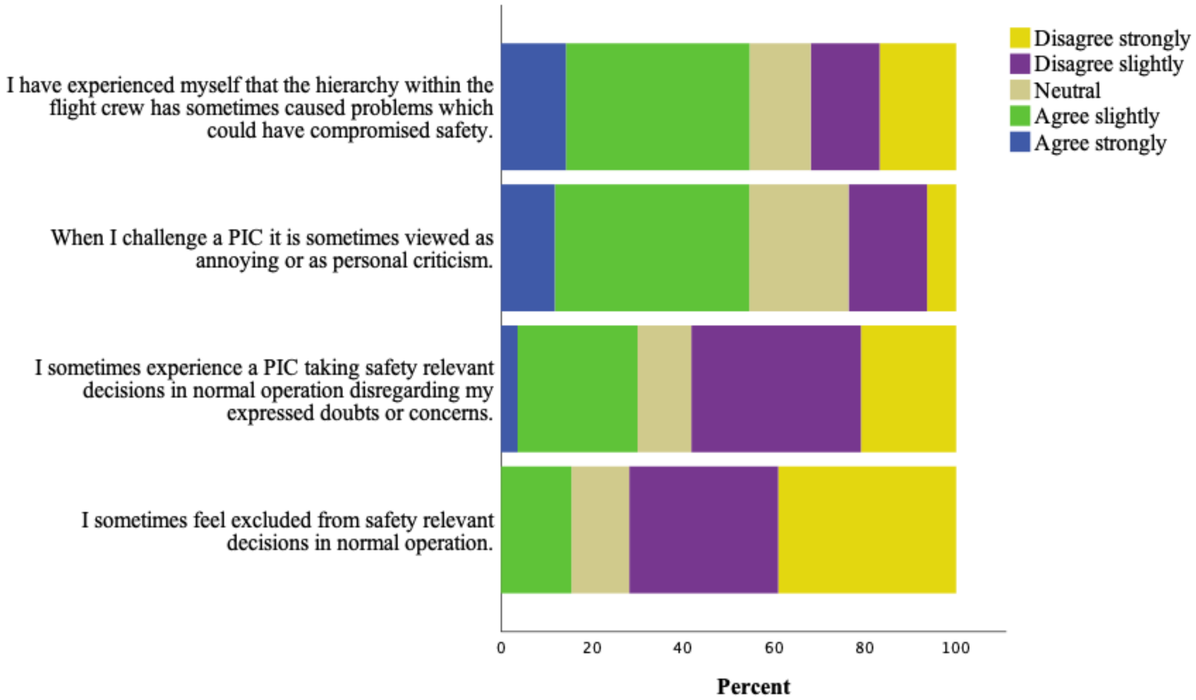
Table 6-10: SICs' negative experience with intervention

Average agreement with the following items				
Scale 1 = disagree strongly, 5 = agree strongly	N	M	SD	Agree (%)
Scale average	-	2.77	.87	-
1. I have experienced myself that the hierarchy within the flight crew has sometimes caused problems which could have compromised safety.*	238	3.20	1.33	54.6
2. When I challenge a PIC it is sometimes viewed as annoying or as personal criticism.	110	3.36	1.10	54.5

3. I sometimes experience a PIC taking safety relevant decisions in normal operation disregarding my expressed doubts or concerns.	110	2.55	1.19	30.0
4. I sometimes feel excluded from safety relevant decisions in normal operation	110	2.05	1.07	15.5

*This item was presented to all pilots irrespectively of their rank.

Figure 6-4: SICs' negative experience with intervention



6.3.7.1 *Pilots' professional self-concept and SICs' negative experience with intervention*

There was no significant association of pilots' human factor orientation with SICs' negative experience with intervention, r (101) = .18, p = .076.

6.3.7.2 *Summary of key findings regarding SICs' experience with intervention*

- Negative effects by status hierarchy and barriers for effective intervention by SICs are still present in today's commercial aviation.
- More than half of the SICs report that PICs react annoyed when being challenged

6.3.8 Pilots' experience with hard interventions in practice

To better understand the current practice of intervention on commercial aviation flight decks we additionally asked participants about their experience with hard interventions such as taking away control, commanding a go-around or refusal to work with each other. The presentation of the relevant items in the 2020 global survey was slightly different than in the 2017 survey. While we had presented each item separately for PIC and SIC to be answered by NO or YES in the 2017 survey, we combined the responses in the 2020 survey by using: NO, never; YES, as PIC; YES, as PIC and SIC; YES, as SIC; so that we could present the question for both pilot groups as one item. During merging the two survey results we re-coded the 2017 responses respectively.

This specific design of the responses to the questions allowed us to better elicit the individual intervention experience of pilots depending on their role on the flight deck. It is important to remember that the career path for pilots still greatly depends on the company seniority and open positions to fly as PIC are limited. This means that pilots having flown in the role of the PIC in one company will not necessarily also fly as PIC when changing companies or even when changing fleets within the same company. Therefore, we deemed it useful to split the responses. We report the numbers related to all respondents in the first row of tables 6-12 and 6-13, in the second row the numbers for the pilots currently flying in the role of the PIC and in the third row the numbers for the pilots currently flying in the role of the SIC. For better overview we split the results so that table 6-12 shows the results for the hard interventions being given or received (items 1-5) and table 6-13 the results for the missing or ineffective interventions (items 6-8). The results reveal that nearly half (43.0%) of the pilots report an initiated control take-over for unacceptable aircraft handling, but only a quarter (26.0%) did so for unacceptable decision-making. For both control take-overs, the results split by rank clearly show that PICs more often take-away control from the SIC than vice versa. In fact, our survey data seems to confirm the findings of our field data research that taking away control from a PIC by the SIC or a grasping into controls by the SIC happens very few times only (see 3.3.1) while the opposite is happening quite often in the industry. A multiple linear regression with the relevant pilot demographics confirms that finding and shows that being in the role of the PIC, $p = .013$, or having a training function, $p = .020$, are significantly associated with providing intervention. However, nearly only pilots in the role of the SIC deny flying with a pilot colleague.

Table 6-11: Pilot's experience with hard interventions (excluding training/incapacitation)

	Current Rank	N (%)	N (%)	N (%)	N (%)	N (%)
			No, Never	Yes, as PIC	Yes, as PIC/SIC	Yes, as SIC
1. Did you ever take away control from the other pilot due to unacceptable aircraft handling by this pilot?	ALL	300 (100)	171 (57.0)	75 (25.0)	32 (10.7)	22 (7.3)
	PIC	178 (100)	68 (38.2)	70 (39.3)	30 (16.9)	10 (5.6)
	SIC	122 (100)	103 (84.4)	5 (4.1)	2 (1.6)	12 (9.8)
2. Did you ever take away control from the other pilot due to unacceptable decision-making by this pilot?	ALL	300 (100)	222 (74.0)	50 (16.7)	11 (3.7)	17 (5.7)
	PIC	178 (100)	116 (65.2)	46 (25.8)	10 (5.6)	6 (3.4)
	SIC	122 (100)	106 (86.9)	4 (3.3)	1 (.8)	11 (9.0)
3. Did you ever experience that a pilot colleague, who was PM, intervened manually in your aircraft handling, without taking control, but by grasping at the controls or selecting auto-pilot modes by him/herself?	ALL	300 (100)	147 (49.0)	9 (3.0)	15 (5.0)	129 (43.0)
	PIC	178 (100)	104 (58.4)	6 (3.4)	13 (7.3)	55 (30.9)
	SIC	122 (100)	43 (35.2)	3 (2.5)	2 (1.6)	74 (60.7)
4. Did you ever experience a pilot colleague taking away control from you?	ALL	300 (100)	235 (78.3)	2 (.7)	2 (.7)	61 (20.3)
	PIC	178 (100)	136 (76.4)	1 (.6)	2 (1.1)	39 (21.9)
	SIC	122 (100)	99 (81.1)	1 (.8)	- -	22 (18.0)
5. Did you ever refuse to fly with a pilot colleague due to different positions in safety relevant decision-making concerning their flight?	ALL	302 (100)	242 (80.1)	11 (3.6)	5 (1.7)	44 (14.6)
	PIC	179 (100)	140 (78.2)	11 (6.1)	5 (2.8)	23 (12.8)
	SIC	123 (100)	102 (82.9)	- -	- -	21 (17.1)

6.3.9 Pilots' experience with missing or ineffective interventions in practice

One of the most important intervention calls during a flight is the go-around call. Go-arounds are normal flight procedures and usually airline's go-around policies allow both pilots, irrespective of rank or experience, to call for this maneuver. Once called it must be completed, if no immediate emergency dictates otherwise (International Air Transport Association (IATA), 2023, sec. FLT 3.11.60). Therefore, the results on item 8 which deals with the overruling of a go-around call provides another hint that the status hierarchy on the flight deck still acts as a barrier to effective intervention. While the overruling of this important call was nearly not at all reported by the PICs, such behavior was reported by the SICs instead.

Table 6-12: Pilot's experience with missing/ineffective interventions

	Current Rank	**N (%)**	**N (%)**	**N (%)**	**N (%)**	**N (%)**
			No, Never	Yes, as PIC	Yes, as PIC/SIC	Yes, as SIC
6. Did you ever experience a situation in your daily flying practice, where you did not intervene at all or your intervention was not effective although you were seriously concerned?	ALL	225	130	16	23	57
		(100)	(57.8)	(6.7)	(10.2)	(25.3)
	PIC	149	88	15	20	26
		(100)	(59.1)	(10.1)	(13.4)	(17.4)
	SIC	76	42	-	3	31
		(100)	(55.3)	-	(3.9)	(40.8)
7. Did you ever experience that neither you nor your pilot colleague(s) on the flight deck called for a go-around even though it was required?*	ALL	297	104	33	45	115
		(100)	(35.0)	(11.1)	(15.2)	(38.7)
	PIC	176	64	32	39	41
		(100)	(36.4)	(18.2)	(22.2)	(23.3)
	SIC	121	40	1	6	74
		(100)	(33.1)	(.8)	(5.0)	(61.2)
8. Did you ever experience a pilot colleague continuing with the approach despite your call for a go-around?*	ALL	266	234	2	3	27
		(100)	(88.0)	(.8)	(1.1)	(10.2)
	PIC	145	125	2	3	15
		(100)	(86.2)	(1.4)	(2.1)	(10.3)
	SIC	121	109	-	-	12
		(100)	(90.1)	-	-	(9.9)

Moreover, item 6 shows that only few pilots in the role of the PIC were reluctant to intervene if necessary, while those who were reluctant were in the role of the SIC. However, most striking is the fact that around two thirds (65.0%) of all pilots report not having called for a go-around when required. Again, this is reported more often by pilots when in the role of the SIC than when being the PIC. These findings clearly reveal that safety silence is more often present within SICs than PICs. To better understand why pilots, and following our findings, mainly PICs, elect not to perform a go-around when needed, we asked respondents to mention the reasons for their reluctance to go-around or the continuation despite a go-around call. The answers given were as follows (in order of the number of times each reason was given):

63x - Landing was judged being the safer option
    No perceived risks (e.g., long runway, good weather, too strict SOP)
    Bad weather on the go-around course, thunderstorm nearby
    Poor ATC or VFR Traffic, Fatigue, Terrain
51x - Cockpit authority gradient
29x - Schedule considerations
18x - Cognitive Bias (e.g. continuation bias, get-there-itis, target fixation, ego)
10x - Thinking about a possible diversion
8x - Insufficient fuel for a go-around
3x - Missing procedures/guidance/knowledge, report avoidance

As we found all of the reasons mentioned by the respondents across all three analyzed samples, these findings suggest not only continuing negative influences of business considerations on pilots' safety relevant decision-making, irrespectively of rank and other relevant pilot demographics, but also highlight the existence of continuing negative effects by the status hierarchy on commercial flight decks. Additionally, the high number of reasons stating that the individual risk perception led to the reluctance for go-arounds offers several insights: first, there might be a misalignment between pilots' individual risk perception and current go-around policies, second, the background for strict go-around policies has not yet been fully internalized by all pilots, third, there are obviously professional pilots trying to start an approach even if their safe exit route (the go-around or missed approach area) is obstructed which may be an additional sign for (subtle) operational pressure to land the aircraft at their planned destination. In this case the industry could think about promoting that the mission for pilots is not to fly from A to B as shown on the passenger ticket or flight plan. Instead, they could promote, by policies and safety promotion, an "A to C" - concept incorporating the idea that a pilot's mission and at the same time the default option for every flight is to take-off safely at the departure airport (A) and to land safely, again at (A) or at some suitable alternate airport (C), but not necessarily on the planned destination (B). In fact, this is not a new concept but reflects current regulations in fuel planning for nearly every commercial flight.

6.3.9.1 Pilots' professional self-concept and their experience with interventions

The coding of the items capturing pilots' experience with hard and missing or ineffective intervention consisted of 4 values: 1 = No, never, 2 = Yes, as SIC, 3 = Yes, as SIC and PIC, 4 = Yes, as PIC. To better determine a possible influence of professional self-concept on the experience with intervention we analyzed the data in two ways. First, we tested any correlations over the whole sample, including those respondents stating that they had never experienced hard or missing/negative interventions. Second, we analyzed only the responses of those who had experienced such interventions to better differentiate the correlation by rank.

When testing over the whole sample we found that both scales on intervention (Hard Intervention provided, r (245) = .21, $p < .001$, and Experience with missing/ineffective intervention, r (245) = .15, $p = .016$) as well as the single item for Hard Intervention received, r (245) = .17, $p = .009$, as referred to in table 6-3 (see 6.2.2), were positively correlated with pilots' human factor orientation. This suggests that a higher human factor orientation of pilots may lead to more active intervention, either by the fact that those pilots feel more encouraged to use hard interventions or by the fact that they may be better able to establish an atmosphere in which the other pilot feels free to apply a hard intervention.

6.3.9.2 Pilots' experience with interventions over time

To control for possible confounding effects by older pilots reporting their intervention experience from times before human factor training became mandatory in commercial aviation (1995) we additionally report in table 6-14 three individual analyses based on the year when the pilots achieved their license. We report the numbers related to the full sample including all respondents in the first row of the table, in the second row the numbers for a subsample consisting of pilots having completed their initial pilot education (license achievement) including and after the year 2000 and in the third row the numbers for a subsample for pilots having achieved their license after and including the year 2010. The results for the full sample reveal that nearly half (43%) of the pilots report an initiated control take-over for unacceptable aircraft handling while this proportion is reduced to a quarter (23.1%) for the second sample (license achievement > the year 2000) and to even less (14.3%)

for the third sample (license achievement > the year 2010). A control take-over for unacceptable decision-making is reported by only a quarter (26.0%) of the pilots in the full sample and even less (13.0%, 10.2%) for the second and third sample. For both control take-overs the results show that in the full sample more pilots in the role of the PIC (25.0%, 16.7%) than in the role of the SIC (7.3%, 5.7%) report having taken away control for unacceptable aircraft handling or decision-making. Obviously, this difference diminishes in the other two "younger" samples due to the reduction of proportion of PIC reporting control take-overs, while the proportion of SIC reporting control take-overs remains nearly constant for both items. This alleviation of control take-overs by younger PIC might be related to both, either to a higher perceived barrier for intervention among younger PIC, e.g., due to seeking for harmony, or to a higher level of younger SICs' abilities resulting in less reported control take-overs. Regarding the overall result that pilots in the role of the PICs take-over control significantly more often than pilots in the role of the SIC one could argue of course that the PICs had to take-over due to bad performance of the SIC. However, this would conversely mean that PICs are generally better pilots than SICs which is unlikely to be the case due to equal training and checking for both groups of pilots.

Interesting however is the fact that we found no difference in proportion regarding the experience of control take-aways among the different subsamples. While this situation was nearly not at all reported by the PICs (<1%) in all samples this was reported by more (20.3%, 19.4%, 18.4%) of the SICs in all subsamples (item 4). In fact, our survey data seems to confirm the findings of our field data research that taking away from a PIC by the SIC happens very few times only, although the proportions nearly equalized for younger pilots (items 1 and 2). Additionally, around half of the SIC (43.0%, 53.7%, 53.1%) report that they experienced a pilot colleague (the PIC) grabbing into the controls while this is reported by only a few (3.0%, 1.9%, 4.1%) of the PIC (item 3). In contrast to this, more SIC report to have already refused to fly with a cockpit colleague than PICs do.

As mentioned above, another hint that the status hierarchy on the flight deck still acts as a barrier to effective intervention is revealed by item 8 which deals with one of the most important intervention calls during a flight, which is the go-around call. While such overruling was nearly not at all reported by PIC the SIC's proportion is nearly equal for all three subsamples (10.2%, 12.1%, 10.4%). Moreover, item 6 shows that across all three subsamples nearly half (42.2%, 44.0%, 42.9%) of all the pilots report missing intervention in situations when it was necessary. Again, this was reported more by pilots in the role of the SIC (25.3%, 37.3%, 42.9%) than by those in the role of the PIC (6.7%, 1.3%, 0.0%). However, most striking is the fact that around two thirds (65.0%, 72.2%, 63.3%) of all pilots report not having called for a go-around when required. Again, this is reported more by pilots in the role of the SIC (38.7%, 63.9%, 59.2%) than in the role of the PIC (11.1%, 0.9%, 2.0%). These findings reveal that safety silence is more often present within SICs than PICs, even among younger pilots who had participated in modern CRM training. This could even be one possible explanation why we found that more SICs than PICs report to have already refused to fly with a cockpit colleague. Some SIC might elect to better avoid the confrontation with an authoritarian PIC instead of running into possible teamwork issues along a flight.

As we deliberately excluded situations related to training flights or in which a pilot became incapacitated these results show that, despite industry efforts to increase the status of the SIC and the PM, the intervention gradient still equals the authority gradient on the flight deck however in a negative sense. While we found that the proportions regarding initiated control take-overs became nearly equal for younger PIC and SICs (see results on item 1 and 2), we found, even after excluding older pilots from the analysis, that throughout the subsamples control was taken more often away from the SICs by the PICs than vice versa (see results on item 3) and SICs experience missing or ineffective intervention more often than PICs (results on items 6-8). This suggests that it is still easier for the PIC to intervene using the established authority gradient and still harder for the SIC to intervene counter to the authority gradient despite an intensified focus on monitoring and intervention in the industry.

To check if the data on these items seamlessly connect to our previous findings on status hierarchy and the status of the PM role, we additionally analyzed the scales shown in tables 6-12 and 6-13 with a subsample of young pilots who have achieved their license after and including 2010 (see table 6-14). We even found a slightly higher agreement of younger pilots with the scale on negative experience as PM (M = 3.42, SD = .64) than in the complete sample (M = 3.10, SD = .74) and nearly the same agreement on SIC’s negative experience with intervention (M = 2.68, SD = .87) like in the complete sample (*M* = 2.77, *SD* = .87) which suggests that our conclusion from the field data analysis that current CRM training could be ineffective as a countermeasure for negative status hierarchy effects may be correct.

Table 6-13: Pilot's experience with interventions in different pilot cohorts

Type of Intervention	N	%	%	%	%
Numbers in 1. row = full sample Numbers in 2./3. row see below*		No, Never	Yes, as PIC	Yes, as PIC/SIC	YES, as SIC
1. Did you ever take away control from the other pilot due to unacceptable aircraft handling by this pilot?	300 108 49	57.0 76.9 85.7	25.0 11.1 6.1	10.7 4.6 2.0	7.3 7.4 6.1
2. Did you ever take away control from the other pilot due to unacceptable decision-making by this pilot?	300 108 49	74.0 87.0 89.8	16.7 6.5 4.1	3.7 .9 -	5.7 5.6 6.1
3. Did you ever experience that a pilot colleague, who was PM, intervened manually in your aircraft handling, without taking control, but by grasping at the controls or selecting auto-pilot modes by him/herself?	300 108 49	49.0 41.7 42.9	3.0 1.9 4.1	5.0 2.8 -	43.0 53.7 53.1
4. Did you ever experience a pilot colleague taking away control from you?	300 108 49	78.3 78.7 81.6	.7 .9 -	.7 .9 -	20.3 19.4 18.4
5. Did you ever refuse to fly with a pilot colleague due to different positions in safety relevant decision-making concerning their flight?	302 108 49	80.1 88.0 89.8	3.6 - -	1.7 - -	14.6 12.0 10.2
6. Did you ever experience a situation in your daily flying practice, where you did not intervene at all or your intervention was not effective although you were seriously concerned?	225 75 35	57.8 56.0 57.1	6.7 1.3 -	10.2 5.3 -	25.3 37.3 42.9
7. Did you ever experience that neither you nor your pilot colleague(s) on the flight deck called for a go-around even though it was required?*	297 108 49	35.0 27.8 36.7	11.1 .9 2.0	15.2 7.4 2.0	38.7 63.9 59.2
8. Did you ever experience a pilot colleague continuing with the approach despite your call for a go-around?*	266 95 48	88.0 87.9 89.6	.8 - -	1.1 - -	10.2 12.1 10.4

*2. & 3. row=subsamples including pilots with license gained >2000 (2. row), >2010 (3. row)

6.3.9.3 Summary of key findings regarding pilots' experience with hard interventions

- Almost only pilots in the role of the SICs (PICs hardly ever) as PF experience that the PM takes away control from them or grasps into their controls
- Almost only pilots in the role of the SICs report that they have denied flying with a pilot colleague
- Almost only pilots in the role of the SICs experience that their go-around call is overruled by the other pilot
- More SICs than PICs report that a go-around was not done although being required
- More SICs than PICs report not having intervened although it was required
- Most/Highest ranked reasons for missing intervention were subjective risk perception, status hierarchy and schedule consideration
- In the current cockpit team-setting a positive authority gradient represents a negative intervention gradient.
- Safety silence is more often present within SICs than within PICs

6.3.10 Discussion

By means of survey questions we investigated pilots' experience with safety relevant decision-making and teamwork in practice and training. We asked respondents about their experience with safe behaviors such as the SOP-discipline, the safety relevant decision-making, the CRM-behavior or their perceived freedom to take safe decisions in a commercial aviation environment. Regarding monitoring and intervention, we explicitly asked the respondents about their experience in the role of the PM and the SIC as well as about their experience with hard interventions such as control-takeovers. All questions were related to normal operation, meaning flights without aircraft malfunctions or emergencies. We found that the pilots rate not all, but most of their cockpit colleagues as being good role models for SOP discipline as well as for a conservative aircraft operation and CRM. The reported percentages by SICs about their experience with PICs SOP discipline are lower than those reported by PICs suggesting that SICs are possibly more often in situations requiring active intervention than PICs. Even more striking was the finding that only a third of the training and check-pilots were viewed as experts in human factors and those pilots were also less seen as role models in CRM. Moreover, pilots report that the feedback culture among each other is very low.

In regard to safety relevant decision-making, we also found that most pilots report feeling free to take additional margins for safety if needed, e.g., by taking extra-fuel or accepting delay, although we found lower age, wide-body and prior experience in the business aviation sector may have negative influence on the perceived freedom to reject time pressure. Especially in regard to the behavior under time pressure the observations by SICs suggest that PICs let themselves be negatively influenced by time pressure more than they admit. In general, the responses by pilots, but also by the other industry stakeholders such as ATCOs, Airline Management and Regulators, revealed that business considerations might significantly influence commercial airline operation which suggests that, across the aviation industry, safety seems not consistently be viewed as the primary goal by all involved. To prevent pilots from unnecessary risk-taking in normal operation it is vital that the monitoring and intervention functions on the flight deck work properly to detect and prevent safety risks early. However, we found that negative effects by the status hierarchy as well as considerations on work atmosphere and personality of the pilot colleague on the flight deck may still act as barriers for effective interventions for many pilots - despite training pilots in CRM for decades. More than half of the respondents reported that their colleagues felt annoyed when being challenged. We found that especially SICs reported to be more reluctant to intervene than PICs which also relates to the role assignment effect found in the field data analysis (study 1). Additionally, there is not only reluctance for intervention within the cockpit but also towards challenging ATC clearances.

Further evidence for the persisting existence of negative effects by status hierarchy is given by our results on pilots' experience with hard interventions in practice. We found that more SICs than PICs report that a go-around was not done although being required, more SICs than PICs report not having intervened although it was required and only SICs experience that their go-around call is overruled by the other pilot - altogether suggesting that safety silence is more often present within SICs than PICs and that the authority gradient on the flight deck represents a negative intervention gradient which acts as a barrier for effective intervention on commercial aviation flight decks. Furthermore, the data on control-take-over clearly show that those are most often initiated by PICs and not by SICs.

Although being self-reported data only, our results from the survey of pilots' safety relevant experience in practice and training support the notion that there might be an interaction between commercial considerations and missing or ineffective intervention on the flight deck probably facilitating serious safety relevant events in commercial aviation supporting our theory on the presence of an *operational syndrome* (see Chapter 5). The survey results on pilots' experience show that business considerations may negatively influence pilots' safety relevant decision-making and at the same time effective mutual intervention. Especially the intervention by the SIC seems still to be hampered by status hierarchy effects and other factors related to the work-atmosphere on the flight deck. This might favor not only unnecessary risk taking by pilots but may also lead to the persistence of the role assignment effect found by the field data analysis. In line with the longstanding suggestion from the medical domain to "make it easy for people to do the right thing and hard for them to do the wrong thing" (Kohn et al., 2000) it could be worthwhile for the aviation industry to critically reassess if their underlying basic premise for on-time-performance and efficiency should be critically reviewed and eventually modified to allow front end staff such as pilots and ATCOs to focus on producing safety in daily practice instead of being tempted to make risky trade-offs. A starting point for the industry could be to promote the “A to C” - concept outlined above (see 6.3.9).

Furthermore, the results from the experience survey support our conclusion from the field data analysis that the current teamwork setting in commercial flight decks seems still be restricting effective mutual intervention and that current CRM-training obviously fails to abrade existing barriers for intervention. Maybe previous industry initiatives ((Civil Aviation Authority (CAA), 2013; Flight Safety Foundation (FSF), 2014) were too much focused on monitoring leaving active intervention, including hard interventions, too much aside. The new approach by the FAA (2022) fortunately incorporates the requirement for training of active intervention and it can be hoped that it helps to lower the barriers for active intervention. Nevertheless, the industry could support this positive trend by considering how command and monitoring can eventually be combined in daily operation (PIC as PM) to further facilitate active and effective intervention on the flight deck. The subsequent analysis of pilots’ attitude towards their roles on the flight deck might elicit further insights to support this endeavor.

6.3.11 Conclusion

Despite training pilots in CRM, the results on pilots’ safety relevant experience in practice and training reveal that effective flight crew teamwork is still negatively influenced by the status hierarchy on the flight deck. The pilot responses also suggest that business considerations seem to negatively influence pilots’ safety relevant decision-making and that safety seems obviously not to be the primary goal in commercial aviation for all involved. Overall, these findings suggest that the role of the PM has not yet reached the required status for effective accident prevention and the status of the SIC is obviously too low to guarantee effective prevention of incidents and accidents. The survey results seem to support our conclusion from the field data analysis that the combination of command and control may be ill-fated, and the combination of command and monitoring (PIC as PM) could provide a better solution for the aviation industry in terms of incident and accident prevention and for counteracting the discovered role assignment effect.

6.4 Study 4: Pilots' attitudes towards teamwork and decision-making

6.4.1 Background

To operationalize pilots' attitudes towards teamwork we created items associated with the roles of the SIC and the PM. To operationalize pilots' attitudes towards their safety relevant decision-making we used three dimensions from practice which have direct influence on the safe outcome of a flight: these are pilots' discipline in adherence to Standard Operating Procedures (SOP), pilots' application of conservatism and pilots' attitude towards safety/business considerations. In the following text we explain why these dimensions are so critical for the safety performance of aviation.

Similar to other high-risk-activities such as sailing a ship, performing a surgery, drilling for oil or even just a day-to-day activity like car driving, the operation of aircraft in commercial aviation is never free of risk. Nevertheless, those activities can still be safely performed if sufficient safety margins are maintained to account for human errors and other unforeseen situations. The operation of technical systems such as aircraft, ships or cars is often limited by its manufacturers based on test results from certification or by regulatory requirements thereby creating an operational safety envelope by design. While the technical system itself might be capable of certain maneuvers beyond such restrictions, "operational limits protect against breaching the safety envelope" as outlined by Flight Safety Foundation (FSF) (2022a) meaning that operation beyond given limits may lead to accidents and incidents.

Like different types of car tires may have different speed limits for safety reasons also aircraft have certain operational limitations which pilots have to observe in practice such as cross- or tailwind limits, weight limits and many more. Those limits are provided to the pilots by their operational documentation and are topics in recurrent theoretical and practical annual training. However, such limits only provide a general envelope which cannot reflect the dynamic nature of practice in aircraft operation as they often do not account for human factor influences such as fatigue, distraction, lack of proficiency, time pressure, effects by cognitive biases and more. For example, in the survey we included a single item asking pilots and ATCOs on their experience with given regulatory limits. We asked them if the "Application of just the legally required separation minima by ATC is always safe in my experience" and found that only about a third (30.2%, $M = 2.65$, $SD = 1.18$) of the pilots and a third (33.3%, $M = 2.73$, $SD = 1.16$) of the ATCOs agreed to this statement. Therefore, practitioners such as pilots and ATCOs have to adapt to the reality of daily operations and may have to further reduce certain limits for safety reasons thereby increasing safety margins. A common saying in aviation training and safety management to highlight this fact is: *limits are no targets*, which expresses the requirement to add additional safety margins and reduce below limits in order to stay safe in practice instead of pushing for them.[28] However, exactly this is hard to accomplish if those practitioners do not feel psychologically safe to do so or if their attitudes make them either prone to accept unnecessary risks or even reluctant to give or accept mutual interventions. Thereby the safety relevant teamwork and decision-making of flight crews may become impaired even in highly regulated environments such as commercial aviation which uses SOPs and other standardized protocols, operational limitations and further guidance from aircraft manufacturers or other aviation stakeholders to ensure safe aircraft operation.

Airline policies require the application of SOP throughout all flight phases and allow deviation only if this deviation will lead to a higher degree of safety. In a dyadic team setting like that on the flight deck the use of SOP and a clear task distribution between PF and PM should enable flight crews to anticipate what their cockpit colleague is supposed to be doing next which at the same time should also facilitate mutual monitoring and intervention. However, many accident and incident reports show that pilots often did not comply with given limits or SOPs but rather went beyond operational limits thereby taking unnecessary risks to complete a landing or try to avoid departure delay as shown by our field data analysis. Instead of going around or accepting departure delays thereby maintaining or increasing their safety margin they did quite the opposite and reduced or even eliminated all their safety margins instead. The factor *preventability* in our field data analysis reflects the frequency of such behavior as we found that nearly all (98.5%) of the analyzed events happening in normal operation were judged as pilot preventable. In contrast to the term "human error" which

[28] For an organization in a high-risk environment, it could probably be beneficial to use in their safety promotion, policies and routine management communications easy to memorize sayings or slogans fostering safe behavior such as *limits are no targets* or *doubt is a fact* or *reduce below the max* in order to signal the expected behavior of employees in practice.

according to Rasmussen (1983) includes skill-, rule- or knowledge-based mistakes or even simple slips or lapses originating from distraction, a lack of discipline or by cognitive biases, the behavior leading to such preventable events is termed “at-risk behavior”. A comprehensive definition of at-risk behavior, which is universally applicable to all high-risk-environments, is provided by the Institute for Safe Medication Practices (ISMP)[29] and reads as follows:

> “Definition. At-risk behaviors are different from human errors. They are behavioral choices that are made when individuals have lost the perception of risk associated with the choice or mistakenly believe the risk to be insignificant or justified.
>
> Why we drift. It is human nature to drift away from strict procedural compliance and to develop unsafe habits for which we fail to see the risk. Human behavior runs counter to safety because the rewards for risk taking (e.g., saved time) are often immediate and positive, while possible adverse outcomes (e.g., patient harm) are often delayed and remote. As a result, even the most educated and careful individuals will learn to master dangerous shortcuts, particularly when faced with an unanticipated system problem (e.g., technology glitches, time urgency). Over time, the risk associated with these behaviors fades and the entire culture becomes tolerant to these risks. Individuals are not choosing to put patients in harm’s way; instead, they feel they are still acting safely. In fact, the more experienced you are at what you do, the less likely you are to recognize that you are in a risky situation when engaging in at-risk behavior.”

In contrast to single operator activities such as car driving or single pilot operations there is a clear safety benefit from operating in a dyadic team as not only SOP deviations but also safety critical at-risk behavior can be detected and mitigated by appropriate intervention. However, neither the avoidance of at-risk behavior nor the effective intervention seems to be that easy on commercial flight decks as suggested by our field data analysis. Based on the reasoning in the introduction we therefore present now the results of our analysis of pilots’ attitudes towards decision-making and teamwork. We first present pilots’ attitude towards SOP-deviation, their attitude towards conservatism in practice and

[29] https://www.ismp.org/resources/differences-between-human-error-risk-behavior-and-reckless-behavior-are-key-just-0

their attitude towards safety versus business considerations followed by the results on pilots' attitudes towards the roles of the SIC and PM and pilots' perceived reluctance to intervene when in these roles.

6.4.2 Pilots' attitude towards SOP-deviations

We created two items to elicit pilots' SOP discipline and asked these questions not only to pilots but to the other aviation stakeholders as well. Both questions deal with SOP adherence and trade-offs for efficiency reasons, the first one in general terms and the second in regard to cooperation between the pilots. As shown in table 6-15 and figure 6-6 we found that efficiency considerations influence pilots' attitude towards SOP adherence so that a third (33.4%) of the pilots agree that efficiency reasons require tradeoffs in adherence to procedures. Even more than a third (41.8%) agree that deviation from SOP for efficiency reasons would be allowed if both pilots agree on it. We also found that SICs (M = 3.21, SD = 1.21) significantly more endorse that deviation from SOP is required and acceptable than PICs do (M = 2.53, SD = 1.28), t (221) = -4.02, p < .001, which suggests that SICs would rather follow a PIC in deviating from SOP than intervene if proposed by a PIC. Furthermore, as we also found in the experience survey that SICs observe more SOP deviations with their PICs than vice versa this suggests that such negative role model behavior by PICs may well negatively reflect on SICs attitudes.

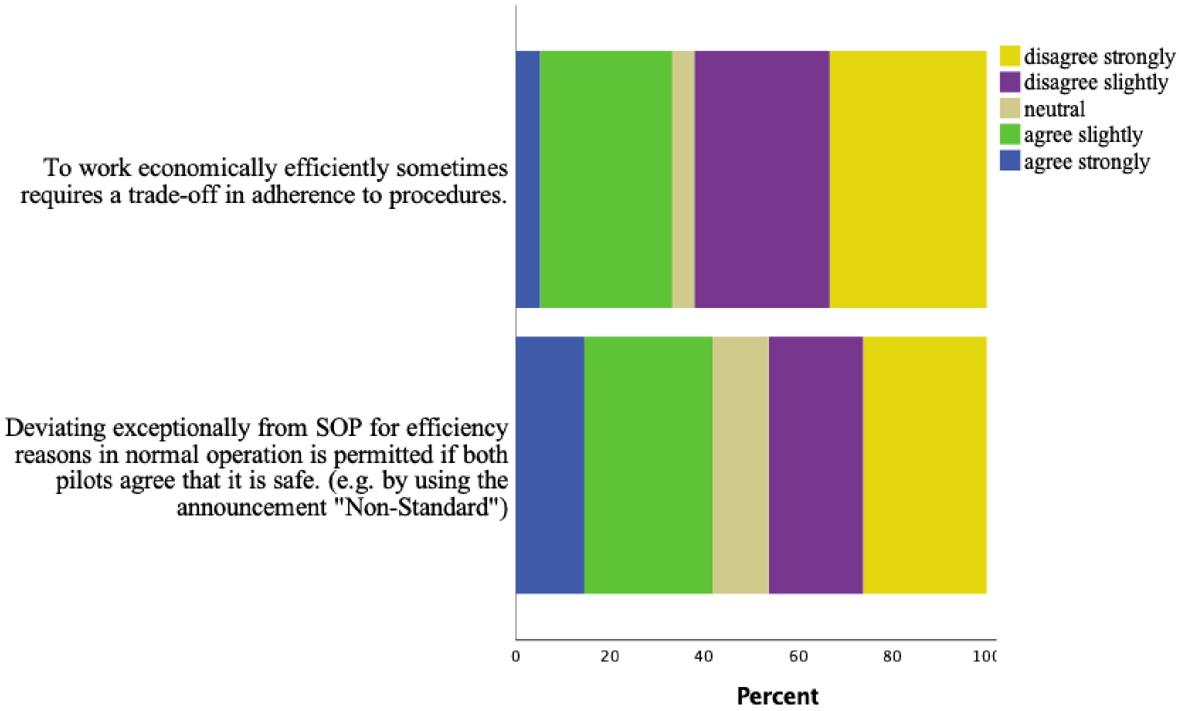
As we asked these attitude questions to the other aviation stakeholders as well, we conducted a one-way ANOVA with Games Howell correction, to compare the responses and found, as expected, significant differences, F (3, 289) = 5.86, p < .001, between the groups. Although there was no significant difference between pilots (M = 2.80, SD = 1.29) and ATCOs (M = 3.06, SD = 1.47), p = .89, we found that both regulators (M = 1.81, SD = 1.15), p = .20, and airline management (M = 2.12, SD = 1.31), p = .009, disagree significantly more with the statements than the pilots. These results reveal a significant difference in view by those working at the frontline of operations (the sharp end of the safety production process) and those supporting and supervising it from the management side (the blunt end of the safety production process), marking a possible gap in aviation between work as imagined (WAI) and work as done (WAD). Furthermore, this highlights the need for good cooperation between sharp and blunt end to determine why and when practitioners feel the need to take procedural shortcuts so that the gaps between WAI and WAD can be closed by the organization, e.g., by re-designing SOP or providing appropriate training which prevents practitioners from taking short-cuts. To enable continuous improvement and organizational learning some airlines are doing so already proactively in the absence of any safety critical events by using operational learning reviews performed by specifically stipulated learning and improvement teams to fully understand the context and dynamics of routine operation and the underlying performance shaping factors affecting their pilots in daily practice in order to critically self-review the given set of SOPs and policies (FSF, 2022). By enlarging the focus of safety management on investigating additionally inconsequential errors and those that were mutually mitigated on the flight deck, on actively asking pilots for discovered ambiguities within procedures and policies and on listening to their experience regarding collaboration with ATCOs may help to gain insights for better practice and continuous improvement.

Given the high number of pilots showing agreement with the two statements we performed a multiple linear regression of the scale derived by the two items with the relevant pilot demographics to assess which type of pilot might be prone to a lower SOP discipline. Firstly, we found that the regression confirmed our results from the t-test that SICs seem to be more responsive to economic pressures influencing their SOP discipline than PIC, $p < .001$. However, we also found that pilots having a university degree, $p = .012$, as well as those having prior business aviation experience, $p = .24$, and side-stick experience, $p = .018$, seem to be rather reluctant for SOP deviations.

Table 6-14: Pilots' attitude towards SOP-deviations

Average agreement with the following items				
Scale 1 = disagree strongly, 5 = agree strongly	N	M	SD	Agree (%)
Scale average	-	2.80	1.29	-
1. To work economically efficiently sometimes requires a trade-off in adherence to procedures.	174	2.43	1.34	33.4
2. Deviating exceptionally from SOP for efficiency reasons in normal operation is permitted if both pilots agree that it is safe.	120	2.84	1.45	41.8

Figure 6-5: Pilots' attitude towards SOP-deviations



6.4.2.1 Pilots' professional self-concept and their attitudes towards SOP deviation

In this study on pilots' attitudes, we wanted to test the hypothesis that pilots' NOTECHS orientation (H1) and pilots' self-image as safety/risk manager (H2) predicts their attitudes towards safety relevant decision-making and teamwork. The analysis revealed that there is neither a significant correlation of pilots' human factor orientation, r (222) = -.79, p = .241, with their attitude towards SOP deviation scale, nor with the single items of pilots' NOTECHS orientation, r (223) = -.02, p = .79, and also not with their self-view as a safety/risk manager, r (222) = -.10, p = .157.

6.4.2.2 Summary of key findings regarding pilots' attitude towards SOP discipline

- ➢ Efficiency considerations may negatively influence pilots' SOP discipline.
- ➢ There is a significant difference between frontline and management perspective on SOP discipline. Pilots seem to be more efficiency oriented than expected by their management.

6.4.3 Pilots' attitude towards conservatism in practice

6.4.3.1 Explanation

Although the operation of aircraft in commercial aviation is highly regulated using SOPs, operational limitations and further guidance from aircraft manufacturers or other aviation stakeholders there is still some opportunity for pilots to vary their safety relevant behavior. As mentioned before, not all SOP and limitations account for the influence of human factors or complex dynamic situations which require the pilots to take extra steps in order to maintain or increase the safety margins. In other words, they have to take extra care and be more risk-averse or, colloquially speaking, be more conservative or defensive in the operation of the aircraft. This is easily comparable to car driving: even when there is no speed limit given on a highway the driver has to adapt and reduce the speed of the car in situations such as when the forward visibility, e.g., due to rain or fog, reduces significantly. This kind of risk-averse safety relevant decision-making equals a conservative or defensive instead of a sporty or risky style of driving. While early initiatives in road safety started to promote defensive driving courses already decades ago (Lund & Williams, 1985), the concept of defensive flying became known in aviation significantly later, just with the introduction of threat and error management (TEM) (Merritt & Klinect, 2006). As outlined before (see 2.1) TEM has a proactive approach supporting pilots in anticipating upcoming or existing threats along their flight. However, identifying threats is only the first step and the next and at least equally important step is the mitigation of these threats to ensure an operation with always sufficient safety margins. For example, the use of operational conservatism is very much promoted in aviation to reduce the risks of runway excursion events (Flight Safety Foundation (FSF), 2021).

Aircraft flight crews have, especially in normal operation, always a more risk-averse option available. In normal operation, meaning with fully airworthy aircraft and no emergency present, take-offs can always be delayed or canceled, go-arounds can always be flown, and aircraft can always divert to a more suitable airfield. While operational flight plans for commercial flights always consider these ultimate options by default, many less ultimate nuances of these options exist along a flight which can lead to a more defensive flying and decision-making. For example, during an approach for landing pilots can always coordinate with ATC if they require more track miles for their descent or an early speed reduction on approach to avoid operating near, at, or even beyond operational limitations, i.e., in regard to aircraft speed, altitude or stabilized approach limitations. However, there are several situations during routine operation when a near or at the limit operation (NLO) of the aircraft is considered as normal and the margin before transitioning to an overlimit operation (OLO) is very low. Such situations may involve take-off, approach and landings near or at given weather or traffic separation limitations and also involve the ATCOs as members of the wider team being responsible for the safe aircraft operation as outlined earlier (see 1.2). We therefore created items which are related to pilots and ATCOs at the same time allowing us to compare their attitude towards conservatism in practice.

Item 1 of the conservatism scale requires respondents to state how they would find it if the aircraft's airspeed when starting an approach to land would be limited to a value commensurate with aircraft manufacturers guidelines which is actually lower than the speed currently expected by ATC at that point for capacity and traffic flow reasons. Item 2 requires respondents to judge how they would find the recommendation for pilots to deny challenging ATC clearances, e.g., by using the wording "unable" as proposed by (Civil Air Navigation Services Organisation (CANSO), International Air Transport Association, EUROCONTROL, International Civil Aviation Organization (ICAO), & International Federation of Airline Pilots Association (IFALPA), 2013), being introduced as a SOP. Item 3 requires respondents to judge how they would find it if SOPs would require pilots to not allow being rushed by ATC when starting the take-off so that both pilots can understand and mentally translate given wind information, passed along by ATC with the take-off clearance, and both pilots can monitor the correct take-off power setting without distraction. Currently, ATC often expects pilots to start the take-off roll immediately due to spacing the aircraft near or at the given legal limit without taking into account human factor issues on the flight deck and jet engine spool up times. Item 4 and 5 require respondents to judge how they would find it if recommendations given by the industry to prevent runway excursions would be made mandatory such as not intercepting the approach path from above or to delay an approach if it was not thoroughly prepared (Flight Safety Foundation (FSF), 2021).

6.4.3.2 Results

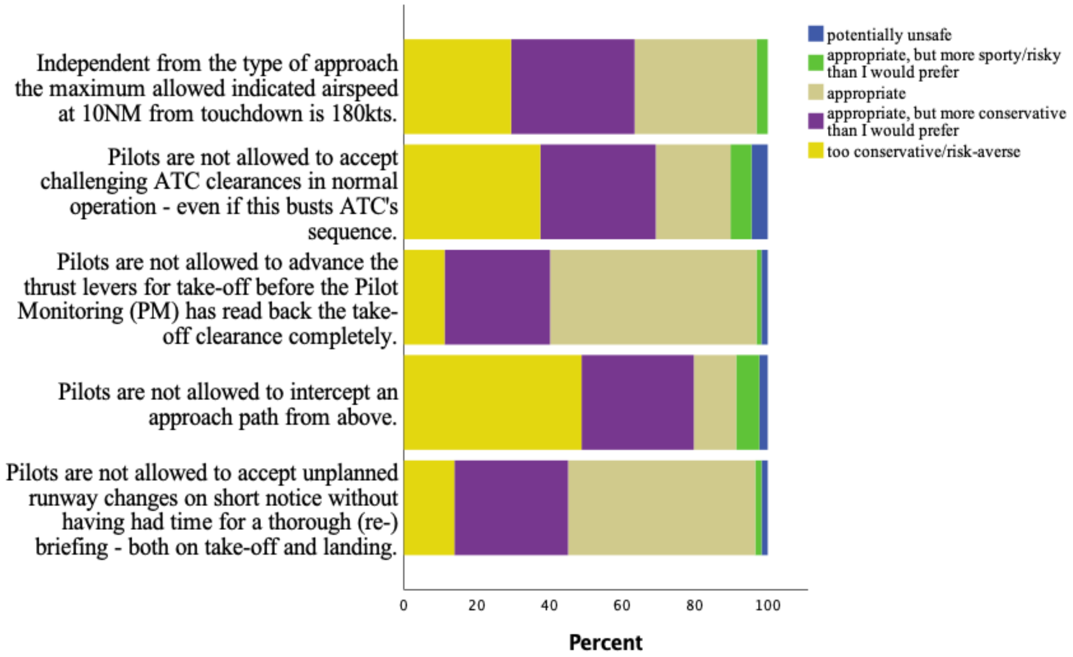
The results on the conservatism scale as shown in table 6-16 and figure 6-7 reveal that pilots (M = 2.18, SD = .60) judge the statements mostly as appropriate, but more conservative than they would prefer or even as too conservative. While we found no significant differences on the conservatism scale between responses from PICs and SICs, a one-way ANOVA with Bonferroni correction, F (2, 255) = 13.33, p < .001, revealed that the regulators (M = 2.93, SD = .61) respond to the scale more risk averse than pilots, p < .001. There were no significant differences on the scale between the responses of pilots and ATCOs nor between ATCOs and the regulators (These items were not presented to airline management). A multiple linear regression with the conservatism scale and the relevant pilot demographics revealed that higher pilot ages led to responding more conservatively, p = .006, but that prior sport flying experience led to responding less conservatively, p = .004.

Table 6-15: Pilots' attitude towards conservatism in practice

Average agreement with the following items				
Percent = aggregate of item response 1 and 2	N	M	SD	Agree (%)
Scale average (only item 1, 2, 3)	-	2.18	.60	-
1. Independent from the type of approach the maximum allowed indicated airspeed at 10NM from touchdown is 180kts.	224	2.10	.86	63.4
2. Pilots are not allowed to accept challenging ATC clearances in normal operation – even if this busts ATC's sequence.	224	2.08	1.10	69.2
3. Pilots are not allowed to advance the thrust levers for take-off before the PM has read back the take-off clearance completely.	224	2.54	.78	40.2
4. Pilots are not allowed to intercept an approach path from above.	172	1.83	1.02	79.6
5. Pilots are not allowed to accept unplanned runway changes on short notice without having had time for a thorough (re-)briefing - both on take-off and landing.	173	2.46	.82	45.1

Scale: 1 = too conservative/risk averse, 2 = appropriate, but more conservative than I would prefer, 3 = appropriate, 4 = appropriate, but more sporty than I would prefer, 5 = potentially unsafe; NM = Nautical miles (1NM = 1.852km), kts = knots = NM/h,

Figure 6-6: Pilots' attitude towards conservatism in practice



6.4.3.3 Pilots' professional self-concept and their attitudes towards safety relevant behavior

We found a positive correlation of pilots' human factor orientation with the conservatism scale, r (221) = .29, $p < .001$. As hypothesized, pilots seem to have a less conservative/defensive, thus more sporty or risky attitude towards aircraft operation, the less they see themselves as safety/risk manager, thus the more as aircraft/system operator, r (221) = .17, $p = .010$ (Bonferroni corrected). As hypothesized as well, we also found that the less pilots are NOTECHS oriented, r (222) = .28, $p < .001$ (Bonferroni corrected), the more sporty or risky attitude they seem to have towards aircraft operation.

6.4.3.4 Summary of key findings regarding pilots' attitude towards conservatism

- ➢ Pilots seem to be less conservative than recommended by safety initiatives
- ➢ Regulators seem to have a more risk-averse attitude than pilots
- ➢ Pilots' professional self-concept could be an influencing factor on their conservatism in practice

6.4.4 Pilots' attitude towards safety versus business considerations

Current role descriptions for pilots still contain references to economic factors to be observed by them during aircraft operation. Even though all flight crew role descriptions also highlight pilots' primary responsibility for safety it can be assumed that the reference to economic and business considerations such as punctuality, sustainability or cost-efficient flying may have, at least, a subtle influence on pilots' value and belief system and thereby their understanding of their role in the aviation system. To estimate a possible tendency of pilots to incorporate business considerations in their safety relevant decision-making we created a scale measuring pilots' attitude towards safety versus business considerations as shown in table 6-4 and figure 6-1.

We found that pilots seem to be generally more safety minded than business oriented (M = 3.36, SD = .70). There was no significant difference between PIC and SIC in this regard, t (265) = -.69, p = .49, and a multiple linear regression revealed no significant influence of the relevant pilot demographics either.

Regarding the safety vs business orientation, we requested responses from the ATCOs, the Regulators and the Airline Management as well. In the case of the ATCOs we substituted *pilot* by *ATCO* for item 1 and 2 and in item 4 we substituted *Co-Pilot* by *radioing ATCO* and *PIC* by *ATCO's supervisor*, but left item 3 and 5 in its original version. For the airline management and regulators, we used the original version of the items. However, due to a mistake in survey design, item 3 was omitted from the survey for the airline management. However, a one-way ANOVA also revealed no significant difference between the scale mean of the different groups of aviation stakeholders (pilots, ATCOs, regulators and management).

However, given the mistake in survey design for the management respondents and due to the fact that Cronbach's alpha of the scale was low (.60) we decided to investigate the responses of the different groups on the individual items using a one-way ANOVA with Games-Howell and Bonferroni post-hoc tests respectively. The following interesting differences in responses of the other groups in comparison to the pilot responses became apparent:

On item 1 the regulators (M = 3.38, SD = 1.59) endorsed more strongly than the pilots themselves (M = 1.92, SD = 1.12) that pilots should be responsible for only the safety and not the efficiency of their flights, $p = .011$. These differences might reflect that the expectation by regulators that business considerations would be naturally suppressed by safety considerations in daily operation, may not necessarily shared by those operating at the sharp end. While there was no significant difference between pilots and regulators regarding carefulness in daily operation (item 2), $p = .70$, the comparison of means in responses by ATCOs and regulators reveal that ATCOs ($M = 3.39$, $SD = 1.38$) do see the requirement for conservative/risk-averse decision-making in practice significantly less than regulators ($M = 4.56$, $SD = .81$), $p = .023$.

Given the fact that we also found mildly significant different responses between pilots and ATCOs on item 2 and item 5, this might point to different expectations regarding safety relevant behavior and decision-making which could lead in practice to frictional losses in the aviation system when pilots and ATCOs are required to jointly guarantee the safety of the aircraft operation. While pilots ($M = 4.33$, $SD = .97$) strongly endorse carefulness in daily operation this may not naturally be shared to the same extent by the ATCOs ($M = 3.39$, $SD = 1.38$), $p = .047$. ATCOs ($M = 2.50$, $SD = 3.33$) also oppose the idea, which instead pilots more strongly endorse ($M = 3.33$, $SD = 1.30$), that pilots should refuse time pressure or ATC requirements for safety reasons (to reduce complexity). The views of pilots and ATCOs may differ in that regard, $p = .052$. These possible differences in views might stem from a basic difference of their roles in aviation. While ATCOs are responsible for the safe separation of aircraft only, pilots are responsible for the overall safe operation of their flights (ICAO, 2018). Additionally, pilots also directly see and feel if air traffic control clearances might be too risky (e.g., in terms of aircraft spacing, speed or altitude control on approach) while ATCOs only see the results from their safety relevant decision-making on radar screens or through glasses from the tower. This might make it easier for pilots to assess if a situation is requiring higher safety margins than legally prescribed while ATCOs might think that sticking to the legal limits is still safe.

Nevertheless, our data from two further individual items regarding safety relevant decision-making support the notion that pilots and ATCOs do share a common view on safety vs business considerations. We asked all four aviation stakeholders to express the extent to which they agree to the statement that “Flying go-arounds is in the long-term economic interest of airlines” and we asked pilots and ATCOs if “The application of just the legally required separation minima by ATC is always safe in my experience”. A one-way ANOVA with Games-Howell post-hoc test, F (3, 238) = 7.61, p < .001, found that pilots most strongly favor go-arounds as beneficial for the long-term economic interest of airlines (M = 4.34, SD 1.00) with no significant difference to ATCOs (M = 3.50, SD = 1.34), p = .076, and regulators (M = 3.50, SD = 1.46), p = .147, but with significant difference to airline management (M = 3.68, SD = 1.36), p = .046.

Furthermore, in both groups, the pilots (M = 2.65, SD = 1.18) and ATCOs (M = 2.78, SD = 1.11), only a third (pilots: 30.2%, ATCOs: 33%) agree that application of the legally required separation minima is safe with no significant difference between their responses, t (185) = -.44, p = .66. Given the low number of participants from the ATC sector (N = 18) these results should surely be treated with care but might warrant further research in the field of collaboration and possible differences in operational perspectives of pilots and ATCOs.

6.4.4.1 Pilots' professional self-concept and their attitudes towards safety vs business considerations

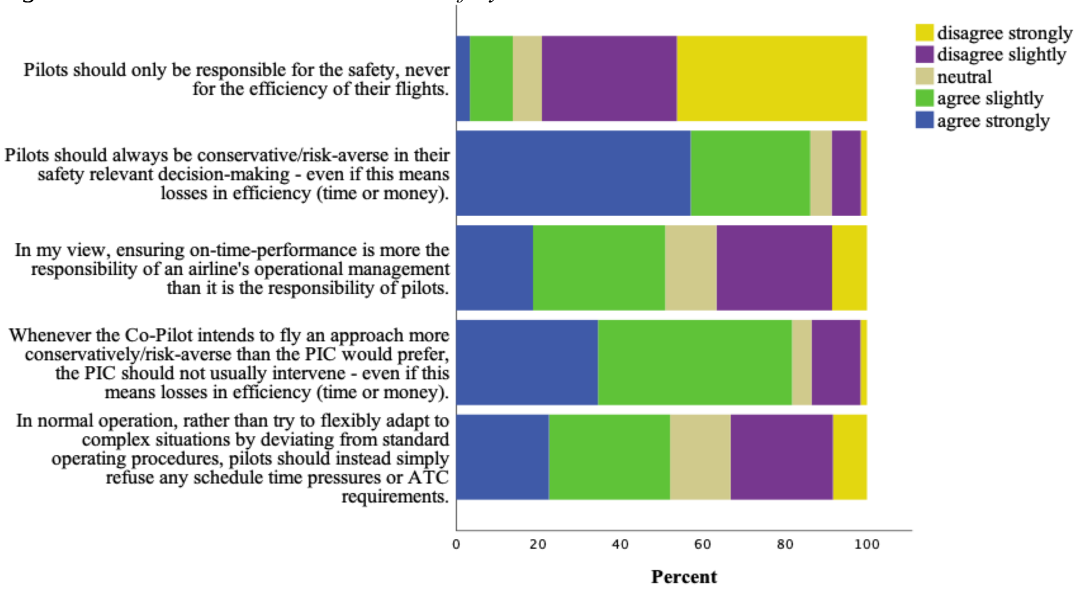
We found that pilots' human factor orientation is positively correlated with pilots' attitude towards safety vs business considerations, r (245) = .14, p = .030. This result suggests that the more pilots are human factor oriented the more safety vs business oriented they are.

A multiple linear regression with the other seven additional single items related to pilots NOTECHS orientation (see 6.2.7) with a Bonferroni corrected alpha level of .007 revealed that the pilot responses to the item “I feel personally responsible for the on-time performance of my flights.”, p < .001, was significantly associated with their attitude towards safety versus business orientation. Furthermore, we found that pilots' responses to the safety vs business orientation scale are significantly associated with the responses given to the conservatism scale, r (222) = .19, p = .005. This suggests the notion that pilots who are less safety vs business oriented seem to be also more prone to more risk-taking in practice.

Table 6-16: Pilots' attitudes towards safety versus business considerations

Average agreement with the following items				
Scale: 1 = disagree strongly, 5 = agree strongly	N	M	SD	Agree (%)
Scale average	-	3.36	.70	-
1. Pilots should only be responsible for the safety and never for the efficiency of their flights.	268	1.92	1.12	13.8
2. Pilots should always be conservative in their safety relevant decision-making, even if this means losses in efficiency (time or money).	268	4.33	.97	86.2
3. In my view, ensuring on-time-performance is more the responsibility of an airline's operational management than it is the responsibility of pilots.	224	3.25	1.28	50.9
4. Whenever the Co-Pilot intends to fly an approach more conservatively/risk-averse than the PIC would prefer, the PIC should not usually intervene, even if this means losses in efficiency (time or money).	252	4.01	1.01	81.7
5. In normal operation, rather than try to flexibly adapt to complex situations by deviating from standard operating procedures, pilots should instead simply refuse any schedule time pressures or ATC requirements.	265	3.33	1.30	52.0

Figure 6-7: Pilots' attitudes towards safety versus business considerations



6.4.4.2 Summary of key findings regarding pilots' attitude towards safety/business considerations

- ➢ Pilots are generally more safety minded than business oriented
- ➢ The more human factor oriented the pilots the more safety versus business minded they are.

6.4.5 Pilots' attitudes towards the role of the SIC

One of the main research interests stemming from the results of the field data research regarding the flight crew role assignment was to elicit how pilots, both PICs and SICs, view the role of the SIC and if there are significant differences between the responses of both groups. Furthermore, we wanted to test if pilots' professional self-concept predicts their attitude towards the teamwork on the flight deck operationalized by the attitude towards the role of the SIC.

As shown in table 6-17 and figure 6-8 pilots' responses to the scale eliciting pilots' attitudes towards the role of the SIC suggest that they endorse a rather high status of the role of the SIC, with no significant difference between responses to the scale by PIC (M = 4.01, SD = .70) and SIC (M = 4.24, SD = .56). A multiple linear regression with the relevant pilot demographics did not reveal significant associations.

Given the fact that Cronbach's alpha for this scale was rather low (.60) and further analysis on pilots' attitude towards monitoring and intervention used some individual items as well (see 6.2.2) we decided to analyze the items of the scale individually but applied a Bonferroni correction and altered the alpha level to .01. We found that nearly all pilots (90.4%), without significant differences between PIC and SIC, seem to support the idea that pilots in the role of the SIC should be properly trained to lead and intervene and also nearly all pilots (91.9%) agree that SICs should be trained to enable joint flight crew decision-making and effective intervention. However, there was less agreement with the items regarding active cooperation and intervention by the SIC in practice. Only three quarters (76.3%) of the pilots endorse the requirement that the PIC should achieve agreement on a decision with the SIC first (item 1). This was endorsed significantly less by the PICs (M = 3.85, SD = 1.36) than by the SICs (M = 4.24, SD = .96), t (266) = -2.78, p = .006, with a Cohen's d of 1.21 showing a large effect size. While there was no significant difference in responses by PICs and SICs regarding PIC's acceptance of intervention (item 2), in which also only three quarters (75.2%) of the pilots were in agreement with, we found some less agreement (71.1%) with the question if SICs should be allowed to assume command when the PIC is taking unnecessary risks. Again PICs (M = 3.68, SD = 1.33) endorsed this significantly less than SICs (M = 4.04, SD = 1.03), t (264) = -2.53, p = .006, with a Cohen's d of 1.21 showing a large effect size. (Remark: given the conservative Bonferroni correction and given the fact that the result was in the predicted direction we report the one-sided significance in this case).

Items 2, 3 and 5 were also presented solely to the group of regulators. The results show that they seem to support the idea that the SIC role should be empowered for effective intervention in the PIC's safety relevant decision-making. Regulators (M = 4.89, SD = .32) more strongly than the pilots themselves (M = 4.57, SD = .80) see the necessity to train SIC to the same extent as PICs in safety relevant decision-making (Item 5), t (31) = -3.52, p = .001. Although a Cohen's d of .78 shows a medium effect size only, this finding might be very interesting given the fact that the industry does obviously not support this idea in general. In the IATA handout on pilots' command training (IATA, 2020) and also in aircraft operating manuals the difference between a PIC and SIC is drawn exactly by the opposite of what our data shows - namely that the industry assumes that the "leadership requirements are higher for Captains than for Co-Pilots".

Another significant difference between the attitude of pilots and regulators in this regard may become apparent on the item by which we tested participants on their view regarding specific flight experience marks related to the role of the SIC such as the minimum hours being required to undertake command training (see table 6-18). While pilots (M = 3,777.2, SD = 1,723.4) estimate more than double of the legally required minimum of currently 1500 flight hours to be required, the regulators (M = 2,399.6, SD = 1,005.0) estimate this value significantly lower, t (19) = 20.69, p < .001. This difference might well stem from the different perspectives on the aviation system by both groups. It may be assumed that regulators based their estimate solely on the current legal framework (1500hrs) while pilots may have been influenced additionally by collective or other agreements within their airlines which often require a minimum of 3,000 or even 5,000 flight hours in the company or on specific types of aircraft before allowing SICs to start a command course. Interestingly, the estimate on this value significantly differs also between PICs (M = 3,447.1, SD = 1,736.8) and SICs (M = 4,237.1, SD = 1,601.7), t (264) = -3.79, p < .001, which reflects that SICs seem to require more confidence before starting a command course than those, who have already passed one, really deem this necessary.

Table 6-17: Pilots' attitudes towards the role of the SIC

Average agreement with the following items				
1 = disagree strongly, 5 = agree strongly	N	M	SD	Agree (%)
Scale average	-	4.10	.65	-
1. Before taking any safety relevant decision in normal operation the PIC should first agree with the Co-Pilot.	270	4.01	1.22	76.3
2. The PIC should always accept the Co-Pilot's intervention whenever this leads to more conservative/risk-averse flying or decision-making in normal operation.	270	3.58	1.13	75.2
3. Co-Pilots should have the authority to assume command whenever the PIC is taking unnecessary risks in normal operation.	270	3.83	1.22	71.1
4. Co-Pilots should be trained so as to be able to lead the aircraft's flight crew as well as cabin crew in normal operation.	270	4.53	.80	90.4
5. Co-Pilots should be trained in safety relevant decision-making to the same extent as a PIC so that in all circumstances they are capable of intervening effectively in the safety relevant decision-making of a PIC.	270	4.57	.80	91.9

Figure 6-8: Pilots' attitudes towards the role of the SIC

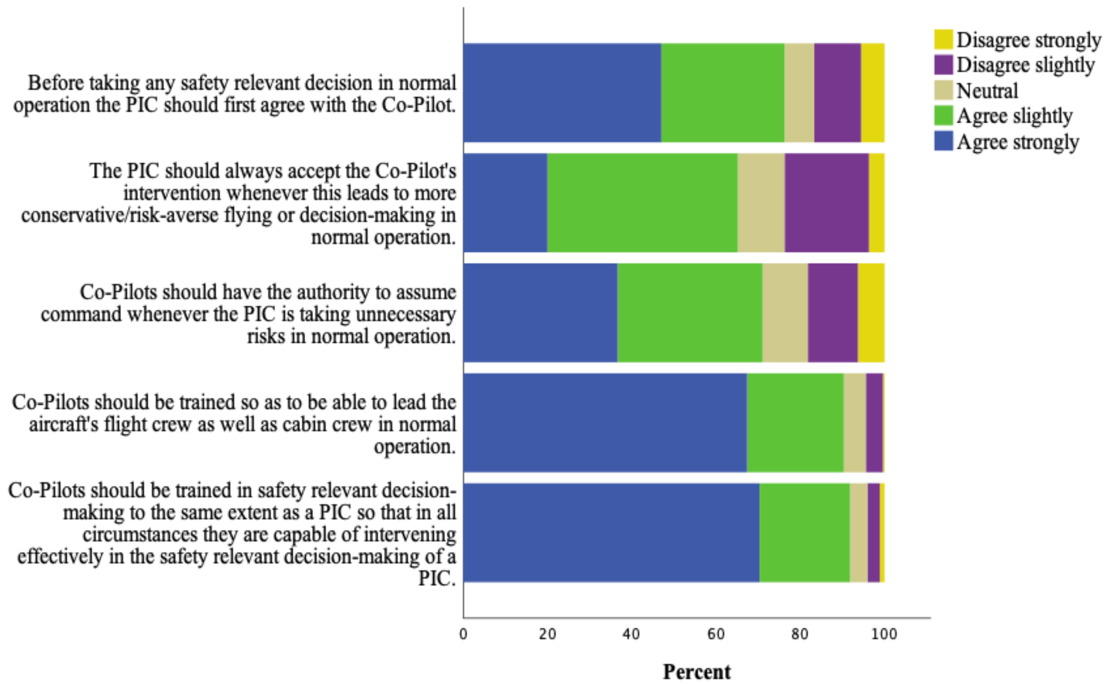


Table 6-18: Pilots' estimate of flight experience marks related to the SIC role

Estimate of line flying experience (in flight hours)			
	N	M	SD
1. How many hours of line flying experience do you think that a Co-Pilot needs in order to be able to intervene effectively in the decision-making of a PIC?	267	2,073.3	1,577.3
2. After how many hours of line flying experience would you rate a Co-Pilot as an experienced Co-Pilot?	189	1,991.8	995.2
3. How many hours of line flying experience do you think that a Co-Pilot should have as a minimum before undertaking command training?	268	3,777.2	1,723.4

6.4.5.1 Estimate of SICs' capacities

A difference in view between the legal and the estimated minimum requirements is also evident regarding the estimated intervention capability of SICs (item 1 of table 6-18) and their overall experience (item 2 of table 6-18), though on these items with no significant differences between responses from pilots and regulators. The responses reveal that pilots (*M* = 2,073.3, *SD* = 1,577.3), as well as regulators (*M* = 1,781.3 *SD* = 1,390.4), think SICs, in order to be able to effectively intervene in a PIC's decision-making, and being viewed as experienced (pilots: *M* = 1,991.8, *SD* = 995.2 and regulators: *M* = 2,007.7, *SD* = 1212.0) require even more experience than the amount of flight hours required to legally become PIC. This finding is really striking as it suggests that they do not allocate the requirement for effective intervention to the SIC within the first 2-3 years of their career (average flight time per year is around 700-900 hours), although SICs are required from the first hour of line flying to be able to effectively intervene in the PIC's decision-making, if necessary, as shown by our field data analysis. However, both estimates should already be alerting the aviation industry and might warrant challenging the current status and training of pilots in the role of the SIC. Our results clearly confirm that there is a gap between what the legal framework (and thereby currently the traveling public) assumes and what is regarded as common by practitioners. This notion is further underpinned by the responses on some single items regarding the status of the SIC. We asked the respondents for their agreement or disagreement with the item: “Currently Co-Pilots are entitled to disagree, but not entitled to veto the safety relevant decision-making of the PIC”. We found that out of 270 total responses nearly half of the pilots (42.6%) agreed, nearly the same number (41.5%) of the pilots do not agree and some (15.9%) were neutral, with no significant differences in responses between PIC and SIC and also no significant differences in responses between pilots and regulators. This additionally suggests a lack of status and power for effective intervention associated with the role of the SIC.

Another hint that the training and duties of the SIC should be critically reviewed give the results on two questions regarding taxiing of the aircraft on the ground. Currently, this task is, often historically, preserved by airline procedures for the PIC only, even if technically feasible for the SIC, e.g., by an additional steering device (tiller) installed for the right-hand seat in the cockpit, which is the seat traditionally allocated to the role of the SIC on fixed wing aircraft. In our survey less than half (37.9%) of the responding 219 pilots reported that Co-Pilots in their airline were officially allowed to taxi the aircraft in normal operation. However, when asked if Co-Pilots should be officially allowed to taxi the aircraft this was supported by nearly all (93.1%) of the 247 respondents, a view which is equally shared by the regulators. Although significantly less PICs ($M = 1.89$, $SD = .32$) than SICs ($M = 2.0$, $SD = .0$) share this view, $t\ (146) = -4.37$, $p < .001$, the low effect size shown by a Cohen’s d of .25 suggests that this difference, despite being significant, is negligible.

To determine the status of the SIC-role from the perspective of the PICs we asked only them if, in their view, the influence of the Co-Pilots is becoming too strong and if they view this as upsetting the appropriate authority gradient on the flight deck. We found that only few (8.3%) out of 157 responding PIC slightly agreed to this statement, some (19.1%) were neutral and most (72.7%) were disagreeing. Additionally, we asked the PICs if they “find it sometimes difficult to balance economically efficient decision-making with the need for cooperation with more conservative minded Co-Pilots”. In this regard we found that a third (32.1%) of the 134 responding PIC agreed to that statement, a quarter (23.1%) was neutral, but nearly half (44.7%) disagreed. These findings suggest that there is generally no rejection against a high status of the SICs by the PICs, but that economic considerations may have at least some negative influence on flight crew teamwork as well.

6.4.5.2 Pilots' professional self-concept and their attitude towards the role of the SIC

We found that the SIC scale was significantly correlated with pilots' human factor orientation, r (245) = .13, p = .048. Although the correlation is rather low it is sufficient to support our initial hypotheses (H1 and H2) that the professional self-concept may be influential for pilots' attitudes towards their roles on the flight deck and especially towards the role of the SIC. In the light of our findings of the field data research this could also suggest that the professional self-concept might possibly qualify for an additional factor underlying the role assignment effect.

6.4.5.3 Pilots' risk appetite and their attitude towards the role of the SIC

Our field data research on accidents and incidents in the period 2000-2020 revealed that 72.2% of the events happened in normal operation meaning with technically fully operational aircraft and no emergency present from which we already concluded that pilots' risk management in these events was flawed. In regard to the role assignment effect, we also found that in 81.8% of the hull loss events happening in normal operation the PIC was acting as PF. This pattern led us to hypothesize that there might be not only an association between pilots' risk-taking behavior and their safety versus business attitude as found previously (see 6.4.4.1), but at the same time also an association of their risk appetite with their attitude towards the role of the SIC.

We hypothesized that this association might act on both hierarchical roles. First, more risk-oriented PIC might be more resistant to intervention by the SIC when, at the same time, also seeing the status of the SIC lower, while second, more risk oriented SIC might be more reluctant to intervene when having a lower attitude regarding their own role on the flight deck. To test this hypothesis, we did a correlation analysis split by the responses of PIC and SIC and found as hypothesized that more risk-oriented PICs also endorsed a lower status of the SIC, r (132) = .30, $p < .001$. We found the same association for the SICs as well, r (88) = .22, $p < .036$, especially on the item asking for SIC's attitude towards taking command in case of unnecessary risk-taking of the PIC (item 3 of table 6-17), r (88) = .31, p = .003.

6.4.5.4 Pilots' attitude towards the role of the SIC and the Power Distance Index

We were able to capture Hofstede's Power Distance Index (PDI) related to the respondents' origin for N = 339 cases and the PDI of the country where the respondents' employing airline had its base as in study 2 in N = 258 cases. This enabled us to check if there are significant correlations with pilots' attitudes towards the role of the SIC and the respective PDI to see if culture has any influence on pilots' attitude in this regard. However, there was neither an association of pilots' country of origin related PDI and their attitude towards the role of the SIC, r (230) = .02, p = .788, nor with the country of their operator's PDI, r (263) = .06, p = .303. This suggests that there is not necessarily an influence of culture on pilots' attitude towards the role of the SIC.

6.4.5.5 Summary of key findings regarding pilots' attitude towards the role of the SIC

- High consensus that the role of the SIC should have a high status, but lower consensus on SIC's authority
- Consensus between SIC and PIC on the training and leadership abilities of the SIC
- Less agreement by PIC than by SIC that PIC should seek agreement
- Less agreement by PIC than by SIC that SIC have the right to take command
- Opposite to the current industry view regulators seem to see a higher status of the SIC role
- Effective intervention by SIC is only expected with 2-3 years of flying experience
- Pilots' responses suggest that they recommend at least doubling the current minimum legal requirement for command training
- The position of the SIC does not warrant effective intervention
- Nearly all pilots and regulators support that SIC should be allowed and trained to taxi
- The more human factor oriented the pilots the higher they value the role of the SIC.
- There is generally no rejection against a high status of the SICs by the PICs, but economic considerations may negatively influence teamwork on the flight deck.
- Pilots' risk-appetite seems to be associated with their attitude towards the role of the SIC
- Culture seems to have no influence on pilots' attitude towards the role of the SIC

6.4.6 Pilots' attitude towards the supervisory function of the SIC and PM

Based on the latest technological achievements in regard to aircraft automation and autonomous flying the research on single pilot operation (SPO) and reduced crew operation (RCO) is currently ongoing, e.g., as recently sparked by the European Aviation Safety Agency (EASA, 2023). While many arguments used by opponents of the idea to reduce the number of pilots on board of commercial aircraft, e.g., by pilot associations (Air Line Pilots Association, 2019), are based on a possible loss of redundancy, e.g., in case of incapacitation of one pilot, we wanted to investigate how pilots see the value of having a second pilot on the flight deck acting as a supervisor of the actions by the other pilot. To better understand how far pilots acknowledge this opportunity for supervision we asked participants two questions in regard to their view on the role of the SIC and PM[30]:

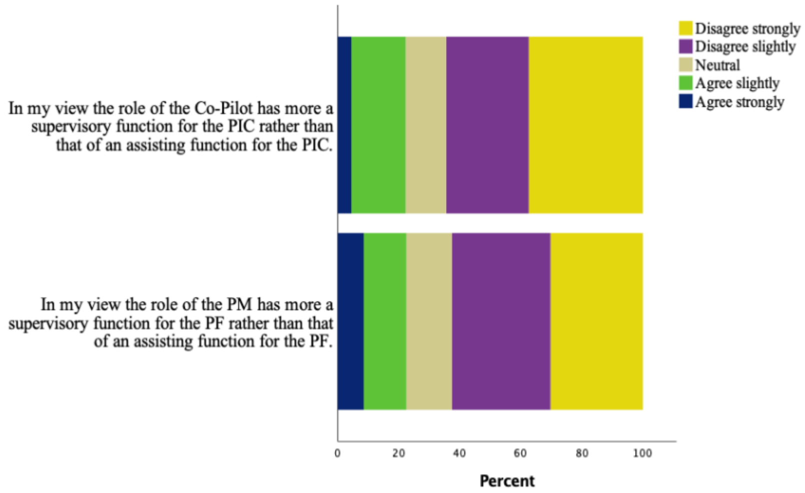
1) "In my view the role of the PM has more a supervisory function for the PF rather than that of an assisting function for the PF."
2) "In my view the role of the Co-Pilot has more a supervisory function for the PIC rather than that of an assisting function for the PIC."

Given the label change from PNF to PM and the industry's initiatives on effective monitoring over the recent years (see 3.1) we hypothesized that at least the role of the PM would be seen rather as a supervisor than as an assistant. However, as shown in figure 6-9 we found that pilots neither agree with the view that the SIC has more a supervisory function for the PIC (M = 2.25, SD = 1.13) nor that the PM has more a supervisory function for the PF (M = 2.38, SD = 1.28). A paired samples t-test revealed that there is no significant difference between those two responses, t (269) = -1.56, p = .121. An independent samples t-test revealed that there are also no significant differences in responses by PIC (M = 2.27, SD = 1.13) and SIC (M = 2.41, SD = 1.11) on the scale for the two items, t (290) = -1.03, p = .305. A multiple linear regression with this scale and the relevant pilot demographics revealed no significant associations.

[30] These questions were presented slightly differently in the 2017 survey: In my view the role of the PM / Co-Pilot is that of a supervisor of the PF/PIC rather than that of an assistant or supporter for the PF/PIC. Based on feedback by respondents the wording was changed to highlight the supervisory function.

As we deliberately framed the questions in a way that pilots had to weigh if they view the roles more as a supervisor or more as an assistant, the results do not reflect the exact proportion as to which a supervisory function of both roles is accepted or not. However, the results clearly highlight the hierarchically lower status of both, the role of the PM and the SIC in comparison to the role of the PF and PIC, suggesting a basic design error in teamwork settings on commercial flight decks. Although both monitoring roles (PM and SIC) clearly include supervisory duties such as effective intervention, if necessary, the required hierarchical power is denied for both roles which clearly shows that the combination of SIC and PM is the least powerful combination to ensure effective intervention. The routine combination of command and monitoring (PIC as PM) would eliminate this contradiction.

Figure 6-9: Pilots' attitude towards the supervisory function of the PM/SIC-role



6.4.6.1 *Pilots' professional self-concept and their attitude towards PM/SIC's supervisory function*

There was no significant correlation of pilots' human factor orientation and their attitude towards PM/SIC's supervisory function, r (245) = .08, p = .198.

6.4.6.2 *Summary of key findings regarding pilots' attitude towards PM/SIC's supervisory function*

- The roles of the PM and the SIC are more viewed as an assistance only
- The roles of the PM / SIC are viewed hierarchical lower than the PF / PIC

6.4.7 Pilots' attitude towards the role of the PM

To further elicit pilots' attitudes on the role of the PM we developed items stemming from practice of commercial flight operations. Items 1 through 5 of table 6-19 and figure 6-10 deal with the authority of the PM and the autonomy of the PF. Items 6 through 8 cover single research items created to test pilots' attitudes regarding complexity and the style of intra-cockpit communication. In their golden rules of group interactions in high-risk-environments Sexton (2004) not only recommended that the SIC should be PF in demanding situations (see 3.3.2.1) but also recommended the use of the first-person plural (we/let's) to foster team perspective. However, our data suggests that there is obviously a science-practice-gap. Both recommendations seem not to be widely spread in commercial aviation as only half (50.8%) of the pilots expect the use of "we" in a typical situation reflecting team performance (item 8) and also only half (49.4%) of the pilots acknowledge that the SIC should be the PF on demanding approaches (item 4) which is in line with our findings from the field data analysis on control changes (see 3.3.2.1).[31]

The results on items 3, 6 and 7 additionally highlight that the teamwork on the flight deck seems not to be entangled, in a way that the roles of PF and PM require mutual consideration for each other, but being characterized more in a paralleled mode in which the needs of the PF seem to be superior to those of the PM. Although specific routine tasks such as checklist reading or configuration changes may have the potential to distract the PM from their primary duty of monitoring, especially in complex and dynamic departure or approach situations, the idea that configuration changes during approach should require prior coordination among the flight crew (item 3) is only supported by a third (35.7%) of the pilots and the use of the autopilot during checklist use (item 7) is even supported by very few (9.1%) of the pilots only. Although it might be necessary in non-normal operation to hand fly the aircraft while the other pilot reads a non-normal checklist, in normal operation it is usually always possible for the PF to switch on the autopilot before requesting a checklist to be done. Both departure and landing operations are prone to complexity, even under optimum weather conditions, especially if they include turns, course or altitude intercepts and additional communication to ATC.

[31] Some aircraft manufactures actually promote the transfer of controls from PIC to SIC, however only when dealing with non-normal situations.

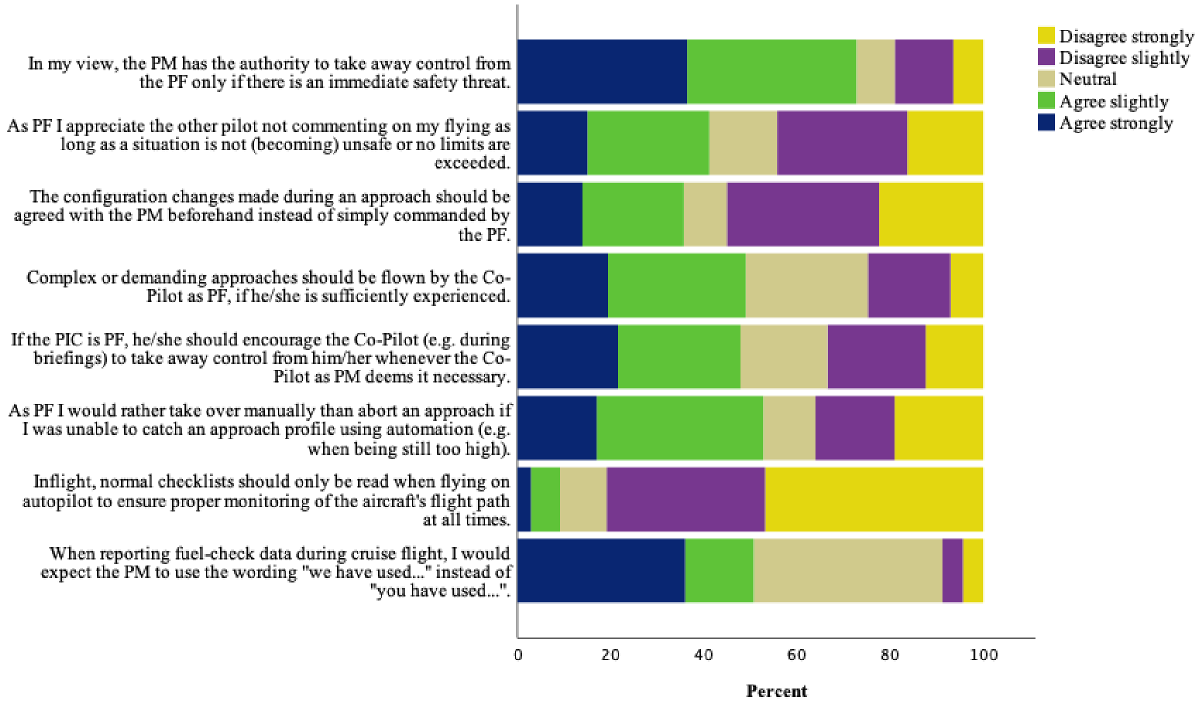
According to Woods et al., (2010, p. 13) “complexity is the enemy of safety” and pilots should strive to reduce complexity as much as possible. To reduce complexity for the PM and at the same time ensure proper monitoring of the aircraft flight path and relevant instruments the PF could easily refrain from flying manually thereby de-complexing the situation for the PM and take-over the critical monitoring duty of the instruments for the short period while the PM does the required checklist items which often require a turning away from the primary flight instruments. The fact that this thinking is obviously not yet reflected in aircraft operating procedures underpins the lower focus on the role of the PM in the industry than on the role of the PF. This lower focus on the PM-role is also reflected by pilots’ responses regarding the choice of reverting to manual control instead of aborting the approach (item 6) which reveal that half (52.8%) of the pilots would tend to accept adding more complexity to an already complex and demanding situation making it even harder for the PM to monitor effectively.

Moreover, the results on the item regarding the authority of the PM (item 1) and the item regarding the PM verbal intervention or assistance (item 2) suggest that the role of the PF is regarded as rather autonomous from the PM role. Not only that most pilots (72.8%) would not like to accept a control take-over except for a dangerous situation (item 1), but nearly half of them (41.2%) do not even appreciate comments by the PM which is in line with our findings on the experience of pilots in the PM role (see 6.3.5). There were no associations of the two items with the relevant pilot demographics and except for item 2 there were no significant differences between the responses by PIC and SIC on the items measuring the attitude of pilots towards the role of the PM. Only, in the regard of disliking comments by the PM we found that this item had less agreement within PICs (M = 2.74, SD = 1.31) than within SICs (M = 3.25, SD = 1.34), t (292) = -3.27, p = .001 (Bonferroni corrected alpha level = .01), with a Cohen’s d of 1.32 showing a large effect size, which may reflect that SICs do not feel sufficiently free to unfold themselves in the PF-role and aid to the overall picture that the role of the PF is seen rather as autonomous from the PM. The results on item asking for PIC’s encouragement of active intervention by the SIC (item 5) also support this and additionally suggest that existing status hierarchy between the PIC and SIC still acts as a barrier for effective intervention in commercial aviation flight decks because only half (47.8%) of the pilots support the idea that the PIC as PF should encourage the SIC as PM to actively intervene by taking control, if necessary.

Table 6-19: Pilots' attitude towards the role of the PM

Average agreement with the following items				
Scale 1 = disagree strongly, 5 = agree strongly	N	M	SD	Agree (%)
1. In my view, the PM has the authority to take away control from the PF only if there is an immediate safety threat.	294	3.84	1.23	72.8
2. As PF I appreciate the other pilot not commenting on my flying as long as a situation is not (becoming) unsafe or no limits are exceeded.	294	2.96	1.34	41.2
3. The configuration changes made during an approach should be agreed with the PM beforehand instead of simply commanded by the PF.	294	2.72	1.39	35.7
4. Complex or demanding approaches should be flown by the Co-Pilot as PF, if he/she is sufficiently experienced.	294	3.36	1.19	49.0
5. If the PIC is PF, he/she should encourage the Co-Pilot (e.g., during briefings) to take away control from him/her whenever the Co-Pilot as PM deems it necessary.	209	3.23	1.34	47.8
6. As PF I would rather take over manually than abort an approach if I was unable to catch an approach profile using automation (e.g., when being still too high).	288	3.15	1.40	52.8
7. Inflight, normal checklists should only be read when flying on autopilot to ensure proper monitoring of the aircraft's flight path at all times.	209	1.84	1.03	9.1
8. When reporting fuel-check data during cruise flight, I would expect the PM to use the wording "we have used…" instead of "you have used…".	203	3.73	1.13	50.8

Figure 6-10: Pilots' attitude towards the role of the PM



6.4.7.1 Pilots' professional self-concept and their attitude towards the role of the PM

There were no significant correlations of pilots' human factor orientation, neither with the item on the PM's authority (item 1), r (245) = .03, p = .598, nor with the single item on PM's commenting (item 2), r (245) = -.02, p = .791.

6.4.7.2 Summary of key findings regarding pilots' attitude towards the role of the PM

- ➢ The role of the PF seems to be viewed as being autonomous from the PM
- ➢ Taking-over control by the PM seems to be not accepted as precautionary measure
- ➢ Status hierarchy between PIC and SIC may act as a barrier in the PM-role

6.4.8 Pilots' reluctance to intervene

Given the results in the field data analysis that teamwork issues including missing or ineffective monitoring and intervention contributed to the vast majority (87.5%) of the events and that we additionally found that only very few (5.5.%) of the control take-overs were initiated by the SIC, we wanted to analyze how free pilots feel in the role of the PM to take away control from the PF. We hypothesized that pilots in the role of the SIC feel more restricted to take away control than pilots in the role of the PIC (item 1)[32]. As shown in table 6-20 and figure 6-11 we found that more than a third (40.2%) of all pilots admit that as PM taking away control from the PF is not an easy thing for them to do (item 1). As hypothesized, we found that the PICs as PM (M = 2.45, SD = 1.43) feel significantly less reluctant to take-away control from the PF than the SICs as PM (M = 3.31, SD = 1.24), t (275) = -5.45, $p < .001$. A Cohen's d of 1.36 shows a large effect size. There was no association of this item with the relevant pilot demographics.

Additionally, we asked the PICs how difficult they would find it to intervene if they flew with another PIC-rated pilot (a pilot in the rank of a captain), either when being the PIC or the SIC of the flight (items 2 and 3). Interestingly, we found that PIC-rated pilots do not respond differently regarding their freedom to intervene. In detail, we found that more than a third (38.7%) of the PIC-rated pilots would find it difficult to intervene when in the role of the SIC and also more than third (39.3%) of the PIC-rated pilots would even find it difficult to intervene when in the role of the PIC. These findings together suggest not only a general reluctance for intervention on the flight deck among commercial aviation pilots, but it also suggests that this reluctance is independent from the adopted hierarchical position on the flight deck when two pilots in the same rank are working together. This might in turn suggest that having a PIC-rating seems to alleviate the status difference between PIC and SIC on a flight deck. A multiple regression of the scale created by items 2 and 3 with the relevant pilot demographics revealed that those respondents with prior business aviation

[32] This item was presented slightly differently in the 2017 survey: I feel free to take away control from the PF at any time I judge it necessary. In order to align it with the items regarding SIC's reluctance to intervene (see 6.4.8) it was adapted in the global survey. The responses were re-coded for the analysis in the merged sample accordingly.

experience would be less reluctant to intervene in this crew pairing, $p = .039$, which can be explained by the fact that this crew pairing is not unusual in the business aviation sector.

Given the long history of the flight crew team setting in commercial airlines consisting of only one pilot being fully trained towards PIC-rating (captain) and a SIC (co-pilot) with overall less requirements in regard to training and competency there is traditionally a reluctance of pilots and their associations against crewing two PIC-rated pilots together (Vereinigung Cockpit, 2001). As an additional item we therefore asked both groups (PIC and SIC) "if they viewed the crewing of two captains (PIC-rated) pilots (1 captain is the PIC and the crew is not enlarged / augmented) as a potential safety threat" and found that there is no homogenous view on this topic among the pilots ($M = 3.00$, $SD = 1.36$). While there was no significant difference in responses between PICs and SICs, less than half (45.0%) of the pilots agree, some (14.6%) are neutral and also less than half (40.4%) disagree with this statement.

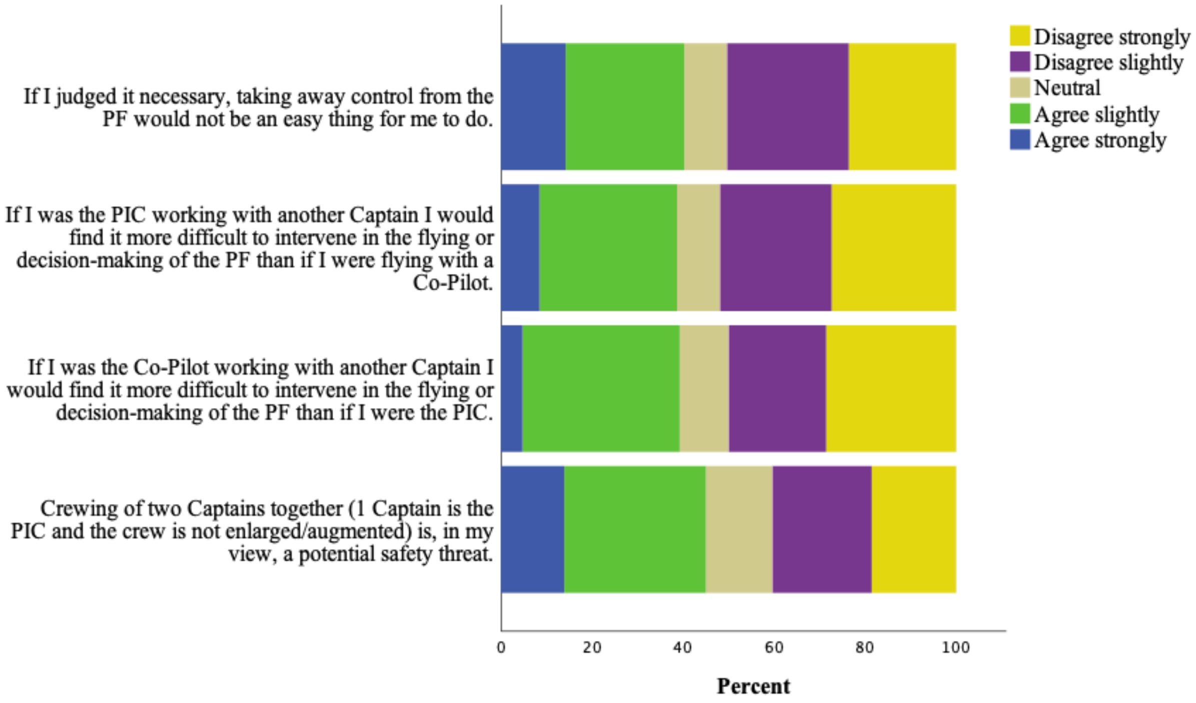
A bivariate correlation analysis revealed, as expected, that agreement with this item was significantly correlated with responses regarding the type of initial pilot education, $r(133) = -.21$, $p = .016$, and type of operator, $r(138) = -.30$, $p < .001$, suggesting that the responses were rather dependent on pilots' professional history. Respondents who did their initial pilot training at airline-owned flight schools and are therefore working for traditional airlines such as legacy carriers or larger low-cost and charter airlines agree more with the statement above than those having done their training not in an airline environment and are working in the business aviation or cargo segment.

This correlation could be explainable because of the fact that especially in legacy carriers with airline owned flight schools the career path of pilots, i.e., promoting to captain (becoming a PIC), is mostly governed by company seniority only. As those airlines are also often regulated by specific collective agreements with pilots' associations, which sometime even categorize Captains and Co-Pilots as two different occupational groups, those pilots habituated to such airline environments are not used to two PIC-rated pilots working safely together and the possibility to imagine that a different team-setup than the one they are used to might also safely work might be restricted. Outside such airlines the opportunities to promote to PIC are often not regulated by seniority and even the crewing of two PIC-rated pilots is often used by business airlines for efficiency reasons as mentioned before.

Table 6-20: Pilots' reluctance to intervene

Average agreement with the following items				
Scale 1 = disagree strongly, 5 = agree strongly	N	M	SD	Agree (%)
1. If I judged it necessary, taking away control from the PF would not be an easy thing for me to do.	288	2.81	1.42	40.2
2. If I was the PIC working with another Captain, I would find it more difficult to intervene in the flying or decision-making of the PF than if I were flying with a Co-Pilot.	106	2.68	1.38	38.7
3. If I was the Co-Pilot working with another Captain, I would find it more difficult to intervene in the flying or decision-making of the PF than if I were the PIC.	84	2.65	1.34	39.3

Figure 6-11: Pilots' perceived reluctance to intervene



6.4.8.1 *Pilots' professional self-concept and their perceived reluctance to intervene*

There was no significant correlation of pilots' perceived reluctance to intervene with their human factor orientation, r (89) = -.11, p = .283.

6.4.8.2 *Summary of key findings regarding pilots' reluctance to intervene*

- There seems to be a general reluctance among pilots to actively intervene
- SIC as PM feel more reluctant to take away control from the PF than PIC do

- There is no homogenous view on the crewing of two PIC-rated pilots among the respondents
- Having two pilots with a PIC rating on the flight deck might help to alleviate negative status hierarchy effects

6.4.9 SIC's reluctance to intervene

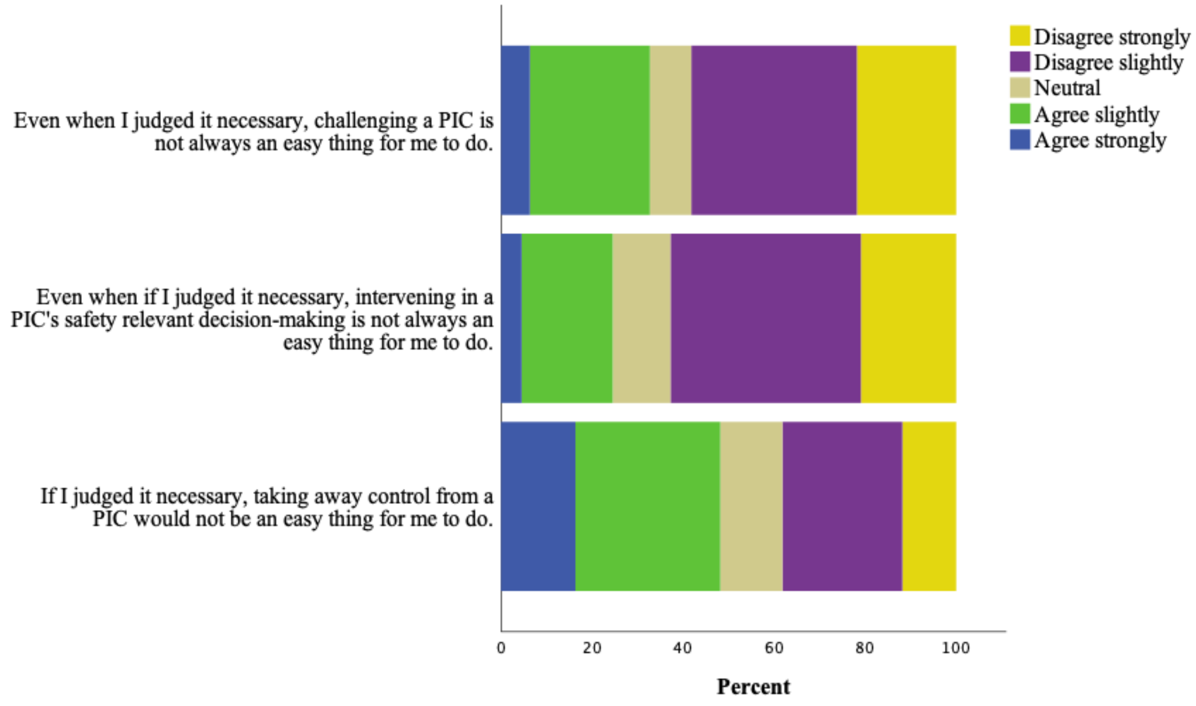
We also asked explicitly the SICs how easy they perceive it to challenge the PIC, to intervene in their safety relevant decision-making and to take-away control from the PIC (items 1-3)[33]. As shown in table 6-21 and figure 6-12 we found that not all SIC feel really free to challenge a PIC. While only a quarter (24.5%) of the pilots report uneasiness to intervene in a PIC's decision-making and a third (32.8%) of them admit uneasiness to challenge a PIC, even half (48.2%) of the pilots admit that taking control from a PIC is an even harder step to do. A paired sample t-test revealed that the difference between the rather soft interventions (item 1 and 2) and hard intervention (item 3) is significant, $p < .001$. There was no association of SIC's reluctance to intervene with the relevant pilot demographics. These results not only indicate that the role of the SIC seems to be underpowered for the role of the PM but also strongly suggest that the regular combination of command and control (PIC as PF) leaving the SIC in the role of the PM seems to be less appropriate to guarantee effective intervention. In contrast, our results indicate that the regular combination of command and monitoring (PIC as PM) would rather be the more effective teamwork setting on commercial flight decks to eventually ensure effective accident prevention.

Table 6-21: SIC's reluctance to intervene

Average agreement with the following items				
Scale 1 = disagree strongly, 5 = agree strongly	N	M	SD	Agree (%)
Scale average (only item 1, 2, 3)	-	2.73	1.07	-
1. Even when I judged it necessary, challenging a PIC is not always an easy thing for me to do.	110	2.59	1.27	32.8
2. Even when I judged it necessary, intervening in a PIC's safety relevant decision-making is not always an easy thing for me to do.	110	2.45	1.16	24.5
3. If I judged it necessary, taking away control from a PIC would not be an easy thing for me to do.	110	3.15	1.31	48.2

[33] These items were presented slightly differently in the 2017 survey: I feel completely free to challenge the PIC at any time I judge it necessary; I feel completely free to intervene in the PIC's safety relevant decision-making at any time I judge it necessary; I feel sufficiently empowered to take away control from the PIC at any time I judge it necessary. Based on feedback and discussion from the pilot survey in 2017 these items were adapted in the global survey. The responses were re-coded for the analysis in the merged sample accordingly.

Figure 6-12: SIC's reluctance to intervene



6.4.9.1 Pilots' professional self-concept and SIC's reluctance to intervene

There was no significant correlation of pilots' human factor orientation and SIC's reluctance to intervene, r (101) = -.001, p = .993.

6.4.9.2 Summary of key findings regarding SICs' reluctance to intervene

- The harder the intervention the more reluctant SICs seem to be to apply it.
- The role of the SIC seems to be underpowered to guarantee an effective PM.

6.4.10 Discussion

By means of survey questions we investigated pilots' attitudes towards their safety relevant decision-making and teamwork in practice and training. We also wanted to test if pilots' professional self-concept which we operationalized by the variable called human factor orientation, an aggregate of pilots' NOTECHS orientation and their self-image as a safety or risk-manager, predict their attitudes towards safety relevant decision-making and teamwork. We asked respondents about their attitudes regarding safe behaviors such as the SOP-discipline and application of conservatism, followed by questions regarding pilots' attitudes towards the roles of the SIC and the PM.

First of all, we have to admit that the results gained from the survey surely have some limitations. Except for the scales regarding pilots' reluctance to intervene and pilots' attitude towards the supervisory functions of the SIC and PM the reliability values of the scales were between Cronbach's alpha of .60 and .70 only and for some analyses we used single items only. Furthermore, not all participants fully completed the questionnaire leading to different base rates for some items, especially regarding the non-pilot respondents of the survey. Finally, our research has the limitation that we only use self-reported attitude data without including personality factors and without a possibility to directly measure related pilot behaviors. However, given the advocacy of previous research in the field of interest (Gregorich et al., 1990; Hunter, 2005) and our considerations regarding the influence of attitudes based on the theory of planned behavior (Ajzen, 2005) which suggested that there is at least some influence of pilots' attitudes on their safety relevant behaviors, we now discuss the results on our attitude questions and possible implications for the commercial aviation industry.

In our survey we found that pilots see themselves slightly more as a safety/risk manager rather than as aircraft operators/system managers, however significantly less than their management and aviation regulators would expect them. Pilots also view NOTECHS-training as less important than technical skills training, especially those pilots who did sport flying prior to their professional pilot education. We also found that the more NOTECHS-oriented the pilots are the more they see themselves as safety/risk-managers.

In regard to their safety versus business orientation we found that most participants reported to be more safety than business oriented and, as hypothesized, we also found that pilots' professional self-concept predicts their safety orientation: the more human factor oriented the pilots the more safety minded they seem to be. Nevertheless, they seem to feel responsible for key business performance indicators such as on-time-performance to the same extent as ATCOs. Although both frontline operators appear to be challenge-seekers (the ATCOs even more than the pilots) both groups view multi-tasking as an appropriate means to deal with complex and dynamic situations. Both groups also do not prefer an in-depth human factor education before their job.

In regard to pilots' attitude towards their SOP discipline we found that efficiency considerations may indeed influence pilots' attitude towards SOP discipline. Pilots seem to be even more efficiency oriented than expected by their management. In regard to our hypothesis that pilots' occupational picture predicts their safety attitude we found that pilots' attitude towards SOP discipline is not associated with their human factor orientation. However, we found that pilots' professional self-concept indeed seems to predict their attitude towards carefulness in daily flight operation (conservatism): the higher the human factor and safety orientation the more risk-averse the pilots' attitude. Nevertheless, pilots seem to be still less conservative than recommended by safety initiatives and seem to have a less risk-averse attitude than regulators would expect.

Based on the results of our field data analysis one of the main focuses of this study was to elicit pilots' attitudes towards teamwork on the flight deck. The results on pilots' attitude towards the role of the SIC revealed that, counter to current industry perspectives, there is a high consensus among pilots, which is even more endorsed by regulators, that the SIC should be trained in leadership and intervention to the same extent as the PIC. Nearly all pilots and regulators even support that SIC should be allowed and trained to taxi the aircraft on the ground. However, we found that there is less agreement by PIC than by SIC that PIC should have to seek agreement with the SIC before making safety relevant decisions and there is also less agreement by PIC than by SIC that SIC should have the right to take command. Although we found that PICs do not perceive a high status of the SIC as a threat for their authority, they report that economic considerations may hamper the realization of integrated teamwork.

In regard to our main hypothesis, if pilots' professional self-concept predicts their attitude towards their roles on the flight deck, we indeed found that the more human factor and safety oriented the professional self-concept of the pilots’ the higher the pilots value the role of the SIC. This might even qualify the pilots’ professional self-concept as an additional factor underlying the role effect, while other factors such as culture seems to have no association with pilots’ attitude towards the SIC. On top of that, the finding that especially more risk oriented (less conservative) PIC and SIC both value the role of the SIC less supports our theory of the possibility of an operational syndrome in aviation described by risky decision-making and ineffective intervention.

One of the most striking results from this study was that pilots do neither see the role of the SIC nor the role of the PM as having a supervisory function but see them more as assistant functions only. We found not only that these roles are viewed hierarchically lower than the role of the PIC and PF as well as that the role of the PF being viewed rather autonomous from the PM but also that there seems to be a general reluctance among pilots to actively intervene as taking-over control by the PM is even not accepted as precautionary measure. Especially SIC as PM feel significantly more reluctant to take away control from the PF than PIC supporting additional findings that the harder the intervention step the more reluctant SICs are to apply it. The data even suggest that pilots expect junior pilots to be able for effective intervention only after 2-3 years of flying experience.

Analogous to our findings in the field data analysis (study 1) and in the study on pilots’ experience in practice (study 3), all of the above shows that the status hierarchy between PIC and SIC has still the potential to act as a barrier for effective intervention in the PM-role and that the current position of the SIC does obviously not warrant effective intervention on commercial aviation flight decks. This further adds to the notion that current pilot training and methods (e.g., CRM-trainings) are rather ineffective in counteracting negative effects resulting from the status hierarchy such as the role assignment effect. While there is no homogenous view on the crewing of two PIC-rated pilots among the respondents, our data suggests that having two pilots with a PIC rating on the flight deck might help to alleviate negative status hierarchy effects which additionally suggests that there is currently a lack of status and power for effective intervention associated with the current role of the SIC.

Finally, our study on pilots' attitudes towards their roles clearly exhibits structural problems in regard to the teamwork and role setting on commercial aviation flight decks which may act as barriers to effective accident prevention. There seems to be neither a homogenous view among pilots on the intervention capability of the role of the SIC nor obviously do current roles ensure that economic pressures prevent all operating pilots from taking unnecessary risks in normal operation. Especially the fact that pilots' attitudes regarding the role of the SIC do not seem to reflect a high intervention capability of this role means that this role is obviously underpowered to guarantee that SICs can always be effective PMs.

However, the results of our study also offer the chance to define ways for improvement and to mitigate the risks stemming from unhealthy safety attitudes in aviation. The research by Gregorich et al., (1990) and Helmreich et al., (1990) has already revealed that CRM training can have a positive influence on pilots' cockpit management attitudes. This is further supported by our findings that a higher NOTECHS orientation may lead to more safety and teamwork mindedness which suggests that a higher focus on human factors in pilots' training, e.g., by CRM training becoming more focused on conservatism and intervention or even by the requirements for pilots to graduate in a human factor or safety discipline before starting to fly, may probably lead to improved safety attitudes. Moreover, as shown below, there is a positive trend in the aviation industry regarding the focus on pilots' attitudes sparked by recent changes in the aviation industry regarding basic pilot education to especially target pilots' attitudes thereby enhancing pilots' ability for critical thinking and better preparing students for the job of a pilot.

After the deliberate crashing of Germanwings flight 9525 in 2015 by the SIC of this flight the regulations for pilots' basic education were amended to not only include mandatory psychological assessments for student and professional pilots but also to set up a new approach to pilot training based on the three pillars of knowledge, skills and attitudes (KSA) which are in turn based on the competencies by ICAO as outlined before (see 2.2.). According to the EASA Flight Examination Manual (European Union Aviation Safety Agency (EASA), 2021) the aviation industry, at least in

Europe, relies on the following definition of attitude[34]: "Attitude is a persistent internal mental state or disposition that influences an individual's choice of personal action toward some object, person or event and that can be learned. Attitudes have affective components, cognitive aspects and behavioural consequences. To demonstrate the "right" attitude, and a learner needs to "know how to be" in a given context."

The attitudes which pilots should demonstrate are then described in more detail and related to the following five sections: flight preparation, take-off, flight maneuvers and procedures, missed approach procedures and landings. The relevant attitudes in terms of pilots roles, decision-making and teamwork in multi-pilot operations are listed therein as follows: "be safety-minded rather than mission-minded; take effective decisions; be assertive when in doubt; be aware of their limited experience and abilities; be assertive, seek clarification of doubts and misunderstandings before acting; use timely, informed decision making and effective implementation; be mindful of the environment and its impact; be assertive in radiotelephony communication; appreciate performance limitation and adopt a conservative planning approach; use realistic and effective decision making, use anticipation and workload management" (European Union Aviation Safety Agency (EASA), 2021). Although describing the required safety attitudes rather superficially, this listing clearly highlights that the aviation industry has already become aware of the issues regarding pilots' attitudes and their relevance for effective accident prevention, especially in regard to safety mindedness, assertiveness and conservatism.

However, from a psychological perspective it is important to remind the aviation industry of the possibility for an attitude-behavior inconsistency, which may inhibit such initiatives from becoming really effective. Brauer (2024) points out that there is not only evidence of limited influence of attitudes on behaviors but changing intergroup attitudes seems to be hard to accomplish in real world settings. Based on results from discrimination research he shows that, in line with theory of planned behavior (TPB) (see chapter 5), there are other factors having more impact in leading to

[34] In this context skills are defined as follows: "Skill is the ability to perform an activity or action. It may be divided into three skill types: motor, cognitive and metacognitive skills." and knowledge is defined as: "Knowledge is specific information required to enable a learner to develop and apply the skills and attitudes to recall facts, identify concepts, apply rules or principles, solve problems, and think creatively in the context of work."

behavioral change such as social norms, habits or self-efficacy. In line with other research, e.g., on vaccination promotion or climate change, he therefore proposes that behavior change more requires structural systemic changes rather than individual attitude changes, especially as people often appear resistant to attitude change, e.g., to prevent cognitive dissonance. Similar to the finding of Kohn et al. (2000) in the medical domain who highlighted the need to “make it easy for people to do the right thing and hard for them to do the wrong thing”, he further proposes that it is necessary to eliminate barriers and to highlight benefits of certain behavior to help people in behaving the correct way or attending training to achieve the latter, however having in mind a possible boomerang effect (i.e. the occurrence of the desired behavior decreases rather than increases) if people do not freely choose to do so but feel forced instead.

This advice is especially important in regard to the effectiveness of the outreach of the latest regulatory changes regarding pilots’ attitudes. First of all, there are few opportunities only to reach all pilots to the same extent. Although new entry pilots might be trained already under the new scheme, more experienced pilots will get in touch with the new focus on attitudes and behaviors only during their annual recurrent training and checking events and then even only if their airline focuses on this topic. Second, and this may be the highest barrier for change within the industry, is that the “how to be” in a given context, as described in EASA’s definition of attitude, will largely be influenced by pilots’ airline specific role descriptions and airline’s safety and company culture. If the specific airlines’ safety policies and role descriptions for the pilots and specifically those for the roles of the PIC, SIC, PF and PM do not clearly and explicitly reflect the requirement to be safety-minded rather than mission-minded, to use a conservative approach rather an approach which accepts operation with reduced or no safety margins and to be assertive within the flight crew as well as towards ATC, then it might be very unlikely that these positive changes will have a global and sustainable effect, especially if the airline’s management and training personnel do not show role model behavior in this regard.

Additionally, there is the fact that ICAO as the overarching body in aviation which is able to spark and provide regulatory and systemic changes on the norms and guidelines used in aviation on a global basis, does only provide guidance for the authority and duties of the PIC, but still not any for the SIC (International Civil Aviation Organization (ICAO), 2022a). Furthermore, ICAO standards and recommended practices do neither promote nor demand *operational conservatism* meaning that practitioners such as pilots and ATCO have, especially in normal operation, always the right to increase their safety margins or have a stop working authority, even in the face of economic trade-offs, if deemed necessary. Reference to the safety responsibility and authority of the PIC is given explicitly only for emergency situations (non-normal operation) or the opaque acronym of 'safety reasons' which leaves a wide room for interpretation as this term is not clearly specified. Moreover, there is no standard or recommended practice by ICAO which clearly defines a right of veto for the SIC and there is also no requirement that the pilot filling the role of the SIC should also have a PIC-rating so that both pilots on the flight deck are equally trained and qualified in leadership and safety relevant decision-making. To lower the barriers and highlight the benefits for conservative and assertive behaviors by practitioners such as pilots and ATCOs, ICAO could consider the necessary structural changes as presented above.

As long as these fundamental changes are not made it is most probably left up to pilots' individual attitude as well as up to their occupational picture, as shown by our analysis, if pilots are rather safety minded and able and open to give or accept effective intervention. Even recent safety initiatives such as the implementation of *leader inquiry* (Hagen, 2018, p. 248), derived from the humble inquiry methodology (Schein, 2013), which requires the PIC to first ask the SIC for their perspective before making safety decisions thereby fostering better teamwork with the SIC, will not be able to cure the underlying systemic safety issues of unnecessary risk-taking and ineffective intervention if pilots did not change their underlying attitudes regarding their roles on the flight deck.

Furthermore, another argument for an increased focus on pilots' attitudes is that the industry has also defined *observable behaviors* allocated to the relevant pilot competencies of *Leadership and Teamwork* and *Problem Solving and Decision-Making.* In regard to pilots' risk-management and effective intervention the full list for leadership and teamwork contains the following observable behaviors: "Encourages team participation and open communication; Engages others in planning; Considers inputs from others; Gives and receives feedback constructively; Addresses and resolves conflicts and disagreements in a constructive manner; Exercises decisive leadership when required; Accepts responsibility for decisions and actions; Carries out instructions when directed, Applies effective intervention strategies to resolve identified deviations, Manages cultural and language challenges, as applicable”. For the competency of problem solving and decision-making the list contains: “Identifies, assesses and manages threats and errors in a timely manner; Seeks accurate and adequate information from appropriate sources; Identifies and verifies what and why things have gone wrong, if appropriate; Perseveres in working through problems whilst prioritizing safety; Identifies and considers appropriate options; Applies appropriate and timely decision-making techniques; Monitors, reviews and adapts decisions as required; Adapts when faced with situations where no guidance or procedure exists; Demonstrates resilience when encountering an unexpected event.” (European Union Aviation Safety Agency (EASA), 2021; International Civil Aviation Organization (ICAO), 2020b).

Again, those behaviors are only described rather superficially than detailed, lacking specific examples and are neither clearly specified regarding the roles of the PIC/SIC or PF/PM nor do they clearly promote operational conservatism or early intervention. To improve those behaviors, it could therefore be worthwhile for the industry to consider using our research items regarding pilots' attitudes to transform them into observable behaviors, e.g. “Does not trade-off SOP adherence for economic efficiency (e.g., time or money)” or “Before taking any safety relevant decision in normal operation the PIC first agrees with the Co-Pilot.” (reflecting leader inquiry) or “Accepts the other pilot's intervention whenever this leads to more conservative/risk-averse flying or decision-making in normal operation”. Thereby relevant observable behaviors could not only be used for more detailed flight examination and pilot training but also by safety research, e.g., when performing safety surveys testing pilots' attitudes on a regular and recurrent interval. Such a measure could be accompanied by safety campaigns highlighting good and bad safety attitudes.

Similar work has already been done before in the industry some decades ago. Berlin et al., (1982) developed a training course for improving pilot judgment and decision-making introducing five hazardous attitudes (Anti-Authority, Impulsivity, Invulnerability, Machoism, Resignation) and their relevant antidotes. Those are still part of today's CRM knowledge and training repository. Based on Berlin's work a further development of a tool measuring pilots' safety attitudes was provided by Hunter (2005) which in combination with Gregorich et al's work (1990) and our research would provide sufficient ground for the industry to develop action plans aiming to align safety attitudes not only among pilots but also across all other relevant stakeholders in aviation such as ATCOs, regulators and pilots' management.

6.4.11 Conclusion

The results of our study on pilots' attitudes suggest that pilots' self-concept, operationalized by their human factor orientation, has indeed influence on their attitudes regarding safety relevant behavior and teamwork. Furthermore, our results suggest that those attitudes might be an underlying factor for unnecessary risk taking and ineffective intervention by pilots in practice, thus being a possible reason for an *operational syndrome* having safety relevant impact on the safety performance of commercial aviation.

On top of the current focus on trying to positively influence pilots' safety attitudes using CRM-training and other interventions (e.g., continuous safety promotion and education), the aviation industry could consider the need for a more systemic approach to enhance its safety performance including normative changes regarding the roles on the flight deck to foster safety minded and assertive behavior of pilots.

6.5 Study 5: Pilots' choices in the Intervention Scenarios

6.5.1 Introduction

Among other factors, previous research associated the role assignment effects with the status difference between PIC and SIC using the argument that it can act as a barrier for the SIC to effectively intervene in the safety relevant decision-making of the PIC (Beveridge et al., 2018). On top of these status hierarchy effects, research by Bienefeld & Grote (2012) found that also a desire for harmony within the flight deck team might lead to missing or ineffective speaking-up behavior (safety voice), especially by the SIC. By using intervention scenarios within our surveys stemming from real-world situations in daily flight operation we not only wanted to test which factors act as barriers for intervention but also estimate if there might be any attitude-behavior consistency within pilots in regard to intervention on the flight deck.

6.5.2 Method and description of scenarios

We alternatively presented the participants of the surveys two intervention scenarios. One scenario dealt with an inflight situation in which a flight crew must circumnavigate a thunderstorm and the other dealt with a situation on ground before the flight when the flight crew decides on the amount of fuel which must be taken for departure. The thunderstorm scenario was responded to by N = 150 participants and the fuel scenario was responded to by N = 149 participants. Although the scenarios described different situations they were constructed in the same way. After the explanatory introduction to the situation the respondents were asked to tell how the SIC in this scenario should behave depending on the PIC's reaction either by accepting the PIC's decision or by (further) intervening. Depending on this selection the scenario ended if the decision was accepted or it continued with a further question. In total the intervention cascade included 4 intervention steps from verbally speaking up towards raising concerns up to threatening the PIC to take-control or denying flying and further up to actively taking control or denying flying with the PIC. The respondents were presented with the following information:

Scenario A:

Thunderstorm-Avoidance-Scenario: Dear Pilot, please consider the following scenario, then choose the statement which best matches your personal view. During the flight (any flight phase) the aircraft has to circumnavigate a thunderstorm. Both pilots want to avoid the thunderstorm, however in this scenario the individual assessment of the required avoidance heading, which should be turned to avoid the thunderstorm, differs among the pilots. There is no other traffic or any conflicting terrain.

1. What should a Co-Pilot in your airline do, in your view, if the PIC wants to pass the thunderstorm significantly closer than the Co-Pilot judges appropriate?
   - The Co-Pilot should accept the decision straight away and should not challenge the PIC at all
   - The Co-Pilot should speak-up and challenge the PIC

If the respondent had chosen to speak-up, then the following question and subsequent choices were presented:

2. What should the Co-Pilot do, in your view, if the PIC rejects the objections, but the Co-Pilot is still concerned that it would be better to avoid the thunderstorm with a greater distance?
   - The Co-Pilot should accept the PIC's decision and make no further objections
   - The Co-Pilot should keep on expressing the concerns and keep on requesting a greater distance
   - The Co-Pilot should threaten the PIC with taking away control, if the PIC does not change mind
   - The Co-Pilot should take away control from the PIC.

If the respondent had chosen to speak-up or threaten to take control, then the following question and subsequent choices were presented:

3. What should the Co-Pilot do if the PIC does not change their mind despite the Co-Pilot's concerns?
   - The Co-Pilot should accept the PIC's decision and make no further objections
   - The Co-Pilot should threaten the PIC with taking away control, if the PIC does not change mind
   - The Co-Pilot should take away control from the PIC.

If the respondent had chosen to threaten to take control, then the following question and subsequent choices were presented:

4. What should the Co-Pilot do if the PIC still does not change their mind despite the Co-Pilot's continuing concerns?
   - The Co-Pilot should accept the PIC's decision and make no further objections
   - The Co-Pilot should take away control from the PIC.

In all intervention steps when respondents had chosen that the Co-Pilot should accept the decision of the PIC, we additionally asked for the reasons why they think so. The following choices were given:

- Acceptable Risk – the PIC's decision is safe
- Accountability – the Co-Pilot's responsibility is limited, the PIC is accountable
- Atmosphere – a (further) discussion may have negative influence on the work atmosphere
- Nit-picking – the Co-Pilot should not be pedantic
- Trust – the Co-pilot should trust in the competency and experience of the PIC
- Other (optional)

<u>Scenario B:</u>

Extra-Fuel-Scenario: Dear Pilot, please consider the following scenario, then choose the statement which best matches your personal view. Before a flight the cockpit crew has to decide on the amount of fuel they want to take (block-fuel decision). However, in this scenario the individual assessment of the required additional fuel (extra-fuel), which should be added on top of the legally minimum required fuel, differs among the pilots. The flight is not weight limited.

1. What should a Co-Pilot in your airline do, in your view, if a PIC intends to add significantly less extra-fuel than the Co-Pilot judges appropriate for the flight?
   - The Co-Pilot should accept the decision straight away and should not challenge the PIC at all
   - The Co-Pilot should speak-up and challenge the PIC

If the respondent had chosen to speak-up, then the following question and subsequent choices were presented:

2. What should the Co-Pilot do, in your view, if the PIC rejects the objections, but the Co-Pilot is still concerned that it would be better to take more extra-fuel than the PIC wants to take?
    - The Co-Pilot should accept the PIC's decision and make no further objections
    - The Co-Pilot should keep on expressing the concerns and keep on requesting more extra-fuel
    - The Co-Pilot should threaten the PIC with denying to fly with him or her, if the PIC does not change mind
    - The Co-Pilot should deny flying with this PIC on this specific flight.

If the respondent had chosen to speak-up or threaten to deny flying with the PIC, then the following question and subsequent choices were presented:

3. What should the Co-Pilot do if the PIC does not change their mind despite the Co-Pilot’s concerns?
    - The Co-Pilot should accept the PIC's decision and make no further objections
    - The Co-Pilot should threaten the PIC with denying to fly with him or her, if the PIC does not change mind
    - The Co-Pilot should deny flying with this PIC on this specific flight.

If the respondent had chosen to threaten to deny flying with the PIC, then the following question and subsequent choices were presented:

4. What should the Co-Pilot do if the PIC still does not change their mind despite the Co-Pilot’s continuing concerns?
    - The Co-Pilot should accept the PIC's decision and make no further objections
    - The Co-Pilot should deny flying with this PIC

In all intervention steps, when respondents had chosen that the Co-Pilot should accept the decision of the PIC, we additionally asked for the same reasons (why they think so) which we used in the thunderstorm avoidance scenario. Additionally, after both scenarios we asked the respondents to answer the following question by using a slider and estimating the relevant percentage:

Scenario A: What percentage of the Co-Pilots in your company, do you think, would take the ultimate step to take away control from the PIC in such a situation?

Scenario B: What percentage of the Co-Pilots in your company, do you think, would take the ultimate step of denying flying with the PIC in such a situation?

6.5.3 Results

Tables 6-22 through 6-26 show the results for each intervention step including the reasons in longhand if entered under “other”. In both scenarios nearly all pilots, with no significant difference between PIC and SIC, selected that the SIC should speak up. Further speaking-up in the following (second) intervention step of the intervention cascade was again selected by most of the respondents in both scenarios (A: 94.0% / B: 78.2%), again with no significant difference in responses between PIC and SIC. While in the inflight thunderstorm avoidance scenario most (62.6%) of the pilots selected that the SIC should, in the next (third) intervention step, now intervene even harder by threatening the PIC to take-over control, in the ground-based extra-fuel scenario most (44.3%) of the pilots selected in the third intervention step that the SIC should accept the decision of the PIC now. However, more than a third (38.3%) of the pilots, with no significant difference between the PIC and SIC, decided that the SIC should further escalate their intervention and nearly a fifth (17.4%) favored that the SIC should deny flying with the PIC. In the last (fourth) intervention step most (A: 88.4% / B: 90.4%) of the remaining respondents, again with no significant difference between PIC and SIC, equally favored in both scenarios the ultimate step that the SIC should then take-away control or deny flying with the PIC.

Interestingly, the answers on the questions after each scenario “What percentage of the Co-Pilots in your company, do you think, would take the ultimate step of taking away control from the PIC in such a situation (Scenario A) and denying flying with the PIC in such a situation (Scenario B) were answered significantly differently by PICs and SICs. While in the inflight scenario SICs estimated that around a third of the SICs in their airline (M = 32%, SD = 28.13) would take the ultimate step, PICs judged this proportion (M = 19%, SD = 22.26) significantly lower, t (133) = -3.21, $p < 0.001$ (Bonferroni corrected alpha level .025). In the ground-based scenario, the answers were similar. The SICs (*M* = 25%, *SD* = 21.72) estimated the proportion significantly higher than the PICs (*M* = 17.03, *SD* = 24.13), *t* (146) = -1.99, *p* = 0.024 (Bonferroni corrected alpha level .025). This difference in perception between the PIC and SIC suggests a possible discrepancy of self- and public view of SICs regarding their intervention capability. Furthermore, the relatively low proportions being reported by all respondents suggest that the actual application of hard interventions do, in practice, not go without saying. It rather seems as if there are high barriers in place inhibiting the use of hard interventions.

Possible explanations for the existence of barriers for intervention are revealed by the analysis of the reasons stated by the respondents in case an acceptance rather than a (further) intervention option was selected. Table 6-26 shows that the ranking of reasons is nearly equal for both scenarios. We found that the respondents selecting the choice that the SIC should (finally) accept the decision of the PIC instead of (further) intervening did so most often because they rated the associated risk as acceptable, followed by the argument that the SIC should trust in the decision-making of the PIC. Further mentioned reasons were that the SIC is, in contrast to the PIC, not accountable, followed by the reason that (further) intervention would have negative consequences for the work atmosphere and the SIC should not be pedantic. The amount and quality of reasons provided under "other" especially from the 2. intervention step onwards (see tables 6-23, 6-24, 6-25) further highlight that going beyond a rather *soft* intervention such as verbally speaking up towards using a rather *hard* intervention such as threatening or to actively take-control/deny flying is not an easy thing to do in reality.

Furthermore, the difference in selections between the inflight and the ground-based scenario after the second intervention step and the quality of reasons mentioned under "other" for the extra-fuel scenario suggest that there is a tendency among pilots to accept a decision despite concerns if there is no imminent threat but, subjectively seen, still options for further intervention available.

Table 6-22: Number (n) and percentages (%) of pilots' choices for 1. intervention step

1. Intervention step	Scenario A		Scenario B	
	n	%	n	%
1a. Accept - do not intervene at all	1	.7	2	1.3
1b. Speak up	149	99.3	147	98.7
Total	150	100.0	149	100.0
Reasons for acceptance in the first step were given as:				
a. Acceptable risk	1		1	
b. Accountability	1		1	
c. Trust	0		1	

Table 6-23: Number (n) and percentages (%) of pilots' choices for 2. intervention step

2. Intervention step	Scenario A		Scenario B	
	n	%	n	%
2a. Accept - do not further intervene	6	4.0	20	13.6
2b. Speak up - expressing concerns	140	94.0	115	78.2
2c. Threaten to take away control / deny flying	1	.7	8	5.4
2d. Take away control / deny flying	2	1.3	4	2.7
Total	149	100.0	147	100.0
Reasons for acceptance in the second step were given as:				
a. Acceptable risk	4		15	
b. Accountability	1		10	
c. Atmosphere	2		5	
d. Nit-picking	2		5	
e. Trust	3		5	
f. Other	3		3	
Scenario A: Further arguing itself cause an unsafe situation, If the PIC avoidance strategy meets SOPs this should be stated reviewed, if PIC does not follow SOPs then continued challenge or control take over, You can always repeat your opinion later if things get more hairy.				
Scenario B: Based on rational discussion, This is a horrible example. Adding fuel above what the computer and dispatcher have calculated is rarely required. The PIC should clearly explain why the fuel is sufficient and what the options are that have been considered.				

Table 6-24: Number (n) and percentages (%) of pilots' choices for 3. intervention step

3. Intervention step	Scenario A		Scenario B	
	n	%	n	%
3a. Accept - do not further intervene	38	27.3	51	44.3
3b. Threaten to take away control / deny flying	87	62.6	44	38.3
3c. Take away control / deny flying	14	10.1	20	17.4
Total	139	100.0	115	100.0
Reasons for acceptance in the third step were given as:				
a. Acceptable risk	28		34	
b. Accountability	11		20	
c. Atmosphere	8		18	
d. Nit-picking	6		11	
e. Trust	21		19	
f. Other	4		17	

Scenario A: Forcibly taking away control from your colleague might be one of the worst things to do in terms of cockpit atmosphere; I would insist on fastening the passengers and cabin crew; The PM should air their opinion and the PF should explain the reasoning behind the requested heading. The crew should arrive at a mutual decision. It isn't black and white complaining and ignoring, it is debate, the PF may have a perfectly justifiable reason for the heading requested.

Scenario B: PIC's rationale should be a reasonable explanation; As long as it is still safe, I would accept the decision, but I would monitor the fuel more closely and keep track of possible alternates more closely than usual; decision inflight are more important; Depends on situation, weather, etc.; Explanation – if the reason for both positions is thoroughly explained; Flight is still legal, however the risk of diversion is increased. Hence diversion must be anticipated; fuelstop always possible; If during the flight the circumstances develop as the FO was thinking of, he has to trigger the captain to come up with a safe alternate. If he, before commencing the flight, thinks this will not be possible he/she will have to refuse to commence the flight with the captain. However difficult this will be I also do think the chance for refusing to take some extra fuel by the captain is very remote if the FO has got able training on non-technical issues; If enroute, Fuel becomes less, then required, a diversion has then to follow. The Co-Pilot then has to insist further; Inflight fuel checks and diversions are still an option; Inflight management of the risk; It does rather depend on the reason – if it were forecast to be thunderstorms in Texas, then I would strongly object. If it were a prob

30 wind out of limits, I would be less forceful. Also, I might be wrong, so we need to get a team approach, not one person who shouts loudest always being heard; OM-A states "the final fuel decision rest with the commander"; Relative low risk at this stage – can always divert/fuel stop; The decision is kind of a "bet" for a situation at the end of the concerning leg. (wx, ATC, other). – For legal requirements it should be enough fuel – but the consequences differ: if there is minimum fuel AND bad wx - an early diversion may become necessary. And therefore I would focus on a clear understanding between the two pilots, that this would be a possible outcome (… to divert); Worst case would be an early inflight diversion well ahead of the destination should the fuel/situation still be unfavorable.

Table 6-25: Number (n) and percentages (%) of pilots' choices for 4. intervention step

4. Intervention step	Scenario A		Scenario B	
	n	%	n	%
4a. Accept - do not further intervene	10	11.6	5	9.6
4b. Take away control / deny flying	76	88.4	47	90.4
Total	86	100.0	52	100.0
Reasons for acceptance in the fourth step were given as:				
a. Acceptable risk	8		1	
b. Accountability	1		2	
c. Atmosphere	4		1	
d. Nit-picking	2		0	
e. Trust	3		3	
f. Other	1		2	

Scenario A: If the aircraft is not being placed in jeopardy and it's a professional call, with no inherent danger, then accept the call.

Scenario B: In case of, an enroute fuel stop should be enforced!

Table 6-26: Number (n) and rank of reasons for acceptance

	Scenario A		Scenario B		Total	
	n	Rank	n	Rank	n	Rank
A. Acceptable risk	41	1	51	1	92	1
B. Accountability	14	3	33	2	47	3
C. Atmosphere	14	3	24	4	38	4
D. Nit-picking	10	4	16	6	26	6
E. Trust	27	2	28	3	55	2
F. Other	8	5	22	5	30	5

6.5.3.1 Pilots' professional self-concept, their attitudes and responses to the intervention scenarios

In order to estimate if there may possibly be an attitude-behavior consistency among pilots as well as an influence of their professional self-concept we assessed the correlation with the relevant survey items and the responses given to the intervention scenarios. We found that pilots' human factor orientation correlated with the third intervention step in the inflight scenario, r (115) = .20, p = .034, and with the first intervention step in the ground scenario, r (123) = .25, p = .007. A multiple linear regression with the scales eliciting pilots' attitudes towards the role of the SIC, towards the supervisory function of the SIC, towards their safety versus business orientation as well as towards conservatism, found no significant contribution of any of these scenario related scales on the responses to the ground-based scenario. However, in the inflight scenario we found that the attitude towards the role of the SIC significantly correlated with the responses given. Within all three verbal intervention steps pilots with a higher view of the status of the SIC also significantly more proposed a (further) intervention step, p = .014 in the first step, $p < .001$ in the second step and p = .014 in the third step. Within the first step the attitude towards safety versus business considerations also significantly contributed to the model, p = .027.

Regarding the attitude of pilots towards the role of the SIC we had used two additional individual items explicitly eliciting only the PIC's attitude towards the role of the SIC. One questioned the authority gradient on the flight deck ("In my view, the influence of the Co-Pilots is becoming too strong. This is upsetting the appropriate authority gradient on the flight deck") and one dealt with economically influenced decision-making ("I find it sometimes difficult to balance economically efficient decision–making with the need for cooperation with more conservative minded Co-Pilots"). While we found, against our expectation, no significant correlation of the latter with the selection on the intervention scenarios, we found that in the third intervention step, marking the change from soft to hard intervention, those PIC not favoring further intervention also viewed the influence of Co-Pilots as too strong, $r\ (33) = -.42$, $p = .014$. At the same time in this critical intervention step, we also found that those SICs having previously reported that taking away control from a PIC would not be an easy thing for them to do, also favored to stop intervention at that point, $r\ (41) = -.31$, $p = .043$.

These findings suggest not only that there might be indeed a consistency between safety attitudes and safety behaviors but also that a crew combination of an SIC feeling not sufficiently empowered to take hard intervention steps together with a PIC being rather opposed to the idea that SICs are allowed to take hard intervention steps does not guarantee effective protection for resolving possible decision-making errors by the PIC, thus this combination will most probably not effectively prevent incidents and accidents.

6.5.4 Discussion

We presented the participants of the survey with two alternating intervention scenarios, one inflight scenario (thunderstorm-avoidance) and the other was ground-based (extra-fuel decision). We found that throughout both scenarios nearly all respondents supported that SICs should challenge the PIC by using verbal (soft) interventions. However, further hard interventions were supported less frequently, especially in the ground-based scenario. The overall low rating and significant difference between a relatively higher self-rating of SIC and relatively lower external assessment by PICs in regard to the capability to use hard intervention in practice further highlight that hard interventions are less supported by pilots. Furthermore, the reasons given for not providing or ceasing intervention were given especially in regard to risk appetite, trust, missing accountability of the SIC and a desire for harmony on the flight deck. Our results also support the notion that pilots' attitudes towards the role of the SIC might be consistent with their intervention behavior in practice, both regarding raising safety voice by the SICs and also regarding safety listening (accepting concerns) by the PICs.

While both are realistic scenarios from daily practice in commercial airline operation, we observed a difference in intervention preference after the second intervention step between the two scenarios. This can be explained on the one hand by the fact that the airborne scenario requires imminent decision-making leaving less room and time for the SIC to postpone or re-engage in intervention while the ground-based scenario leaves additional options for the SIC to further intervene along the flight. On the other hand, there might be different experiences by pilots regarding the fuel decision depending on their airline policies or culture which might prevent pilots from engaging in a discussion on extra-fuel if the company restricts taking extra-fuel per se (see comment in table 6-23). Nevertheless, the results from the inflight scenario further support our previous findings from the field data analysis as well as from the experience survey that, especially for the SIC, there seems to be high implicit barriers for hard interventions on commercial aviation flight decks – despite CRM-training.

That such hard interventions are sometimes necessary and may not be postponed, especially by the SIC, is highlighted by a prominent example[35] from the year 2000 in which an Airbus A310 bound from a Greek island to Germany ran out of fuel during an emergency landing in Vienna after the flight crew had mismanaged a gear failure. Despite early concerns verbally raised by the SIC in the initial cruise phase the PIC decided to continue the flight in the face of an increased fuel flow due to the not fully retracted gear. While the flight was running out of fuel along the cruise the SIC again verbally raised concerns but did not take-over control to prematurely land the aircraft. Instead, the flight continued with the intention to reach German airspace but had to turn towards Vienna due to low fuel on board where both engines stopped operation shortly prior to touchdown due to fuel starvation.

[35] https://skybrary.aero/accidents-and-incidents/a310-vienna-austria-2000

6.5.5 Conclusion

The results from the intervention scenarios presented here highlight not only that pilots favor soft over hard interventions but also that PICs more than SICs oppose hard interventions by the SIC such as taking away control. Our results also support the notion that pilots' safety attitudes in regard to the role of the SIC and towards intervention and safety relevant decision-making are consistent with the proposed intervention behavior of the SIC. Common barriers in the aviation system preventing effective intervention by the SIC are differences in risk perception, a requirement to trust the PIC, a missing accountability for the role of the SIC and a desire for harmony on the flight deck. These findings suggest that the current measures such as CRM-trainings taken to counteract any status hierarchy effects and to support active intervention on the flight deck by the SIC are insufficient to foster also hard interventions which are required to prevent serious safety relevant events.

6.6 Study 6: Pilots' choices in the Decision-Making Scenarios

6.6.1 Introduction

Pilots' decision-making is one of the most critical factors for the prevention of accidents and incidents in commercial aviation (Bearman et al., 2009; Cook & Woods, 1994; K. Mosier et al., 2011; K. L. Mosier & Fischer, 2010; Orasanu, Fischer, & Davison, 2002). For decades this competency is therefore not only part of pilots' initial and recurrent human factor (CRM) training but will also be annually assessed in pilots' simulator and line checks using the CBTA framework as mentioned above (see 2.1). Given the complicated and sometimes complex nature of the aviation environment one of the key abilities which pilots need is the ability to make safe decisions under risk and uncertainty to maintain the necessary margins of safety. Therefore pilots, like other practitioners in high-risk-environments, should be aware of and trained in identifying and mitigating possible systematic errors negatively influencing their decision-making.

These systematic errors got increased attention within the research field of judgement and decision-making (JDM) by the heuristics and biases research approach starting in the 1970s. It was based on the idea that people not only follow normative considerations when making decisions but that their choices are often based on imperfect and simplified methods (heuristics) and influenced by inclination towards one judgement rather than another (biases) which are also often described as judgement fallacies or cognitive illusions (Keren & Teigen, 2004). According to Kahneman (2011) they origin from the individual purpose and limits of the two systems our brain uses to make decisions. While there is an automatic system (system 1) defined by Kahneman as operating "automatically and quickly, with little or no effort and no sense of voluntary control", the other more mentally effortful one (system 2) "allocates attention to the effortful mental activities that demand it, including complex computations" requiring attention, focus and concentration. This task distribution usually helps to minimize effort and optimize performance when dealing with routine problem solving and decision-making, but especially the automatic functioning of system 1 makes it prone to systematic errors in judgement – the biases, fallacies or cognitive illusions – leading to wrong assessments and decisions. According to Kahneman system 2 is not designed for taking over the functions of system 1 so that one of the best strategies for mitigation of biases is to learn recognizing "situations in which mistakes are likely and try harder to avoid significant mistakes when the stakes are high". There are many biases known which can influence human behavior[36]. The most common biases identified in aviation accident reports are confirmation bias, plan-continuation-bias, the primacy or recency effect bias, anchoring, expectation and belief bias, or automation bias (R Key Dismukes, 2010; Moriarty, 2015; K. L. Mosier & Fischer, 2010).

One specific bias we were interested in due to its influence on risk preference is the framing effect described initially by Tversky & Kahneman (1981). By simple experiments they found that people's choices depend on how the expected outcome is framed meaning that wording can influence human decision-making. In a nutshell, their prospect theory predicts that altering the way a possible outcome is worded, however without changing the actual value of the outcome, shifts the preference of choice by people. Their prospect theory predicts that humans tend to avoid taking risks, meaning they prefer to choose the more certain option (risk aversion), if choices are framed positively featuring a gaining situation. However, people tend to seek risks, meaning they prefer to choose the more uncertain option, if choices were framed negatively featuring a loss situation (loss aversion).

For their experiments Tversky and Kahneman basically used the "Asian disease" scenario in which they asked two individual groups the same question however they worded or framed the options differently. The presented problem for which a decision should be made was: "Imagine that the U.S. is preparing for the outbreak of an unusual Asian disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimate of the consequences of the programs are as follows. Which of the two programs would you favor?"

The first group (N = 152) was presented with the following options:

If Program A is adopted, 200 people will be saved.

If Program B is adopted, there is 1/3 probability that 600 people will be saved, and 2/3 probability that no people will be saved.

[36] An organized list and illustration of cognitive biases is shown on: https://betterhumans.pub/cognitive-bias-cheat-sheet-55a472476b18.

The second group (N = 155) was presented with the following options:

If Program C is adopted 400 people will die.

If Program D is adopted there is 1/3 probability that nobody will die, and 2/3 probability that 600 people will die.

The expected value for each option was the same in a way that the options for Programs A & C and Programs B & D were identical except in the way the outcome was described, e.g., using program A a number of people will "be saved" and in program C a certain number "will die". However, most (72%) of the respondents of the first group chose program A meaning they behaved in a risk-averse way; but in the second group most (78%) of the respondents chose program D meaning they behaved loss averse. Kahneman & Tversky named this the *"framing effect"* describing the preference reversal which resulted just from re-wording the sentences, either highlighting the gain or the losses, but without changing the actual expected value. The framing effect was studied in many domains such as in the field of behavioral economics, the military or in the medical domain (Bohm & Lind, 1992; Haerem, Kuaas, Bakken, & Karlsen, 2010; Kühberger, 1998; Peng, Jiang, Miao, Li, & Xiao, 2013; Uyar & Paksoy, 2020), however to our present knowledge not yet in the domain of commercial aviation.

Given the fact that professional pilots in commercial aviation are specifically trained in human factors which also incorporate training and awareness on biases and fallacies in decision-making we wanted to see if this training is effective to prevent pilots from being susceptible to the framing effect. The framing effect in pilot decision making may be particularly troubling if pilots varied their risk-appetite depending on different presentation of a problem. We therefore created a decision scenario based on a common situation in practice (scenario 1). For example, a flight plan change proposed to a flight crew by a dispatcher (the person or group preparing and coordinating the flight plans of an airline) to avoid a major delay imposed by air traffic control restrictions along the route may involve altitude or route changes leading to a higher fuel consumption thus requiring a higher fuel amount upon departure which may not have been considered during previous fuel upload. Considering that such situations can often occur even after having already completed all flight preparations and being ready to depart, this may leave the flight crew with the decision to accept or reject the new flight plan depending on the amount of extra-fuel they had previously taken into account for their flight. It could therefore have safety critical implications if pilots varied their decision-making depending on the wording the dispatcher would use when proposing how to deal with the situation.

In commercial aviation there are at least two important key performance indicators (KPI) which are relevant for airlines from a business or sustainability perspective and which incorporate flight crew decision-making: fuel usage and on-time-performance. To test if and how these business factors might probably influence pilots' safety relevant decision-making we created and additionally to the framing scenario presented in the survey two further scenarios involving fuel and time related decisions frequently observed in practice (scenarios 2 and 3). Both scenarios dealt with situations on the ground. One was related to a decision on how much fuel to take for a flight depending on different information on economic losses related to this decision and the other was related to a time-critical decision.

Furthermore, we then wanted to investigate if pilots' choices were associated with their professional self-concept. Although we were not able to test real behavior of pilots but survey responses only, survey responses may be indicative of how pilots may behave in practice. To evaluate whether there might be any influence of the dimensions selected to determine their professional self-concept we further assessed the correlation with the relevant survey items and the responses given to the decision scenarios.

6.6.2 Method and description of scenarios

For all three scenarios we used a between-group design presenting alternating choices for each respondent. Given the fact that not all respondents fully completed the survey the number of each group and decision-scenario varied. The framing scenario was taken by N = 227 pilots, the fuel scenario was taken by N = 225 pilots and the time scenario was taken by N = 203. The latter scenario was also presented to the ATCOs and was completed by N = 19 respondents.

6.6.2.1 Description of the Framing scenario (scenario 1)

We created a decision-making scenario based on regular practice in commercial airline operation regarding on-time-performance which was congruent to the “Asian disease” problem. For each frame (gain or loss) we developed two options accordingly. The scenario was as follows: Imagine that dispatch is preparing your flight which is expected to have a delay of 60min. Two alternative options to reduce the delay are proposed. Assume that the exact estimates of the consequences are as follows:

(The first group (N = 117) was presented with the following options framed as gains.)

Certain Option: If option A is adopted, 20 minutes of the expected delay will be saved.

Risky Option: If option B is adopted, there is a one third probability that all 60 minutes of the delay will be saved and a two-third probability that no time will be saved.

(The second group (N = 110) was presented with the following options framed as losses.)

Certain Option: If option A (C) is adopted, your flight will have 40 minutes of delay.

Risky Option: If option B (D) is adopted, there is a one third probability that your flight will have no delay and a two-third probability that your flight will have 60 minutes of delay.

6.6.2.2 Description of the Fuel scenario (scenario 2)

The fuel scenario dealt with a common situation related to every single flight when, before departure, the amount of fuel is determined which should be taken. The decision on the amount of fuel required before departure (Block-Fuel) is usually taken jointly by the PIC and SIC together. However, the final decision on the selected amount rests with the commander of a flight (International Air Transport Association (IATA), 2023). In the scenario the weather and airport information provided for the destination airport included rainy weather with crosswinds that are close to a commercial aircraft’s operating envelope. Under the presented weather conditions the provided runway length at the destination is not short but also not very long and the available Instrument Landing System (ILS) provides a good and easy to use guidance for landing. However, due to the 30% probability that the winds may become strong and gusty the flight crew might consider extra-fuel for possible holding in case the wind at the time of arrival is actually above their crosswind limit or in case the approach becomes unstable due to the gusty winds so that a go-around, which costs extra-fuel, has to be performed. The wording for the participants contained industry specific coding which we assumed all professional pilots were familiar with and was as follows:

Block-Fuel Scenario: Dear Pilot, please consider the following scenario,
then choose the statement which best fits your personal view: Before a flight the cockpit crew has to decide if and how much extra-fuel they want to take on top of the legally required minimum fuel. The weather forecast for the destination airport (single runway: 09/27, 2700m, ILS) for the time of arrival in this scenario reads: 180/10 5000 RA BKN010 PROB30 TEMPO 180/20G30. There are no weight limitations to observe, no significant shortcuts or better enroute winds to expect as well as no traffic at destination at the time of arrival.

Scenario A:
How much extra-fuel should a cockpit-crew take, in your view, if their operational flight plan specifies a loss/cost of 200$ per ton of extra-fuel taken while the aircraft uses 100kg of fuel per minute?

- no extra-fuel at all (no cost)
- extra-fuel which equals 10min of additional time ($200 cost)
- extra-fuel which equals 20min of additional time ($400 cost)
- extra-fuel which equals 30min or more of holding time (min. $600 cost)

Scenario B:
How much extra-fuel should a cockpit-crew take, in your view, if their operational flight plan specifies a loss/cost of 2$ per ton of extra-fuel taken while the aircraft uses 100kg per minute?

- no extra-fuel at all (no cost)
- extra-fuel which equals 10min of additional time (2$ cost)
- extra-fuel which equals 20min of additional time (4$ cost)
- extra-fuel which equals 30min or more of holding time (min. 6$ cost)

Following the respective decision, the respondents were additionally asked to answer the following question by using a slider in the survey and selecting a value between 0 and 100%:
How many pilots in your company, do you think, would in practice be influenced by the information on fuel cost in their fuel decision? (Please give your best estimate)

6.6.2.3 Description of the time scenario (scenario 3)

The time scenario dealt with a common situation in practice related to a decision on starting or not starting the pushback from the parking position depending on given time constraints and a runway change situation. The runway in use on an airport is determined by the airport authority in coordination with the Air Traffic Controllers based on the weather situation, especially in regard to the wind direction and velocity, but also based on local regulations such as noise abatement restrictions. As the routine weather information available to pilots is not updated every minute, but usually in a 10-20 minutes interval only, it can happen that a flight crew has prepared for a certain runway direction and is informed about an impending or just performed runway change by ATC just shortly prior or during requesting the pushback clearance.

However, to change the relevant aircraft’s take-off performance parameters and the required navigational setup for the departure route from the new runway and to re-consider possible threats and re-brief the new setting within the flight crew usually takes 5-10 minutes, as a minimum, if done properly. If the flight has been regulated by air traffic control services and has received a calculated take-off time (CTOT), e.g., due to enroute traffic demands or expected fog conditions at destination reducing airspace capacity, meaning that there is only a small time-window allowed for departure this fact in combination with a runway change can impose significant time pressure on a flight crew. As this situation involves not only pilots, we presented this scenario to the ATCOs as well. The wording for the participants was as follows: Dear Pilot, dear ATCO. Please consider the following scenario, then choose the statement which best fits your personal view:

Scenario A:

The flight in this scenario is well ahead of schedule while the crew is ready for pushback at the parking position. Upon requesting the pushback-clearance ATC advises them that the airport has just changed the runway in use. ATC is not able to change it back again due to inbound traffic. What should the crew do, in your view (Pilots), or what do you expect the crew to do (ATCOs) in order to prepare the take-off from the new runway?

- Cancel pushback and do the necessary work at the parking position.
- Start pushback and do the necessary work progressively during pushback and taxi.

Scenario B:

The flight has a given take-off time (CTOT/Slot) which would be missed if pushback is not started in the next 2 minutes. The crew is ready for pushback at the parking position, but upon requesting the pushback clearance ATC advises them that the airport has just changed the runway in use. ATC is not able to change it back due to inbound traffic. A new CTOT/Slot would lead to a significant delay. What should the crew do, in your view (Pilots), what do you expect the crew to do (ATCOs) in order to prepare the take-off from the new runway?

- Cancel pushback and do the necessary work at the parking position.
- Start pushback and do the necessary work progressively during pushback and taxi.

Following the respective decision, the respondents were additionally asked to answer the following question by using a slider in the survey and selecting a value between 0 and 100%:

How many crews in your work environment (Pilots: company, ATCOs: airspace), do you think, would in practice when under significant time pressure start the pushback, then do the necessary work, like new toperf, fms/nav-setup, re-briefing, progressively during pushback/taxi? (Please give your best estimate)

6.6.3 Results

6.6.3.1 Pilots' choices in the framing scenario (scenario 1)

In total 227 respondents took the framing scenario of which 117 were presented with the gain framed choices and 110 with the loss framed choices. As proposed by prospect theory more pilots (71.8%) were attracted to the sure option when the choices were framed as gains rather than as losses (54.5%); by the same token more pilots chose the risky option – selecting the gamble - when the options were framed as losses (45.5%) than when the option was framed as gain (28.2%) (see table 6-27). In short, the risk appetite of pilots seems to significantly vary relative to the presented frame, χ^2 (1, N = 227) = 7.27, p = .007. Independent samples t-tests show that there were no significant differences in responses between PICs and SICs, neither for the gain-framed choices, t (108) = .54, p = .593, nor for the loss-framed choices, t (115) = -.04, p = .966. Interestingly, a correlation analysis revealed that respondents who claimed prior knowledge of the framing effect, was correlated with risk-seeking in the domain of losses, r (87) = -.28, p = .008.

Table 6-27: Number of choices (n) and percentages (%) per frame and risk

	Gain frame	Loss frame
Risky choice	33 (28.2%)	50 (45.5%)
Certain choice	84 (71.8%)	60 (54.5%)
Total	117 (100.0%)	110 (100.0%)

6.6.3.2 Pilots' choices in the fuel scenario (scenario 2)

In total 225 respondents took the fuel scenario of which 114 completed the scenario with the low costs (2$ cost per 1000kg Extra-fuel) and 111 the scenario with the high cost (200$ per 1000kg Extra-fuel). A chi-square test confirmed that pilots' choices varied significantly depending on the expected costs leading to fewer pilots taking a higher amount of extra-fuel in the high-cost scenario, χ^2 (3, N = 225) = 11.0, p = .012. As shown in table 6-28 we found that the higher the resulting cost of taking extra fuel the greater the reluctance of pilots to take extra-fuel. While only a few (10%) of the pilots took only a relatively small amount of extra-fuel for the given weather conditions in the low-cost scenario a binomial test showed that significantly more pilots (20.7%) took this small amount in the high-cost scenario. While a third (36.0%) of the pilots chose to take 20 minutes of extra-fuel and nearly half (44.7%) of the pilots chose to take 30 minutes of extra-fuel in the low-cost scenario, the proportions reversed significantly in the high-cost scenario such that nearly half (44.1%) of the pilots now took 20 minutes of extra-fuel and only a quarter (26.1%) of the pilots took 30 minutes of extra-fuel, χ^2 (1, N = 170) = 5.65, *p* = .018. Independent samples t-tests show that there were no significant differences in responses between the PICs and SICs, either for the low-cost choices, *t* (109) = .98, *p* = .327, or for the high-cost choices, *t* (112) = .51, *p* = .611.

Regarding the follow up question, ("how many pilots in your company, do you think, would in practice be influenced by the information on fuel cost in their fuel decision?") we found that both groups answered very similarly indicating that they believed that about one third of the pilots in their company would be influenced in their fuel decision by the information on fuel cost (Scenario A: *M* = 35.1, *SD* = 30.1, Scenario B: *M* = 38.8, *SD* = 29.7).

Table 6-28: Number of choices (n) and percentages (%) per cost and extra-fuel in minutes

	2$ Cost / 1000kg Extra-Fuel	200$ Cost / 1000kg Extra-Fuel
No Extra-Fuel	11 (9.6%)	10 (9.0%)
10 Min Extra-Fuel	11 (9.6%)	23 (20.7%)
20 Min Extra-Fuel	41 (36.0%)	49 (44.1%)
30 Min Extra-Fuel	51 (44.7%)	29 (26.1%)
Total	114 (100.0%)	111 (100.0%)

6.6.3.3 Pilots' choices in the time scenario (scenario 3)

The results of the pushback scenario are very similar to the results of the framing scenario. In total 203 pilots took the framing scenario of which 99 were presented with the scenario without time pressure and 104 with the time pressure scenario. We found that more pilots (71.7%) showed a risk-averse behavior when there was no time pressure rather than when there was time pressure (46.2%), and more pilots have chosen the risky option when under significant time pressure (53.8%) than when there was no time pressure (28.3%) showing that the risk appetite of pilots varied relative to the existence of time pressure (see table 6-29). A chi-square test revealed a significant association between frame and risk appetite of pilots, χ^2 (1, N = 203) = 13.66, p < .001. Independent samples t-tests show that there were no significant differences in responses between the PICs and SICs, neither for the scenario without time pressure, t (97) = .44, p = .662, nor for the time-pressure scenario, t (102) = .48, p = .635.

Regarding the follow up question, how many crews in your work environment (Pilots: company, ATCOs: airspace), do you think, would in practice when under significant time pressure start the pushback, then do the necessary work, like new toperf, fms/nav-setup, re-briefing, progressively during pushback/taxi, we found that both groups answered very similarly indicating that they think that about two thirds of the pilots would take the risky choice when under significant time pressure (Scenario A: M = 67.2, SD = 26.0, Scenario B: M = 66.0, SD = 25.9).

Table 6-29: Number of pilots' choices (n) and percentages (%) per time and risk

	No time pressure	Time pressure
Risky choice	28 (28.3%)	56 (53.8%)
Safe choice	71 (71.7%)	48 (46.2%)
Total	99 (100.0%)	104 (100.0%)

6.6.3.4 ATCOs' choices in the time scenario (scenario 3)

The pushback scenario was taken by 19 ATCOs only. However, the results shown in table 6-30 reveal that from an ATCO perspective there is no significant difference in expectation about pilot behavior in terms of time pressure, χ^2 (1, N = 19) = 1.35, p = .245. While independent samples t-tests show that there is no significant difference in responses between pilots and ATCOs in the time pressure scenario, t (9) = -1.18, p = .267, there is indeed a significant difference between pilots' and ATCOs' responses in the scenario without time pressure. ATCOs (M = 1.40, SD = .52) significantly more expect pilots to take the risky choice than pilots (M = 1.72, SD = .45) would prefer in a situation without time pressure, *t* (107) = 2.09, *p* = .039. This might be related either to insufficient knowledge of ATCOs about the risks associated with performing the required tasks for a runway change when being distracted by taxiing an aircraft, or due to different experiences in practice. The latter possibility is further supported by the results on the question: “how many crews in your work environment do you think, would in practice when under significant time pressure start the pushback, then do the necessary work, like new toperf, fms/nav-setup, re-briefing, progressively during pushback/taxi)”. We found that the ATCOs answering the scenario without time pressure would have expected more than half of the pilots (*M* = 64.5, *SD* = 31.0) to take the risky choice, and those answering the time pressure scenario less than half of the pilots (*M* = 40.3, *SD* = 26.6).

Table 6-30: Number of ATCOs’ choices (n) and percentages (%) per time and risk

	No Time Pressure	Time Pressure
Risky choice	6 (60.0%)	3 (33.3%)
Safe choice	4 (40.0%)	6 (66.7%)
Total	10 (100.0%)	9 (100.0%)

6.6.3.5 Pilots’ professional self-concept, their attitudes and their responses to the decision scenarios

We found that there was neither a significant correlation of pilots’ professional self-concept with the responses to the framing scenario nor any significant correlation of the responses to the scenario with pilots’ attitudes towards safety relevant decision-making. Given the fact that the scenario itself did not contain obvious safety relevant cues for the respondents this result was not unsurprising.

However, we expected that for the scenarios at least dealing with safety relevant decisions such as the block-fuel or the pushback decision to find positive correlations of responses with pilots’ self-image as a safety or risk manager or with their safety orientation providing any clue towards a possible attitude-behavior consistency. Indeed, we found that the more safety oriented the pilots were, the more extra-fuel they had chosen for the high-cost scenario, *r* (109) = .21, *p* = .031 and also in the low-cost scenario, albeit not significantly more in that specific case, r (112) = .18, p = .058. While there was neither an association of pilots' responses with their self-image nor with their NOTECHS orientation in the fuel scenario, we additionally found that the item "I feel completely free to take as much extra-fuel as I deem necessary for my flights" was, as expected, positively correlated with taking more fuel, both in the low-cost scenario, r (111) = .20, p = .035, and in the high-cost scenario, r (107) = .27, p = .001.

Regarding the pushback scenario we did not find a significant correlation with pilots' safety versus business orientation or their self-image as a safety or risk manager. However, while there was also no correlation of pilots NOTECHS orientation for the push-back scenario without time pressure we found that, in the push-back scenario with time pressure, that the more pilots were NOTECHS oriented, the more they rejected the time pressure and chose to cancel the pushback, r (102) = .25, p = .010. To check for consistency within the pushback scenario we used the SOP-deviation scale incorporating the items "To work economically efficiently sometimes requires a trade-off in adherence to procedures" and "Deviating exceptionally from SOP for efficiency reasons in normal operation is permitted if both pilots agree that it is safe." and found that it was significantly correlated with the responses to the scenario without time pressure, r (97) = -.20, p = .050, meaning that those pilots being more open for SOP deviations also opted more often for the risky choice. Interestingly, this association was not found in the time-pressure scenario. Despite different expectation there was also no significant correlation of the time pressure scenario with the item "I feel completely free to make or accept delay, if necessary, to perform procedural steps or checklist prior to off block without any haste or hurrying" nor with the item "I feel personally responsible for the on-time-performance of my flights." which might suggest that significant time pressure, according TPB (see chapter 5) possibly representing any subjective or social norm, might override any possible attitudinal influence on pilot behavior.

6.6.4 Discussion

By using a decision-making scenario similar to the original Asian Disease scenario used by Tversky & Kahneman (1981) we wanted to test whether professional pilots are susceptible to the framing effect as predicted by prospect theory. Indeed, we found that pilots vary their risk appetite relative to the frame presented in the direction predicted by prospect theory. Relatively more pilots took the certain option when the choices were presented as gains and relatively more pilots took the risky option when the choices were framed as losses. These findings give reason for concern as it shows that even professional experts in high-risk-environments, who are trained in human factors, are susceptible to a framing effect with, potentially, safety critical implications. How this might relate into the daily practice of commercial aviation suggest our results from the pushback scenarios which were very similar to the results of the framing scenario. We found that pilots vary their risk appetite relative to time pressure being present or not. Relatively more pilots chose the safe option when there was no time pressure, and relatively more pilots took the risky option when under significant time pressure. This latter finding is consistent with research in road safety showing that time pressure can lead to risky behavior in car drivers (Naveteur, Cœugnet, Charron, Dorn, & Anceaux, 2013).

Although not directly related to a framing effect, our data on pilots' fuel decision-making revealed that the amount of extra-fuel taken also varied with the information on cost related to this decision. A higher total cost for taking extra-fuel led to less extra-fuel being taken. While this might just represent a usual trade-off made by common economic agents, these findings suggest that pilots, although being primarily responsible for the safety of their flights, let themselves actually be influenced by economic considerations, though this depended somewhat on their individual attitude towards safety and business factors. In sum, the results on pilots' choices in the decision-scenarios reveal not only that pilots, independent of their roles as PIC or SIC, are susceptible to decision-making fallacies, despite being trained in human factors, but also that pilots' safety relevant decision-making might be negatively influenced by business factors in situations when safety should be balanced with other considerations, however always in a way that it is prioritized over the others.

The presence and negative influence by conflicting goals, often perceived as operational pressures acting on practitioners at the frontline of high-risk-environments such as aviation or medicine (Cadieux, 2014, p. 138), has already been described in many studies (Causse, Dehais, Péran, Sabatini, & Pastor, 2013; Cook & Woods, 1994; K. Mosier et al., 2011; K. L. Mosier & Fischer, 2010; Orasanu et al., 2002). Noting these findings from safety research the results of our decision-making scenarios suggest that these negative influences found there are persisting. Given the fact that the need for special debiasing training to prevent such negative influences from taking effect has been raised already in the past (R Key Dismukes, 2010), our findings in turn suggest not only a possible research-practice gap (similar to the one we found in our field data study regarding optimum role allocation on the flight deck, see 3.3.2.1) but might also imply that, despite a safety-first approach in aviation, the current decision-making policies and training for pilots may not be sufficiently effective to eliminate negative influence by economic considerations.

Alongside with the research on heuristics and biases, proposals were made how to de-bias or mitigate the influence of biases in various domains with differing outcomes. In the medical domain A. Schwartz & Bergus (2008) conclude that “No universally effective methods for debiasing these judgmental tendencies have been developed; indeed, because they are so deeply rooted in our intuitive system, and because our intuitive system is essential to everyday operation, it seems unlikely that such methods could ever be developed.”, while S. Schwartz & Griffin (1986), pp. 169–171, report that at least some techniques and training approaches to mitigate biases revealed mixed results. In contrast, Almashat, Ayotte, Edelstein, & Margrett (2008) found that intensified elaboration of a medical problem can reduce the framing effect or in behavioral economics Huang & Guenther (2024) found a method how to debias the disposition effect. Morewedge et al. (2015) report about a debiasing training intervention which was domain general, however in a laboratory environment only, Sellier (2019) found, as well in a laboratory environment, promising results in regard to training intervention to effectively mitigate confirmation bias and Jugnandan & Willows (2023) presented an integrated approach to debiasing using decision support systems. On the one hand these examples reveal difficulties in finding effective debiasing techniques while on the other hand there seem to be promising options.

The aviation industry currently relies mostly on policies and procedures to mitigate the most prominent biases as mentioned before. To mitigate the plan-continuation bias the industry has introduced and tightened strict stabilized approach criteria and improved go-around policies. Furthermore, within aviation problem solving and decision making tools are commonly taught in CRM classes and introduced by airlines to support the decision-making process of their pilots (Soll, Proske, Hofinger, & Steinhardt, 2016), however those often do not provide guidance on how to avoid or mitigate specific biases. A notion how this could be done within those tools is given by Moriarty (2015) p. 61, who additionally highlights the important role of the SIC to act as a kind of supervising brain system 2 for the PIC if the PIC's system 1 is being influenced by biases. However, Moriarty (2015) p. 289-271, being a flight captain and chief CRM trainer himself, admits in his conclusions that current CRM training for pilots is obviously ineffective and superficial only or in other words "a waste of time" as it did not deliver the required knowledge for pilots.

The dilemma in managing the balance between safety and business success, or in other words between production and protection, is well known in aviation and defined by ICAO in their safety management manual as navigating *the safety space,* which is, simply speaking, viewed as walking the line between bankruptcy and a catastrophe (International Civil Aviation Organization (ICAO), 2018). This concept allows organizations in the aviation industry, by means of their safety risk management processes, which are embedded in their overall safety management systems, to find optimum solutions in balancing profitability and safety. However, this principle can only apply to the blunt end of the safety production process in high-risk-environments meaning the organizations, manufacturers and regulators in the background of operations. It may not necessarily be the optimum pathway for safety relevant decision-making of practitioners at the front line (sharp end) such as pilots or ATCOs.

While organizations have not only the time and resources to do sophisticated and in-depth risk assessments and often have multi-layered decision-making processes involving several people and opinions, they are also not directly imperiled by the threats pilots are facing in daily flight operation which according (Ale, Slater, & Hartford, 2023) can have significant influence on the people's choices. In contrast, pilots (as well as ATCOs, although not facing the threats pilots are facing) are working directly at the frontline most often in dynamically changing conditions being risk-managers and decision-makers at the same time. Research in the domain of naturalistic decision-making (NDM) has shown that practitioners such as pilots, when confronted with goal conflicts, time pressure or uncertain and dynamic situations, often search for matching patterns which they have previously experienced to base their decision-making on, which makes the quality of their decisions dependent on the accuracy of their situation assessment and their level of expertise (K. L. Mosier & Fischer, 2010). If this situation assessment is negatively influenced by biases, as shown in our research, or the required expertise in safe risk-management is missing, the risk of unsafe decision-making by pilots is promoted.

Furthermore, our results of the decision-making scenarios suggest that risk preference may not solely be manipulated by altering choices in terms of wording for gains or losses (risky-choice framing) but also just by presenting different salient economic factors. Although the other two decision-making scenarios (fuel and time) were not framing scenarios, given the fact that the values of the manipulated information in the scenarios actually changed instead of being constant (2$ vs. 200$ cost per ton of extra-fuel or time pressure vs. no time pressure), the results were similar to those expected by the two other forms of framing, which are *attribute* and *goal framing* as proposed by Levin, Schneider, & Gaeth (1998). Within the fuel scenario the different cost label on the operational flight plan led to more risk-taking by assigning higher costs and within the time scenario the different time frame led to more risk-taking under time-pressure.

These results clearly reveal a vulnerability for the commercial aviation industry regarding their safety performance. Those being allegedly seen as expert decision-makers, the pilots, seem to let themselves be influenced in their safety relevant decision-making by economic considerations. Therefore, it might be worthwhile for the industry to consider not only looking for possible methods in establishing effective debiasing training for pilots (e.g., by including role play and realistic normal operation decision-scenarios in CRM-training) but also consider relieving pilots from negative influences by business considerations so that they can focus in practice on creating or maintaining always sufficient safety margins to finally achieve *safefficiency*, meaning the optimum mixture of safety and efficiency ensuring always sufficient inclination of safety over efficiency.

Regarding the fuel decision our results suggest that it could be helpful to remove any cost information regarding fuel uplift from the operational flight plans. In regard to preventing negative influence by time constraints a more general approach might be helpful. Instead of using current decision-making policies and role descriptions for pilots which include the need for considering economic factors on top of safety considerations, representing a pre-designed goal conflict for practitioners in a high-risk-environment, the aviation industry could easily eliminate these influences and provide policies and role descriptions for pilots that focused on maintaining sufficient safety margins. Like judges who are free and independent in their jurisdiction, only bound to the law and their conscience, it might be helpful for the aviation industry to also import this principle for pilots (and ATCOs) given the fact that those practitioners have the most influence on the safe operation of an aircraft.

This approach could be further supported by introducing a professional codex or oath for pilots (and ATCOs) similar to those made by practitioners in the domain of medicine or jurisdiction. Such an oath or '*codex praeventis'* could include statements requiring pilots to always apply a risk-averse (defensive/conservative) decision-making style, especially in normal operation, supported by a documented stop working authority (SWA) for pilots in the roles of the PIC and SIC to ensure both, freedom to make safe decisions and effective intervention. As in an everyday activity such as car driving, when it is always possible to adapt the driving to be more risk-averse (defensive/conservative), aircraft flight crews always have, especially in normal operation, a more risk-averse option available. In normal operation, meaning with fully airworthy aircraft and no emergency present, take-offs can always be delayed or canceled, go-arounds can always be flown, and aircraft can always divert to a more suitable airfield. While operational flight plans for commercial aircraft always consider these ultimate options by default, many less ultimate nuances of these options exist and can lead to more defensive flying and decision-making to avoid operating near, at, or even beyond operational limitations (e.g., aircraft speed or altitude limitations, stabilized approach limitations, human performance limitations, flight duty time limitations, etc.). Similar to the efficiency strategy of long-range cruise in flight operation, which trades off 1% range for 3-5% higher cruise velocity (Roberson, Root, & Adams, 2007), a decision-making and aircraft operation strategy trading off – metaphorically speaking – only a small amount of efficiency for a significant higher amount of safety could help to prevent safety critical events in commercial aviation.

While early initiatives in road safety started to promote defensive driving courses some decades ago (Lund & Williams, 1985), the concept of defensive flying only became known in aviation significantly later, with the introduction of threat and error management (TEM) by Merritt & Klinect (2006). As outlined earlier (see 2.1) TEM has a proactive approach supporting pilots in anticipating upcoming or existing threats along their flight. However, identifying threats is only the first step and the next and at least equally important step is the mitigation to ensure an operation with always sufficient safety margins. Our previous research on pilots' attitude towards risk averse flying (conservatism) has shown that there is variance among pilots on how risky certain aircraft operation is perceived (see 6.4.3.1). Therefore, being operated by, at least, a dyadic flight deck team can be seen as an advantage of commercial aircraft operation over a single-operator activity such as car-driving, as it allows, in theory, mutual detection and mitigation not only of errors, but of overly risky flying and decision-making as well. In regard to the tested decision scenarios on fuel and time decisions by pilots we assume that this potential supervision will become increasingly important as reduced resources, sustainability and on-time-performance efforts within the industry will put further operational pressure on those ultimately responsible for the safe operation of their aircraft - the pilots.

6.6.5 Conclusion

We found evidence that pilots are not only susceptible to decision-making fallacies such as the *framing effect* but also that their safety relevant decision-making might be negatively influenced by business factors such as fuel cost or time. We found that pilots seem to vary their risk appetite depending on the nature of presented information which in turn highlights a vulnerability for the safety performance of commercial aviation. Furthermore, our findings suggest that current policies and training of pilots in decision-making do not sufficiently cater for these negative effects. We propose several options to mitigate these effects such as ceasing the presentation of fuel cost data on operational flight plans, or more general ideas such as the implementation of a *codex praeventis* and improved role descriptions for pilots demanding defensive flying and decision-making only, rather than demanding a balancing of a pre-designed goal conflict between safety and commercial considerations.

7 Research summary

7.1 Summary of research findings

Based on empirical data on incidents and accidents in the period 2000 - 2020 involving medium and large commercial aircraft we found that most (71.0%) of these events happened in the flight crew team setting with the Captain (PIC) as Pilot Flying (PF). We found evidence that this role assignment effect, described by previous research already in the 1990s, is still present in today's aviation system thirty years later, even with an increasing trend, despite training pilots in crew resource management (CRM), a teamwork method developed decades ago to counteract the problem. We also found that most (72.2%) of these events happened in normal operation, meaning with technical airworthy aircraft and no emergency. Within the category of hull losses, meaning an accident where an aircraft was destroyed or damaged beyond repair, the analysis revealed that in even more (81.8%) of the events happening in normal operation the PIC was acting as PF and nearly all (98.7%) of the hull losses were preventable by the pilots accounting for nearly all (96.3%) of the 5712 fatalities associated with these events.

Although we found differences in the geographical distribution of the role assignment effect further analysis regarding the influence of culture did not reveal a significant association. However, we found that the age of the Second-in-Command (SIC) and the on-type experience of the PIC was associated with the role assignment effect supporting the theory that status hierarchy on the flight deck is a factor underlying the role assignment effect. The negative influence of the status hierarchy between the pilots on the flight deck on the teamwork and safety relevant decision-making was also confirmed by findings from our online surveys eliciting pilots' attitudes and their experience with teamwork and safety relevant decision-making in practice and training.

Pilots participating in our safety surveys reported that negative effects by the status hierarchy between the PIC and SIC on commercial aviation flight decks are still present and may act as barriers for effective intervention by the SIC. More evidence for the presence of negative effects by status hierarchy was the fact that almost only SICs, when being PF, experienced that the PM took away control from them or grasped into their controls, a behavior which is hardly ever experienced by PICs.

Furthermore, almost only SICs experienced that their go-around call was overruled by the other pilot and more SICs than PICs report that a go-around was not performed despite being required. Although more SICs than PICs report not having intervened although it was required, we even found that there is a general reluctance for effective intervention among pilots when being in the role of the PM. Among the most and highest ranked reasons for missing intervention were subjective risk perception, status hierarchy and schedule considerations. By means of intervention scenarios we also found that other reasons acting as barriers for effective intervention by the SIC include a desire for harmony and the deference of not appearing to pedantic on the flight deck.

The possible origins underlying these negative teamwork experiences, and thereby in turn also underlying the results delivered by the field data analysis, were elicited by the analysis of pilots' attitudes towards the roles of the SIC and PM. One of the main reasons seems to be that both roles are not considered as having a supervisory function but are more viewed as assistant roles. Furthermore, the responses of the pilots regarding their attitude towards the roles of the PF and PM suggest that similar to the higher status of the PIC-role also the PF-role is viewed as autonomous and being hierarchically higher than the PM-role. For example, a precautionary control take-over by the PM seems not be acceptable among pilots.

Like the analysis on pilots' experiences, we also found within their attitudes that there seems to be a general reluctance for hard interventions suggesting that especially the current position of the SIC does not warrant effective intervention. Although pilots showed a broad consensus that the role of the SIC should have a high status and that SICs should be trained in leadership and intervention, our data shows that the status hierarchy between PIC and SIC may still be perceived as a barrier for an effective PM-role. SICs seem to feel more reluctant to intervene than PICs and there is less agreement by PIC than by SIC that PIC should seek agreement before making safety relevant decisions (humble inquiry) and there is less agreement by PIC than by SIC that SIC have the right to take command. Especially more traditionally oriented pilots (system operators) have a lower view on the status of the SIC. The ability of the SIC to effectively intervene in the safety relevant decision-making of the PIC is expected on average with 2-3 years of flying experience only. Moreover, pilots' responses suggest that the current minimum legal requirement for command training should be doubled. Nevertheless, nearly all pilots and regulators support that SIC should be allowed and trained to taxi the aircraft on ground.

The results from the intervention scenarios highlight that pilots seem to favor soft over hard interventions they support the notion that pilots' safety attitudes in regard to the role of the SIC and towards intervention seem to be consistent with the proposed intervention behavior of the SIC. Common barriers in the aviation system preventing effective intervention by the SIC seem to be differences in risk perception, a requirement to trust the PIC, a missing accountability for the role of the SIC and a desire for harmony on the flight deck. These findings suggest that the current measures taken to counteract any status hierarchy effects and to support active intervention on the flight deck by the SIC may be insufficient to foster hard interventions which are required to prevent serious safety relevant events.

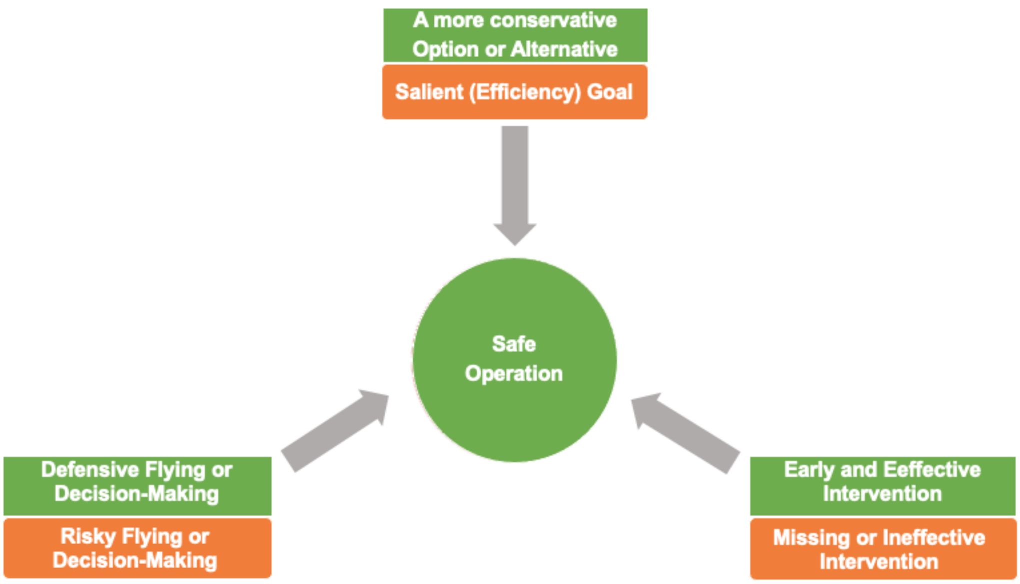
On top of the issues with missing or ineffective intervention the results of our analyses on pilots' attitudes and choices in the decision scenarios suggest that business factors may have negative influence on pilots' safety relevant decision-making. We found that pilots seem not only being susceptible for decision-making fallacies such as the *framing effect* but also that their safety relevant decision-making seems to be negatively influenced by business factors such as fuel cost or time. We found that pilots seem to vary their risk appetite depending on the presented information which in turn highlights a possible vulnerability for the safety performance of commercial aviation.

Moreover, our unique research approach delivered findings regarding the influence of pilots' professional self-concept on their attitude towards their roles. We found that pilots see themselves slightly more as a safety/risk manager rather than as aircraft operators/system managers. They self-report being generally more safety minded than business oriented, but they see NOTECHS-training as less important than technical skills training. Additionally, our analyses revealed that pilots' self-concept seems to predict their attitude towards teamwork and safety relevant decision-making. As hypothesized, we found that the more safety and human factor minded the pilots, the more risk-averse and the more teamwork oriented they are. These associations might be helpful to develop possible mitigation strategies to counter negative effects resulting from status hierarchy and business considerations.

7.2 Summarizing Discussion

There are various implications for the aviation industry resulting from our research. Some of the results regarding teamwork and the influence of practitioners' self-concept may even be of interest for other high-risk-environments as well. The analyses presented in this thesis not only show clear evidence of predictable variation in aviation risks that indicate strong potential for introducing reforms to improve safety in aviation, but also highlight new insights into the psychology behind safety relevant events by introducing the self-concept of pilots as a safety relevant factor. We found associations between pilots' self-image, their attitudes towards human factors and their safety versus business orientation suggesting that pilots who are less safety and less human factor oriented have lower safety attitudes regarding the role of the SIC and towards defensive (conservative) aircraft operation. The association of safety attitudes and pilots' self-concept offers several possible starting points for mitigations regarding the *role assignment effect* as well as the *operational syndrome* meaning the interaction of a salient (efficiency) goal, unnecessary risk-taking and missing or ineffective intervention (see chapter 5). As an antidote we propose the concept of *operational conservatism* as outlined below (see Figure 7-1) leading eventually to *safefficiency* meaning the optimum inclination of safety over efficiency:

Figure 7-1: The elements of Operational Conservatism as an Antidote to the Operational Syndrome



Each of the three leverage points (substituting a (salient) efficiency goal by a more conservative option; defensive flying or decision-making; early and effective intervention) might already prevent safety relevant events by its own. The first leverage point, especially in normal operation, is to eliminate any goals which might seduce pilots to take unnecessary risks. In theory this is already given as airlines, air navigation service providers, maintenance and training organization are required to run a safety management system which incorporates a safety policy as the highest organizational policy. Those policies should guide management and staff behavior in practice. They have to be approved by aviation regulators and require highlighting the priority of safety throughout all operations (European Union Aviation Safety Agency (EASA), 2023, sec. ORO.GEN 200). However, safety policies developed and issued by individual organizations might be insufficiently effective in preventing any goal seduction in practice. In line with findings regarding behavior change from other domains, e.g. discrimination research (Brauer, 2024), we propose a more multi-facetted approach proposing, on top of attitude improving measures such as CRM-trainings, predominantly normative measures on the systemic level to achieve a safe balance of safety and efficiency at the sharp end of aviation operation.

First, the aviation industry could consider if the introduction of a clear binding oath or professional codex applicable to all practitioners in a certain domain of aviation, i.e., commercial pilots or air traffic controllers (ATCO), as it is common in other professions outside aviation (e.g., jurisdiction or medicine), could be beneficial as an additional barrier to prevent goal seduction and support safe decision-making and procedure compliance in practice. Suggestions how this could be done and what should be considered is given by de Bruin (2016) who examines oaths introduced for bankers and other practitioners in the finance sector after the global financial crisis around 2008. Rittberg (2023) analyzed the implications related to the introduction of a professional oath for mathematicians. In reflecting on research on the effectiveness of oaths he found mixed results, showing that the assessment of their effectivity largely depends not only on the research approach taken (e.g., from a social science or philosophical perspective), but also that oaths can have different impact on the individual or the structural level. The use of oaths to guide practitioners in ethical praise-worthy behavior is used especially in jurisdiction, e.g., when new judges are appointed, and in medicine. As highlighted by Antoniou et al. (2010) the Hippocratic Oath still serves for stabilizing the harmony of the triadic relationship between physician, patient and illness, although factors such as new technologies, cost-efficiency and regulations can derange this sensitive triangle.

In aviation, the advantage of introducing a kind of Hippocratic oath for pilots or ATCOs could be that such oath or codex, (e.g., a *codex praeventis*), highlighting the need to avoid safety critical trade-offs in practice such as taking procedural short-cuts for efficiency reasons ("ETTOing" see chapter 5), could be integrated into initial pilot and ATCO education thereby positively influencing not only their self-concept from the beginning of their careers and acting as an initial immunization against unsafe behavior but could also serve as an additional social norm or commonly accepted code of conduct in daily operation.

A further option for the industry to refine their norms and thereby fostering safe behaviors in aviation is to promote the "A to C" rule (see 6.3.9) meaning that pilots are not expected to fly from A to B as planned but that performing a go-around and a possible diversion are the *default options* for every flight instead of the (remote) alternate options. This paradigm shift in thinking about the "mission" of pilots could support them in taking safe decisions by reducing any seduction from viewing an on-time-performance or landing at the destination as their primary mission goal. As outlined before this concept is already basically incorporated in current flight planning processes.

A further measure which could help to reduce goal seduction is to quit presenting costs about fuel upload on operational flight plans. Interestingly, pilots are usually never informed about the costs arising from a de-icing treatment to not seduce them not taking this safety critical step[37]. However, they are informed about fuel cost on their operational flight plans, although our research has shown that pilots are vulnerable to be negatively influenced by such information. Therefore, we propose that a measure to reduce goal seduction is to cease presenting values of losses for taking extra-fuel on operational flight plans. How far pilots can be seduced to take unnecessary risks in regard to fuel can

[37] How important this de-icing treatment is can be seen by the prominent accident of a B737-200 in 1982 in Washington (https://skybrary.aero/accidents-and-incidents/b732-vicinity-washington-national-dc-usa-1982) and the accident of a Fokker 100 in Almaty in 2019 (https://en.wikipedia.org/wiki/Bek_Air_Flight_2100)

be seen by the case of LaMia Flight 2933[38] in 2016, contracted by a Brazilian soccer team, which crashed due to complete fuel exhaustion when the pilots decided to continue towards their planned destination to fulfill the mission given by their company despite being fully aware of the low fuel state. Further measures to eliminate any salient (efficiency) goal promoting an operational syndrome could be to not use on-time-performance or other performance measures related to the safety of the aircraft as key business performance indicators thereby reducing operational pressures on the sharp end. Although the commercial aviation is a highly competitive environment the aviation industry could seek ways how to keep this competition and challenge away from those at the frontline of operations to eventually achieve the industry's goal of zero fatalities by 2030.

However, those measures alone might still be insufficient to prevent pilots from taking unnecessary risks, the second factor in the operational syndrome. Despite many regulations ensuring the priority of safety throughout all aviation operations, those regulations are only a basic coverage against safety relevant events. In practice of flight operations, it is the responsibility of flight crews to adapt to the actual threats in their operation and incorporate additional safety margins for their flights if required, which the following three examples show. For example, the fuel amount calculated on the operational flight plan for reaching an alternate field may be legally correct, but unrealistic under given conditions such as the expected routing or weather conditions. Second, the minimum enroute or departure and approach separation between two aircraft may be legally correct, but does not, under certain wind conditions, prevent wake turbulence leading to safety relevant events. Or third, the speeds expected by ATC to be flown by the pilots on a final approach, e.g., 160kts to 4NM final, are not safely achievable depending on wind, aircraft and stable approach limitations. There are many more examples in daily operation in which legal requirements are insufficient to prevent safety relevant events so that practitioners at the sharp end such as pilots have to add more safety margins, e.g., in terms of adding time, fuel or further reducing operational limits. However, they need to feel

[38] https://www.aerocivil.gov.co/autoridad-de-la-aviacion-civil/investigacion/listado%20de%20accidentes%202016/Final%20Report%20-%20ACCIDENT%20CP2933%20-%20English%20Version.pdf

free to do so, otherwise operational or peer pressures from line managers or other aviation stakeholders (ATC, Operations Control) might hinder pilots from applying such safety enhancing behavior.

The concept of *psychological safety* introduced by Edmondson (1999), which deals with such perceived freedom but which focuses on fostering speaking up behavior in safety critical teams, does not include conservative or defensive behavior (Newman, Donohue, & Eva, 2017) nor does the concept of resilient behavior as outlined by Ruault, Vanderhaegen, & Luzeaux (2012) explicitly incorporates conservatism or defensiveness. However, our research suggests that it could be helpful to include *being conservative or defensive* explicitly into the concept of psychological safety and operational resilience or even highlight it as a feature of a positive organizational safety culture to make conservative and defensive behavior more acceptable among all stakeholders. In fact, being conservative or defensive is very similar to speaking up. An example from a day-to-day activity such as car driving is when a driver adapts to outside conditions (e.g., reduced visibility) by reducing speed despite braking other drivers behind by this measure. Within the wider team being responsible for the safe operation of the aircraft, including pilots, ATCOs, and operations personnel, (see 1.2) a shared view on conservatism or defensiveness would support those practitioners in mutually preventing unnecessary risk-taking, e.g., when seduced to do so by any (perceived) goal. To further support this the rather superficial wording "Safety First" commonly used throughout safety critical environments to indicate the priority of safety over any other demands could be altered towards a more proactive wording *"First, create safety margin"* indicating what needs to be done to finally achieve that safety really comes first in daily operations.

Being conservative or defensive in aircraft operation by using a defensive (risk-averse) style of flying or decision-making is also still not clearly defined in the current list of observable behaviors within the CBTA framework nor is it mentioned in the relevant ICAO document on the duty of the PIC ((International Civil Aviation Organization (ICAO), 2022a), but it is supported by other industry initiatives (Flight Safety Foundation (FSF), 2021) and was basically the initial underlying idea of TEM (Merritt & Klinect, 2006). Including operational conservatism within the CBTA framework and relevant ICAO documentation could further prevent unnecessary risk-taking in practice and can in addition positively influence pilots' self-concept. This could be additionally supported by promoting tools such as TEM-checklists, TEM-cards or TEM-quick reference handbooks (see Chapter 5) to be routinely used by pilots throughout normal operation like it is already common regarding the use of checklists from quick reference handbooks for non-normal situations. This could foster pilots' anticipative capacity as well as support their risk-management especially in normal operation. In general, it might be additionally helpful that aviation adopts the nomenclature of academia regarding risk-management and decision-making. While the CBTA competency regarding decision-making is captioned as "Problem Solving and Decision-Making" the more generic term of Judgment and Decision-Making (JDM) as being used throughout the academic field of risk-management and decision-making might better reflect the competency which pilots should have.

Regarding the third factor of the operational syndrome, the missing or ineffective intervention, our research on the role assignment effect and the survey on attitudes and experience of pilots clearly revealed that the aviation system has a weak spot regarding effective intervention. Therefore, the focus of attention for the antidote on this third factor of the operational syndrome is especially on the roles of the SIC and the PM. Our research has shown that the current flight crew team setting allowing the PIC to be routinely acting as PF is potentially dysfunctional and that this combination of command and control is prone to safety relevant events, especially in normal operation. The need for reform of flight crew team setting is further supported by our findings from the experience and attitude surveys highlighting especially the underpowered role of the SIC for effective intervention.

We therefore promote that the combination of command and monitoring could be a better solution for the aviation industry in terms of incident and accident prevention as it combines the power and authority of the PIC role with the crucial role of the PM and avoids negative effects on the intervention behavior originating from the status hierarchy on the flight deck. The routine allocation of the PIC in the PM role would in turn promote the supervisory function of the role of the PM. As mentioned before, a further evolution of the label for this role could be *Pilot Supervising (PS)* which would signal its main responsibility and would include active intervention more than the current term of pilot monitoring would suggest. An additional positive safety effect stemming from having the PIC routinely in the PM role, the role which is also handling the ATC-communication on the flight deck, could be that the situational awareness of the PIC in regard to ATC clearances will be increased given the *production effect* which brings a memory advantage when saying worlds aloud during reading back ATC clearances (Forrin & MacLeod, 2018).

The regular combination of command and supervision would certainly have implications for the role of the SIC. The results from our research also suggest that the role of the SIC requires re-consideration and probably a fundamental reform as it is currently seen as having primarily an assistant function only, which might be an outdated stereotype of this important role. The role of the Co-Pilot is not even defined within the ICAO framework, instead all regulations regarding safe flight operation are focused on the PIC, the Flight Operations Officer (FOO/Dispatcher) or the ATCO only. (International Civil Aviation Organization (ICAO), 2022a). Accordingly the legal status of the Co-Pilot was termed by Pyne & Kane (1994) as a “legal shadow” only.

Our research has shown that most pilots value the role of the SIC and support this role being trained in leadership and decision-making to the same extent as the PIC and that there should be no differences between both roles regarding aircraft operation. However, currently the role of the SIC seems to be artificially capped in its competency as the pilots in the role of the SIC are often not allowed to taxi the aircraft or to manage a flight and do not always receive the same training and checking as PIC. Therefore, it could be worthwhile for the aviation industry to consider how this role could be further upskilled to not only ensure that pilots in the role of the SIC, by definition the deputy of the PIC, are capable, from their first line flight onwards, to always actively intervene in the PIC’s flying and safety relevant decision-making, if required, but are also capable of taking the leadership and decision-making duties of the PIC, if required.

Given the current discussion in the US regarding the 1500 hours rule[39], meaning that pilots who want to be employed within airlines as co-pilots should have at least 1500 hours of flight experience instead of previously 250 hours, our research results rather suggest taking a generally new perspective

[39] https://www.ecfr.gov/current/title-14/chapter-I/subchapter-D/part-61/subpart-G/section-61.159. Further discussion on this rule can be exemplary seen from this source: https://reason.com/2023/10/23/lawmakers-and-unions-defend-burdensome-airline-regulations-with-bogus-statistics/

on the initial education and training of pilots. To realize the routine combination of command and supervision (PIC as PM) without eroding the flying proficiency of PICs, it would be required that both pilots on the flight deck have a PIC-rating for their aircraft so that the roles of PF and PM (PS) can be routinely exchanged between two PIC-rated pilots. Although such a change in teamwork settings might require further careful research it can be assumed that a routine exchange of roles offers several opportunities for cross-role-experiences allowing PIC-rated pilots to continuously self-reflect and learn regarding their own leadership and intervention behavior.

From our research it might follow that, instead of raising the flight hours requirements allowing entry into the airline environment, it might be more useful for the enhancement of aviation safety to discuss how the initial pilot education and training could be reformed to enable new entry pilots being accelerated to reach command status, meaning to achieve their PIC rating, within 1500hrs (the regulatory limit) up to around 3700hrs[40] as suggested by the participants of our surveys (see 6.4.4.1). It might therefore be more useful to demand a basic human factor and safety-oriented education (e.g., an academic course on human factors, including in-depth training in judgement and decision-making and accident prevention techniques) before even starting to be trained in technically operating an aircraft to ensure an initial immunization of pilots against risky and unsafe behavior and ineffective intervention. Additionally, it could be considered to define pilots with less than 1500hrs of airline experience as inexperienced pilots requiring specific limitations during flight operation similar to the current regulations on inexperienced flight crew which impose restrictions to pilots within their first 150hrs after their type rating or command course (European Union Aviation Safety Agency (EASA), 2023, sec. ORO.FC.200). Furthermore, even new entry, low experienced, pilots in airlines could be trained in leadership and decision-making, thus in PIC duties, right from the beginning of their career in multi-pilot-airline-cockpits. This is already possible under the PIC under Supervision (PICuS) scheme (see 3.4), a form of delegated leadership, which, if routinely used as a mentoring measure during line flights within the first 1500-3000hrs, could lay the basis for pilots reaching their PIC-rating and command status significantly earlier than it is common today. Further raising the

[40] The average airline pilot will possibly do an amount of approximately 700-900 flight hours per year depending on the individual airline and fleet operation.

competency level of the SIC could therefore be beneficial for flight crew's teamwork and ultimately for the safety performance of aviation.

Although the current leadership and followership arrangement on the flight deck assumes that the PIC should be the designated and the functional leader of the cockpit team at the same time (Cortes, 2008), meaning that the PIC has the final authority and at the same time is managing the operation by taking decisions on her/his own, our research results on the experience and attitude of pilots regarding the role of the SIC suggest that it might be worthwhile for the industry to overthink this paradigm. Already today the PIC may delegate leadership and decision-making duties to the SIC under the PICuS scheme mentioned above. Considering that having a PIC-rated SIC as PF, meaning a SIC who is also fully trained and checked in leadership and decision-making, this would allow to routinely use this method of delegated leadership (PICuS). This would mean that the SIC as PF manages the flight and takes safety relevant decision on her/his own, but under the supervision of the PIC. Moreover, having a PIC-rated SIC as PF in the role of the functional leader, especially in normal operation, also has the benefit of eliminating negative effects by status hierarchy and avoiding cognitive overload of the PIC. The cross-cockpit authority gradient is still there but can now be positively used for effective intervention in possible risky behavior or decision-making of the SIC as it better allows the PIC to concentrate on supervising and monitoring the operation with a clear focus on safety instead on efficiency. Such altered concept of leadership leading to an *intervention-based decision-making* might also enhance a more entangled teamwork between PF and PM, thus the SIC as PF and the PIC as PM, as it fosters a more natural form of *leader inquiry* when the subordinate asks the supervisor for her or his agreement or thoughts before taking a decision, if required.

Currently the convention in commercial aviation is that, except for certain training or check flights, the PIC is always sitting in the left-hand seat (LHS) of a fixed wing aircraft. As both pilots can be trained and checked to be flying in either seat of an aircraft (European Union Aviation Safety Agency (EASA), 2023, sec. ORO.FC.235) the team-setting of delegated leadership (*PICuS* or *Monitored Operation*) allows the PIC as PM to be routinely sitting in the right-hand-seat (RHS). Furthermore, this team setting with an *RHS-commander* could also support the introduction of guarding the flight controls or talking through by the PM in specific flight phases as proposed in our analysis of the field data (see 3.4) because it may be more acceptable to the pilot community if this is done by the PIC.

The concept of intervention-based decision-making may even be extended towards the use of decision-making tools which are frequently promoted within current CRM-courses. As listed and discussed by Soll, Proske, Hofinger, & Steinhardt (2016) there are currently many different tools available (e.g. FORDEC, TDODAR)[41] which should support flight crews in systematically dealing with problem solving. All these tools are built in the same manner starting with a situation analysis, followed by a risk/benefit analysis, a decision and a review, but they all have also in common that they miss the critical steps of intervention and a check for hazardous attitudes or biases. Irrespectively from any consideration regarding leadership and teamwork it could therefore also be helpful for the aviation industry to incorporate the critical steps of intervention and self-reflecting, e.g., as a de-biasing measure, directly into these tools.

Figure 7-2: Example of an Intervention-based Decision-Making Tool

I–TDODAR	
INTERVENTION BASED DECISION-MAKING – includes A B C (Attitude, Bias, Conservatism) - Check	
1 - TIME Time available will influence how subsequent elements of the decision-making tool are accomplished. AIRCRAFT (P/P, GW, FIRE/SMOKE) - FUEL STATE (FOB, FF, FU, MINDIV) - TERR/WX (MSA, 360°-CHK, CB/TS) → **PAN/MAYDAY?** → **SET GATES** (clock, fuel, reminder, waypoint/alt.) → **G/A or use Stop Work Authority!** **WRITE DOWN TIME / FUEL GATES / NXT STEPS (UPDATE, if necessary):**	**4 - DECIDE** Consider the risks and benefits with each option. Decide on option to use. Breath & Think - Use least risk team option (LRT-DM), - Use mindful/heedful flying and decision-making - PICuS-DM: PIC takes responsibility **WRITE DOWN DECISIONS IN SHORT (UPDATE, if necessary):**
A B C - CHECK - Do or did we react hasted or impulsively? - become startled or surprised? → breath, think, relax, sit on hands, hand-/ takeover control, De-complex (buy time), if able	**A B C - CHECK** - Do or did we fear the strain of consequences?- show machoism or overconfidence?- feel uncomfortable or concerned? → "I don't like that", "No", "Stop"
2 - DIAGNOSIS Review information and indications using all relevant sources, discuss openly and agree (avoid confirmation bias) SYSTEM CHECK- Recall/EICAS/ECAM, Lights-, C/B-, Config- Check, Resets?, Cycling?, Instrument Switching, fotos/films RESOURCES: QRH/OI,OM,FCTM,MEL, ATC, OPS, MX, CAs, PAX → **Time avail: Keep looking for other facts!** **WRITE DOWN NUMBER OF PROBLEMS, PRIORITIZE (UPDATE, if necessary):**	**5 - Act or ASSIGN** Implement the decision by acting or assigning tasks (Crew, Staff, OPS, ATC) and inform relevant parties. - Communicate intention to others, - Delegate, organize, assign tasks, - Do not expect correct execution **WRITE DOWN TARGET GROUPS/PERSONS, if required (UPDATE, if necessary):**
A B C - CHECK - Do or did we judge on own beliefs? - tend to confirm own preconception?- just assume mutual mental-models?- appear invulnerable? → stay open, objective, team-minded	**A B C - CHECK** - Do or did we communicate clear & effectively? - rush or push, show signs of stress? - show over-confidence or machoism? → be honest & realistic
3 - OPTIONS Establish available options and associated risks and benefits. Use dynamic information updates. - OPS ISSUES? (NCF, FDT, DBC, PAX, SERVICE, HOTAC, WX/TFC trends) - RISKS? – THREATS/HAZARDS, ETTO, GOAL CONFLICTS, SAFETY NOT FIRST - ALTERNATIVES (ALTN, WX., NOTAM) → **INVITE CRITICS – BE SELF-CRITICAL!** **WRITE DOWN OPTIONS, MARK BEST/WORST (UPDATE, if necessary):**	**6 - REVIEW** Monitor & review situation/decisions, track progress. New I-TDODAR to challenge mindset? - Confirm task-execution (closed loop) - Re-check performed steps/items - Review parameters, situation, goals **WRITE DOWN TIME / FUEL GATES FOR REVIEW (UPDATE, if necessary):**
A B C - CHECK - Do or did we anchor too heavily on a trait?- weigh initial/recent events too high?- under-/over-estimate rare, frequent?- just agree for harmony/dishonesty? - show wishful thinking or resignation?	**A B C - CHECK** - Do or did we feel cognitive dissonance?- anchor too heavily on a trait? - decide too conservatively? → keep challenging the status quo

[41] FORDEC = Facts – Options – Risk/Benefits – Decision – Execution – Check; TDODAR = Time – Diagnose – Options – Decision – Assign – Review

In any case, if further research will support the proposed teamwork setting or if the aviation industry continues to allow the PIC to act as PF, our research clearly calls for a review of the current status and further empowerment of the role of the SIC. We promote that, like for the PIC, there should be a role description for the SIC in global regulations highlighting the basic responsibility and authorities of the SIC. Those descriptions as well as airline specific role descriptions for the SIC should definitely include a right of veto for the SIC in safety critical decisions of the PIC. However, the ultimate emergency authority of the PIC should remain, but could require written statements when having been used to overrule a SIC who is demanding a more conservative option, e.g., if the PIC decides to overrule a go-around call by the SIC. As the term *Co-Pilot* may transport the notion of being an assistant pilot only it might be useful for the industry to consider skipping this term and substitute it solely by the more appropriate term of Second-In-Command (SIC) throughout all legislative and aircraft related documents.

On top of reviewing and possibly adapting the role descriptions for the SIC, airlines could, even with the current team setting, consider modifying their policies regarding decision-making on the flight deck to foster the role of the SIC and thereby building an antidote to missing or ineffective intervention. Currently all decisions regarding a flight are allocated solely to the role of the PIC. The general decision paradigm in aviation safety risk management, which has to be performed by organizations such as airlines, is that safety risks associated with the operation of aircraft should be reduced by mitigation actions to a level that is *as low as reasonably practicable* (ALARP). “The underlying meaning is that the safety risk should be reduced using all available resources within the organization.” (Müller, Wittmer, & Drax, 2014). This ALARP-principle is in use in other societal domains (Ale et al., 2023) and high-risk-environments such as the maritime sector as well (Neff, 2020). However, the use of the ALARP principle is a rather subjective method than a scientific based approach so that eventually the accountable executive of an organization may decide to take certain risks despite concerns by others.

The same ALARP principle is in use on aircraft flight decks as well. Currently the PIC can still decide against the concerns of the SIC. Our survey has shown that this frequently happens even for go-around decisions when there is an exemption from the rule that only the PIC may take a decision.

Therefore, we propose to slightly modify the decision-making paradigm ALARP for use in dyads and small teams in high-risk-environments. By introducing the requirement that for certain decisions the SIC has to formally agree, e.g., where appropriate by their signature, it would be possible to lower psychological barriers for effective intervention by subordinates and increase the barriers for rejection of concerns by superiors[42]. By mitigating safety risks associated with the operation of aircraft to a level that is not only as low as reasonably practical (ALARP) but also *as low as required by one* within the team (*ALARBO*) it will be easier for the team to prevent safety relevant events as it automatically takes into account the highest risk perception of each team-member eventually leading to a *least risk team decision-making* (LR-TDM). Table 7-1 shows a comparison of current allocation of decisions in flight operations (ALARP) with an allocation of decisions incorporating the SIC actively into the decision-making process (ALARBO).

Table 7-1: Comparison of Decision-Making tasks using the ALARP or ALARBO concept

Decision-Making Task	**Current (ALARP)**	**Next Gen (ALARBO)***
Block-Fuel Decision	PIC only	PIC and SIC
Acceptance of Operational Flight Plan	PIC only	PIC and SIC
Acceptance of Load-Sheet	PIC only	PIC and SIC
Acceptance of Aircraft (Technical Logbook)	PIC only	PIC and SIC
Take-off Abort / Reject Decision	PIC only	PM only (PIC or SIC)
Decision to start an approach	PIC only	PIC and SIC
Acceptance of ATC clearances	PIC only	PIC and SIC
Go-around Decision	PIC and SIC	PIC, SIC, ACM**, ATCO
Flight Duty Time Variation	PIC only	PIC only (regulatory)
Aircraft Team (incl. Cabin Crew) - Briefing	PIC only	SIC as PF

*Overruling of SIC by PIC requires written statement **Additional Crew Member, e.g., enlarged flight crew

[42] Colloquially speaking this concept provides the SIC with a “Brake Pedal” which they can use in cases when the PIC is going to take unnecessary risks

Irrespective of any change in decision-making paradigms there is still the requirement to train all pilots in effective intervention as recently promoted by the FAA (2022). In addition to the call for classroom CRM as well as simulator trainings to include sessions with intervention training, we suggest that these trainings focus especially on early intervention, incorporating not only verbal (soft) intervention such as *nudging*, but also early hard interventions such as taking away controls already sufficiently early, e.g., when observing trends for certain flight parameter deviations instead of using the option of taking control as a last resort only when limits where already exceeded. As mentioned before, we additionally promote that further research should focus on investigating if guarding the flight controls by the PM or talking through by the PM in certain flight phases could be introduced as a standard operating procedure to make it easier especially for the PM to be proactive in their intervention and also to react promptly in cases of covert incapacitation of the PF, e.g., by startle or surprise effects.

These combined measures, which may be summed together as an *enhanced crew coordination concept* (ECCC), could help to overcome any reluctance to use effective intervention in practice and can promote *prevention by intervention* as a general approach to resilient behavior in aviation thereby eventually achieving the goal of zero fatalities in aircraft operations. Table 7-2 shows a comparison between the current and the proposed (enhanced) crew coordination concept.

Table 7-2: Comparison of traditional and enhanced Crew Coordination Concept

Traditional Crew Coordination Concept (CCC)	**Enhanced Crew Coordination Concept (ECCC)**
PF-centered	PM-centered (team-centered)
PM as assistant for PF	PM as supervisor (preferably PIC as PM)
Active Monitoring and deviation calls by PM	Active Intervention (verbally and physically) by PM
Configuration change on PF command only	PM initiative/request for configuration change
Only PF has hands/feet on controls	Talking/Following through by PM*
PIC-only decisions allowed	Least Risk Team Decision-Making concept
Routine combination of Authority & Leadership	Routine combination of Authority & Intervention
SIC training as Co-Pilot only	PICuS training for Co-Pilots from the beginning

* During take-off, landing, go-around

The proposed measures as well as the research approach we took by including the self-concept of practitioners to investigate the psychology behind safety relevant events might be an interesting starting point for research in other high-risk-environments or teamwork settings as well. Although there are certainly limitations regarding our research such as the use of self-reported survey data only, gathered from a rather small sample of professionals in relation to the total global population of pilots, as well as the focus on negative safety events such as incidents and accident only, we propose that our research results on the associations of intervention and decision-making with the role settings of practitioners may have implications for human teamwork and decision-making in general. More insights on the influence of status hierarchy and other factors effecting human teamwork and decision-making and possible criticism regarding our research could be drawn from observation and research of routine operation of practitioners such as proposed by the recently promoted Learning from All Operations (LAO) Initiative (Flight Safety Foundation (FSF), 2021). As our research has also revealed that there are opportunities for the aviation industry to better learn from data gained from safety relevant events, both positives and negatives, by building a single global and freely accessible database, there is sufficient data available allowing further comprehensive research.

7.3 Summarizing Conclusion

This research on flight crew teamwork and decision-making reveals evidence for a systemic safety issue in commercial aviation related to the current practice of flight crew team- and role settings. More serious safety relevant events happen with the Pilot-In-Command (PIC) on the controls as Pilot Flying (PF) and the Second-In-Command (SIC) as the pilot monitoring (PM). The results of the analysis of demographic data of the pilots involved in the events and the analysis of our global safety surveys suggest that the status hierarchy between the PIC and SIC still has negative effects on the teamwork between the pilots despite training them in teamwork methods intended to counteract this issue. However, we also found a general reluctance among pilots to apply hard interventions such as taking away control. Furthermore, our research has revealed that most of the events happen in normal operation, meaning with technically airworthy aircraft and no emergency. By means of online questionnaires and decision-making scenarios we also found that pilots' safety relevant decision-making seems to be vulnerable to negative influence of business considerations and biases making them prone to unnecessary risk-taking in practice.

By applying a novel approach to investigate the psychology behind safety relevant events in commercial aviation we found that pilots' self-concept may have a safety critical influence on pilots' attitudes towards teamwork and decision-making and may be an underlying factor for role assignment effect which is known to the industry for more than four decades now. Therefore, we discuss the implications from our research for the aviation industry and propose fundamental reforms regarding flight crew roles, their risk-management and decision-making and their team setting on commercial aircraft flight decks to mitigate the discovered safety risks. We propose a new crew assignment design, one that combines command and monitoring (PIC as PM), thereby eliminating adverse status hierarchy effects. While the legal premises for such a reform are already provided by current aviation regulations, we discuss the possible implications and requirements for a paradigm shift in commercial aviation pilots' career path and training.

In general, the research highlights that current focus of the industry on monitoring needs to be enlarged to effective intervention, including taking-away control, irrespectively of rank, age or flight experience to progress towards the goal of zero fatalities in aviation operations.

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