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Future air transportation and digital work at airports – Review and developments

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ABSTRACT

Air freight logistics has always been on the forefront of technological and international collaboration developments. With the increasing integration of digital systems at airports, issues in human-technology interaction are becoming important for efficient logistics processes. This paper provides a literature review with 123 analyzed papers from 2010 to 2021 about the core developments regarding the collaboration of humans and digital systems. Whereas for example autopilots were seen as a comfortable addition in the past, today digital systems emerge that fundamentally change the role of human workers and collaborative processes. This has to be integrated on all levels of management, not least due to safety and security regulations to keep up quality and efficiency. The importance of digitalization trends is also reflected in a rising number of research publications: Most topics are security, human-technology interaction and performance measurement in the wake of digitalization at airports and in the air transportation sector.

1. Introduction

The air transportation sector and airports are cornerstones for global passenger and cargo traffic (Sun et al., 2022). Due to the COVID-19 pandemic, the sector suffered tremendously since 2020: Suffering a major downturn in 2020, national and international passenger traffic in 2021 reached only 4.6 billion PAX, half of 2019 (IATA, 2023). This disruption implies deep changes and challenges, including the use of automation and digitalization in order to reduce personnel headcount and cost levels. International traffic for the year 2022 is over 2.5 billion passengers, which is 68.5 % of 2019 levels (IATA, 2023).

In the wake of the COVID-19 pandemic and the resulting requirements of social distancing, a high importance of digitalization has become visible in all areas of supply chain management as well as within air transportation where technology already plays an essential role (Barnett, 2019; Halpern et al., 2021; Sahoo et al., 2021). In addition, required optimization and efficiency improvements are on the top priority list for airlines and airports – leaving two options in general: first, seeking incremental changes due to specific process optimization (Bombelli and Fazi, 2022; Tseremoglou et al., 2022); second, aiming at comprehensive improvements mainly due to digitalization of processes and tasks throughout ground handling and flight operations (Chung, 2021; Remencová and Sedláčková, 2021; Wang and Sarkis, 2021).

Given such a background, it is the objective of this paper to analyze the relevant impact of digital technologies within the work settings and environments of airports (Fontainha et al., 2022; Sundarakani et al., 2018). The contributions are threefold: (a) We examine the current status of digitalization at airports regarding technology implementation; (b) we identify impacts of digital transformation and digital technologies especially regarding the specified professional groups of pilots, of cabin crew and of security staff in the context of airports; and (c) we derive a future research agenda based on the findings discussed.

Quite recently, digital transformation processes have been taking place in different segments and application areas within air transportation and at international airports. These transformation processes included applying automated processes, making information widely available on a digital basis, and using artificial intelligence (AI). There are numerous examples of such technologies at airports, like for example

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as using AI for maintenance processes with airplanes, developing and applying digital self-check-in systems for passengers, or automated screening technologies to support airport security. This is crucial as safety issues are at the heart of international air transportation (Sobieralski and Hubbert, 2022; Ruskin et al., 2021). The use of new communication networks such as the aeronautical telecommunication network (ATN) leads to improved communication quality on route with a reduced number of interpretation errors for the take-off and landing system, but also to a reduction regarding fuel consumption or flight times due to shorter flight pathways (Joshi and Sharma, 2020). During a given plane flight, a flight management system (FMS) helps to define the flight path and provides information to the pilot regarding an appropriate flight route according to flight plan and current meteorology. Continuously during this process, a pilot controls the FMS application and can provide instructions (Adams et al., 2012). As another example, instrumental landing system (ILS) are taking over a significant role from pilots during the landing phase. ILS facilitates automated processes while landing and reduces airplane accidents as a result. Before introducing ILS, it was difficult or even impossible to land manually in adverse weather conditions with sometimes zero visibility. Additionally, innovative digital applications help to assess weather conditions through meteorological observations and forecasts (Joshi and Sharma, 2020).

With innovation and transformation trends due to digital technologies, a coexistence of digital automated and human decision-making capabilities can be observed at work for the analyzed air traffic professions (Hamid et al., 2017). These developments have not yet been analyzed in a structured way regarding the implications for human–human and human-technology interaction. The term human-technology interaction includes all interactions between humans and technologies, where technology can be interpreted as machines, computers or other digital devices. In the context of airports and in relation to the professional groups, technologies are, for example, FMS (Wang et al., 2018) in the cockpit or screening technologies for cabin baggage on the ground (Huegli et al., 2020).

For the paper objective, a structured literature review is implemented, and results are outlined with the addition of a discussion and outline of current developments (Demir et al., 2015; Durach et al., 2017; Meixell and Gargeya, 2005). The structure of the paper is as follows: Section 2 is outlining the conceptual framework of the question towards digitalization in air transportation. Section 3 is describing the method applied in the structured literature review. Section 4 is explaining the results according to the six analyzed professional groups as well as dedicated sub-topics. Section 5 is showing discussion points extracted from the reviewed literature. With the view at the discussion points, propositions can be derived for further exploration. Section 6 is giving an outlook on possible future research streams.

2. Conceptual framework

For the following search process and analysis of existing literature about digitalization at the airport, the framework needs to be defined. In this paper, the term airport is used to refer to various areas around and within the airport. The definition includes the airplane and its personnel with pilots and cabin crew, the security staff at the airport main building, the airport tower with its staff for supervision of flight operations and the airplane maintenance with maintenance staff. Fig. 1 shows an overview of the different areas of the airport that are included in this literature review.

The professional groups that are addressed in this literature review with special focus (pilots, cabin crew, security staff) are also included in the overview. Digitalization in air transportation and at the airport usually has the main function to assist human decision-making (Eschen et al., 2018; Pritchett et al., 2016). Digital technologies help to generate inputs and feedback (Richards and Lamb, 2016), speed up and improve processes (Hättenschwiler et al., 2019), interconnect different areas of the airport (Al-Rubaye and Tsourdos, 2020), and make information more accessible (Kim and Kaber, 2014).

Technologies are applied in the air transportation sector and at airports to support the work of humans rather than replacing then. There are only a few examples where digital technologies at the airport completely take over the work of a professional group (Lee et al., 2014). For example, digital technologies are implemented in the security field by screening the cabin baggage with the help of automated explosive detection systems which analyze the contents and support the security staff in their decision-making (Huegli et al., 2020). With the use of an increasing number of digital technologies, there is also increased interaction between technology and humans. New forms of interactions are generated as a result of the use of digital technologies. The following example demonstrates the importance of the interaction between humans and technologies.

When we take a look into the cockpit of an airplane, there are several instances involved in any relevant decision-making process: a pilot, a co-pilot, an autopilot and a FMS. Regarding this scenario for a standard airplane, there are two digital applications interacting with two human operations and collaborate among themselves too (Wang et al., 2018). Whereas a FMS suggests a possible flight path to an autopilot application, the autopilot subsequently operates it. The human pilots can also manually set a direction or speed with the help of a cockpit control panel. During the automated flight phase, pilots are monitoring autopilot and FMS. Therefore, a complex decision-making situation can be identified among digital applications, among humans as well as between digital devices and humans.

The cabin crew on the airplane also has to coordinate constantly with each other to guarantee safety on board. Besides the coordination and agreements between the cabin crew and the pilots in the cockpit, there is also an interaction with the technology on board. For example, the cabin crew operates with alarm and warning systems that inform them of potential dangers and critical situations. In the airplane, interactions between humans but also interactions between humans and different technologies and warning systems take place.

Looking at the security check-in at the airport, there are also various different actors that interact with each other and are included in this security process. For example, there is typically one security officer who

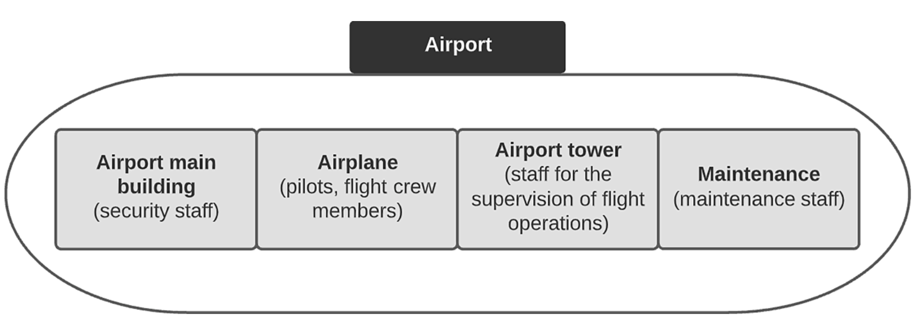

Fig. 1. Airport areas in the literature review.

screens the passengers, and the other security officer is focused on screening the cabin baggage of the passengers. The security officer usually cooperates with a cabin baggage screening technology. On the display, the security officer can identify shapes of objects that allow him to imagine what is in the cabin baggage. In this process the security officer refers to his own experience to identify dangerous objects. Additionally, it is also possible that the screening technology makes suggestions about which objects are suspicious. In the case of any insecurities, in addition to the interaction between the security officer and the screening technology, there is also an interaction with a second security officer possible. In the daily work of security staff, there is permanent coordination of decisions between humans and technologies that have a significant influence on the safety at the airport in general and in the airplane.

In the seldom case of relevant errors, in an airport context there is a high potential for damages. Maintaining an organization's operational performance in case of interruptions is of high importance. For this reason, airports among other organizations can be classified as high-reliability organizations (HRO). Dealing with uncertainty is especially critical for HRO, as they face life-and-death situations in health, safety, or emergency response (Leveson et al., 2009; Roth et al., 2006). One of the characteristics of HRO is that they must maintain their operations in a dynamic environment and characterized by potential accidents or disruptions. This can refer to working with high-risk technologies but includes all organizations responsible for the safety and well-being of large numbers of people such as customers, patients, and passengers (Weick and Sutcliffe, 2007). In this context, digitalization can increase safety and security and help to detect and avoid errors at an early stage (Agarwal et al., 2010), as digital technologies also promote an increase in data relevant to work organization and help to monitor individual performance and thus detect errors. However, digitalization in these contexts can also contribute to increased uncertainty when, for example, actions require congruent interpretation of data by multiple actors. Airports are also characterized by high reliability and high technical risk, among other things. The potential hazards ostensibly result from the dynamic environment that surrounds the organization and fosters the occurrence of errors. This, in turn, can cause errors to accumulate into unexpected events. In such situations, vital decisions must be made quickly. The respective teams in the HRO must therefore be able to keep track of the team's current status and provide all background information about what is happening, gathered with and without digital devices. Information sharing is imperative not only to reconstruct past situations, but also to use it in current and future situations to avoid potential mistakes or improve overall team performance.

Especially in HRO, maintaining functionality is critical and errors should be avoided (Arcúrio et al., 2020; Cantu et al., 2021; Foster et al., 2021; Kanki and Hobbs, 2018; LaPorte and Consolini, 1991; Roberts, 1990; Swuste et al., 2020; Weick and Sutcliffe, 2006). This is connected to the implementation of digital technologies and applications – and the core methods to unveil these changes with the presented review are outlined in the following section.

3. Methods

Based on a systematic literature review, we analyze the impact of technologies in the working environment of airports with the professional groups pilots, cabin crew and security staff. Implementing this literature review, we identify papers applying specified keywords within *Web of Science* and *EBSCOhost*. For an investigation of the impact of the digital transformation on operational work conditions, this literature review provides an overview regarding the state-of-art at airports and regarding digital changes and challenges in airports (Halpern et al., 2021; Kluge et al., 2020; Pacios Álvarez et al., 2021; Vogel, 2019). The proceeding of the literature review is based on Tranfield et al. (2003).

3.1. Search strategy

In order to make the literature search transparent and to ensure objectivity, in a first step, keywords were defined for the literature search. The search strategy is documented as detailed as possible in order to make it reproduceable (Tranfield et al., 2003). To enable a comprehensive search, in the process of defining the keywords also possible synonyms are included and categorized into keyword groups (KG) (see Table 1). KG1 contains keywords that refer to the three professional groups being considered in this literature review. KG2 refers to the environment of the airport and air transportation. KG3 includes keywords relating to various concepts about digitalization. KG4 addresses the concept of HRO and KG5 refers to the changes and challenges of digitalization.

For the search of literature in the search engines *Web of Science* and *EBSCOhost*, the keywords of the KGs are combined with each other. The keywords within a group were separated with the search operator *"OR"* and the keywords between the different KG with the search operator *"AND"*. The combination of the KGs with each other is shown in Table 2. The keywords are searched in the title, abstract and author keywords and the time span of the search is depending on the specific KG combination (see Table 2). The search of KG combinations, which include the KG3 and KG5 are time limited. In this search, results should only be shown from the year 2014 until 2021 as the last accessible complete publication year at that time, because the aim of the literature review is to identify current digital technologies in air transportation management. Publications before 2014 do not seem to be relevant with regard to the dynamic development of digital technologies.

3.2. Article selection

For the inclusion and exclusion of the literature found using the keywords (see Tables 1 and 2), criteria for exclusion are established. The procedure can be divided into two steps. Fig. 2 shows the entire process, including the number of search results and exclusion criteria.

In the first exclusion round, literature was excluded which was represented more than once in the search results, which was not in English, which did not cover the main core issue, which addressed a different subject area and those papers which were not articles, such as editorials. The term "Missing core issue" means that the paper basically addresses the topic of the search but does not refer to the airport.

Instead, an article might refer to aerospace or other similar topics. "Other subject area" means that the topic does not generally correspond to the subject area searched for. In the second exclusion round, a full text

Table 1
Keywords for literature search categorized into KG.

KG1	KG2	KG3	KG4	KG5
pilot OR pilot in aviation OR security OR airport security OR flight crew OR airport crew OR cabin crew OR security crew OR airport profession OR airplane profession	airport OR airplane OR aircraft OR air transportation OR air transportation management OR cockpit OR flight OR smart airport	digital OR digitalization OR digitalization OR digital transformation OR ai OR artificial intelligence OR machine learning OR automatic OR automatization OR automatization OR machine intelligence OR technologies OR digital technologies	HRO OR high reliability organization	digital change OR digital challenge

Table 2
KG combinations and number of search results.

KG combination	Time limitation	Number of search results EBSCOhost	Web of Science
KG1 AND KG2 AND KG3	From 2014 until 2021	286	526
KG2 AND KG4	–	15	8
KG1 AND KG4	–	14	71
KG2 AND KG5	From 2014 until 2021	3	263

screening of the articles is conducted. In this step, eight reasons for exclusions can be defined: papers are excluded from the literature review, which (1) have no relation to the human factor, (2) are specialized on unmanned aerial vehicles, (3) have no relation to digitalization or digital technologies, (4) are not related to the professional groups of pilots, cabin crew or security staff, (5) have a main focus on mereology and weather conditions, (6) analyze the mobile passport for passengers, (7) show no relation to airports or airplanes and (8) are not available. By manually searching for more relevant literature within the bibliographies of the articles included after the second round of exclusion, another 30 articles can be identified and included. This procedure of the snowball search is a common method in the search strategy of literature reviews (Wohlin, 2014).

4. Results

The results of the literature review are divided into two parts. In the descriptive analysis, we examine, describe and summarize the literature based on simple and descriptive characteristics. In the thematic analysis, we document and summarize the content of the included literature in an appropriate way (Tranfield et al., 2003). After that, we identify content-related conclusions and discussion points.

4.1. Descriptive analysis

Overall, 123 articles are included and considered in this literature review, which address digitalization and digital work at the airport. An overview of the years of the publication of the literature is shown in Fig. 3. The three publications before the year 2014 were found with the search term and keywords with HRO, because there was no restriction of the year with these search terms. When looking at the number of publications in the timeline, it is apparent that the number of publications has increased significantly since year 2018. In 2017, as well as in the

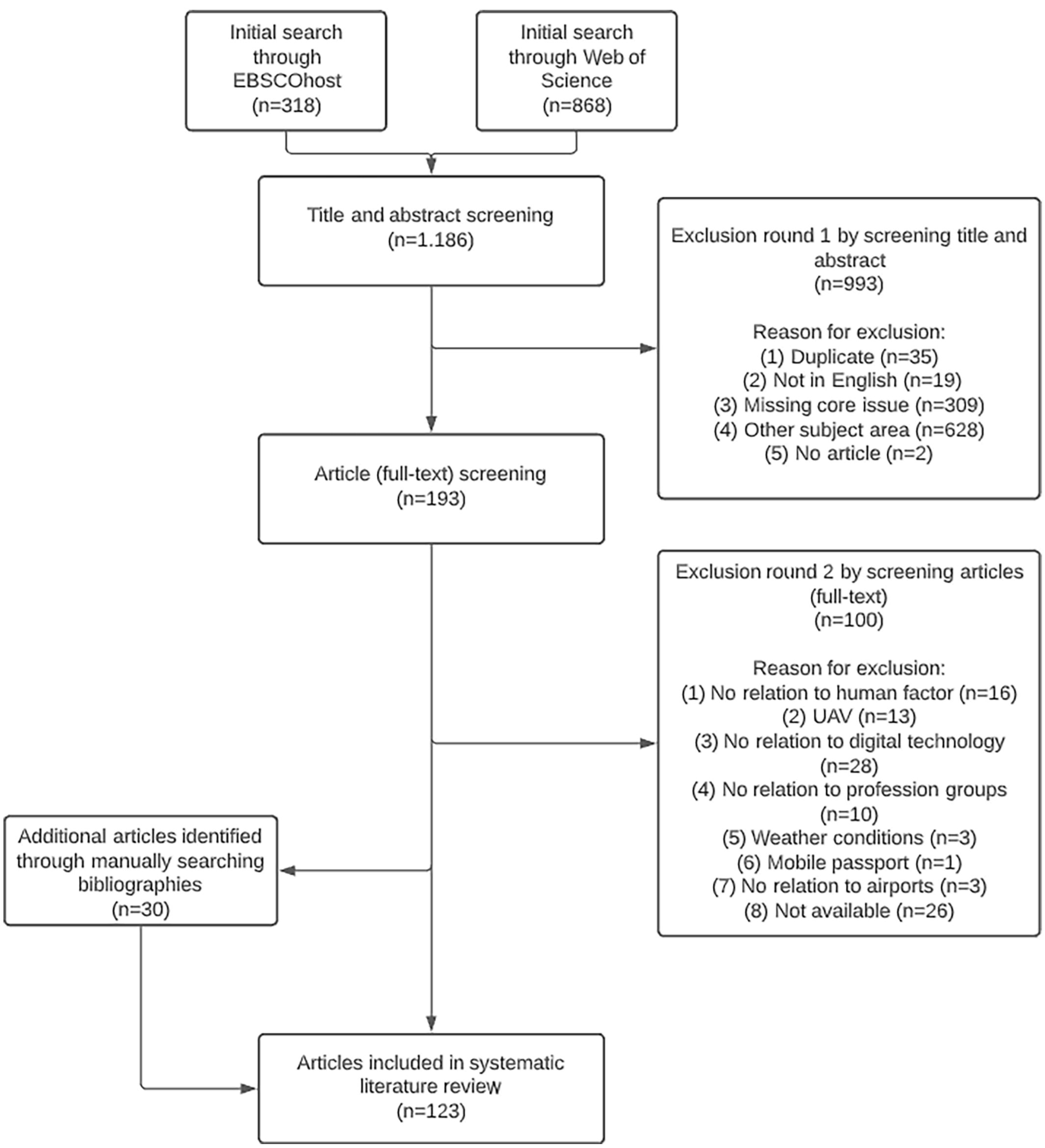

Fig. 2. Systematic review article selection with criteria of exclusion.

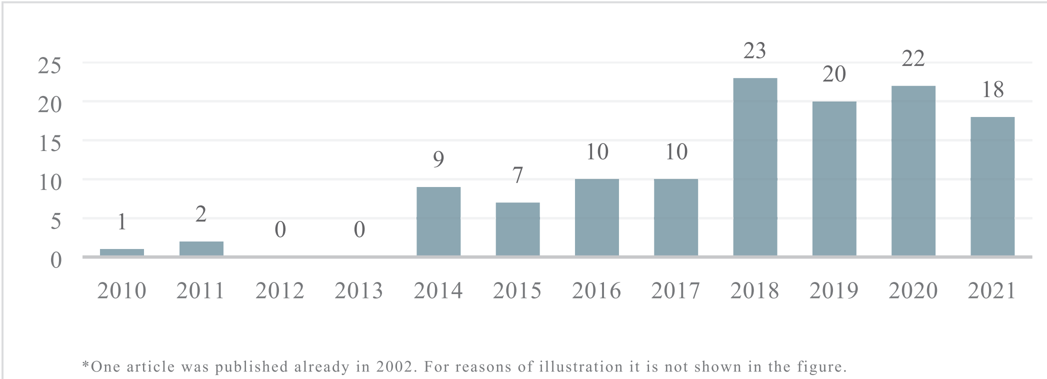

Fig. 3. Overview regarding years of publication.

year before, only ten publications were published with the topic of digitalization and digital work in airports. In year 2018, there were 23 publications, more than twice as much as the year before.

The literature can also be categorized by geographic attributes. Fig. 4 shows the continent of the articles where the authors' research institution is located. Most of the articles on air transportation management and digital work at airports were published from authors of European institutions (n = 53). North-America (n = 32) and Asia (n = 22) are ranked in second and third place. Furthermore, twelve intercontinental articles were identified.

In the literature investigated, different methods are applied. It is apparent that the method of simulations is used very often in context of digitalization at the airport to examine digital technologies, in which the technology can be tested on a limited and risk-free scale. In HRO, like the airport, the study of new technologies is useful because the impact of the use of digital technologies is not always predictable and in HRO people's lives may depend on it. For example, pilots' flight awareness is tested by measuring the fatigue status of the pilots in a simulation based on heart rate variability (Alefari et al., 2018; Qin et al., 2021). In another study, pilots' visual scanning strategies are investigated in a flight simulation (Lounis et al., 2021). In the study of Hättenschwiler et al. (2019), a simulation is used to investigate how 2D-imaging differs from 3D-imaging when examining cabin baggage with x-ray images.

In a simulation, an aim is to reproduce real circumstances and situations as exactly as possible in order to gain insights into how to deal with certain situations without any risk to the participants. This might lead to the result that the participants do not perceive the simulations as reality and that the behavior of the participants differs from that in reality.

The literature reviewed also often used the methods of qualitative interviews or quantitative surveys. These methods have been used in studies, where the object of investigation is the mindset and the perception of professional groups. For example, qualitative guided interviews were conducted to highlight what functions an ideal intelligent system on board an airplane should fulfil. The perspectives of the interviewed pilots regarding their training and the selection of pilots were also included. In addition, the analysis of the interviews provided insights into the social effects that could arise from the use of an automated system in the cockpit (Cummings et al., 2016). At the same time, quantitative methods in the form of an anonymous web-based survey of professional pilots were also used to investigate the relationship between sources of work-related stress, effects on well-being and coping mechanisms using a regression model (Cahill et al., 2021).

4.2. Thematic analysis

The thematic review of the extracted literature is divided into three parts. In the first part, referring to the aim of the literature search and the corresponding research strategy, literature is deductively classified according to the professional groups searched for with the keywords. In the second and third part of the thematic analysis, we analyzed the main and the sub topics with an inductive approach.

4.2.1. Professional groups analysis

The largest part of the literature with 47 % and 59 out of 123 publications, relates to the profession of pilots. With 30 %, the second largest part of the literature is not directly assigned to any of the three professional groups and refers more generally to all professional groups at the airport. 26 out of 123 papers (20 %) refer to the security staff at airports. It is noteworthy that only three papers address the professional group of cabin crew. This represents only 3 % of the conducted literature. Fig. 5 shows a diagram of the articles related to professional groups in the literature review.

At the airport in general, technologies like multi-cloud software

Fig. 4. Geographical location of the authors' research institutions.

(Muntés-Mulero et al., 2019), flight radar technologies (Su et al., 2020), 5G-networks (Al-Rubaye and Tsourdos, 2020), AI (Mayer, 2019), blockchain (Di Vaio and Varriale, 2020; Mayer, 2019), condition-based maintenance systems (Koenig et al., 2019), real time analytics (Guo et al., 2020), augmented and virtual reality (Eschen et al., 2018), self-check in services (Gures et al., 2018; Lee et al., 2014), biometric e-gates (Morosan, 2016; Negri et al., 2019) and wireless connectivity in airplanes (Schmidt et al., 2021) are implemented and examined in the literature.

For the professional group of pilots, technologies were presented like the autopilot (Casner and Schooler, 2014), the flight guardian (Khan et al., 2018), head-up displays (Kim and Kaber, 2014; Richards and Lamb, 2016; Stanton et al., 2020), gaze-behavior tracking (Rudi et al., 2020; Ziv, 2016), visual and tactile displays (Tippey et al., 2017), dedicated ground sign systems (Brukarczyk et al., 2021) and voice multilateration systems (Burczyk et al., 2021).

The professional group of cabin crew is not represented much in the literature in context of digitalization at the airport. As only two articles refer to the cabin crew, there are any technologies that are applied in this professional group.

For the professional group of the security staff, technologies are analyzed in the literature such as luggage control systems (Álvarez-Díaz et al., 2017), baggage security screening (Skorupski et al., 2018; Skorupski and Uchroński, 2018), deep learning-based object detection (Dhiraj and Jain, 2019), x-ray screening (Chavaillaz et al., 2019; Hättenschwiler et al., 2018; Hättenschwiler et al., 2019; Movafeghi et al., 2020), automated detection systems (Huegli et al., 2020), laser detection technology (Wu et al., 2017), facial recognition software (Tucker, 2020) and biometric security (Kim et al., 2020).

4.2.2. Main topics of the literature

In the second part of the thematic analysis, the main topics developed by reading and screening the literature based on its specific content. The literature can be classified into the main topics “Digital transformation at the airport”, “Digitalization of work” and “HRO”. The main topic “HRO” represents the smallest part of the main topics with 6 % of the total literature and eight publications. The literature in this main topic focuses on the airport as a HRO. The percentage of literature that addresses the digitalization of work at the airport is the largest with 58 % and 71 publications. The literature classified to this main topic is related to a specific professional group or job task with regard of the digitalization.

The second largest amount of literature, with 36 % and 44 publications, relates to digitalization at the airport in general. These publications focus on digital transformation at the airport, but do not address any specific professional group, job task or activity. Fig. 6 shows a diagram of the main topics of the literature review.

4.2.3. Sub topics under consideration

The sub topics described are analyzed with the consideration of the main topic they belong to. In a heat map, the subtopics are presented in combination with the main topics (see Table 3). When considering the sub topics in combination with the main topics, the main topic “Digital transformation at the airport” includes the most articles of the sub topics “Airport security/Security technology”, “Technology deployment” and “Internet of things (IoT)”. Within the main topic “Digitalization of work”, the sub topics “Performance monitoring”, “Human-technology interaction” and “Digitalization of cockpit” are most represented. Since the main topic “HRO” does not include many publications, the number of articles in the individual sub topics within this main topic “HRO” does not differ strongly, but the sub topic “Challenges in HRO” and “Airport strategy/Technological change” are the most represented. This hints at a possible research gap linking the digitalization and technology development with existing research regarding HRO concepts and learnings.

4.2.4. Sub topics of the literature

Independently of the classification of the literature into a main topic, all articles of the literature review could also be inductively classified into more specific sub topics. In the following, these sub topics are presented without consideration of their classification into a main topic. Fig. 7 presents the 13 extracted sub topics with their number of articles. The largest number of publications (n = 23) classifies into the sub-topic “Performance monitoring”. These articles mostly analyze digital technologies. They focus on the influence of implemented technologies on the performance of the employees at work. Various aspects are addressed here, for instance the analysis of safety, security and efficiency in airport terminals under an improvised explosive device attack

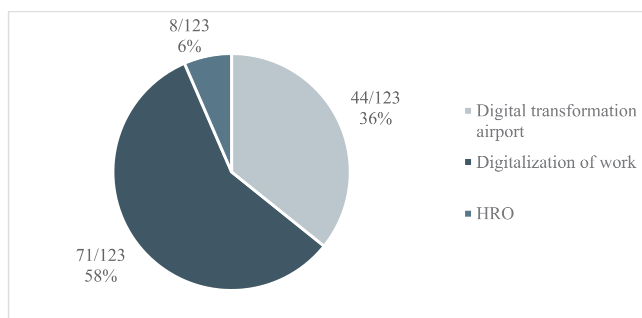

Fig. 6. Diagram of the main topic of the literature review.

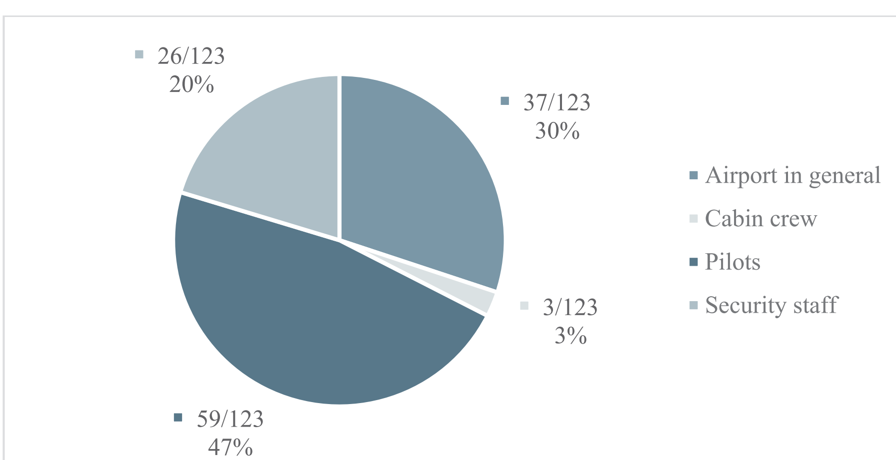

Fig. 5. Diagram of the articles related to professional groups in the literature review.

Table 3
Main topic and sub topic heat map.

	Main topic		
Sub topic	Digital transformation airport (Airport 4.0)	Digitalization of work	HRO
Airport strategy/Technology change	5	0	0
Airport security/Security technology	12	2	3
Challenges in HRO	0	0	4
Digitalization of cockpit	1	13	0
Education/Training of professionals	0	1	1
Air traffic control	4	0	0
Human factor	3	7	0
Human-technology interaction	1	14	0
Influence on teamwork	0	6	0
Internet of things (IoT)	9	0	0
Performance monitoring	1	22	0
Technology acceptance	0	6	0
Technology deployment	8	0	0

Number of articles in the literature review:					
0	1-5	6-10	11-15	16-20	20-25

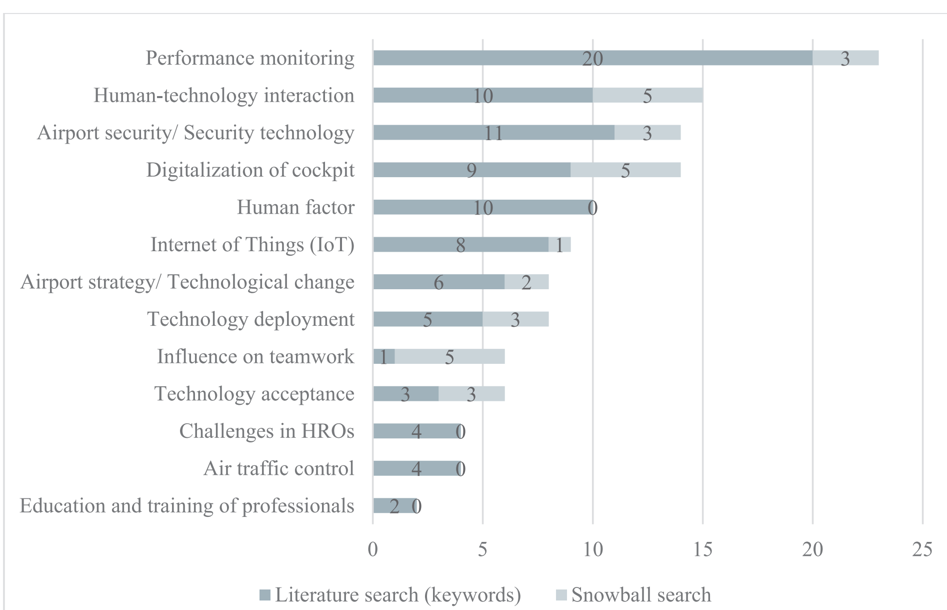

Fig. 7. Diagram of the sub topics of the literature review.

(Janssen et al., 2019), the classification of pilots' mental states using a multimodal deep learning network (Han et al., 2020), the prediction of airport screening officers' visual search competency with rapid assessments (Mitroff et al., 2018) or the establishment of air traffic management performance criteria for airlines (Evans et al., 2016).

The human being is often included in the analyses and questions are considered like how the performance of human workers changes when a specific technology is used. Airport security and the related security technology are addressed in many publications. In this context, the safety and security aspects of digital technologies are of particular interest and in the main focus of the studies.

The topic of human-technology interaction is also examined in relevant publications of the literature review (n = 15). In this context, a digital technology and the human interaction with this technology are analyzed for a selected professional group. Studies show that difficulties can occur at exactly these human-technology interactions. For example, the detection of explosives in passenger bags is being investigated by an explosive detection system for cabin baggage screening (EDSCB). The results of the research show that the isolated use of the EDSCB achieves better results with less errors than the combination of the EDSCB as a diagnostic aid with the decision by the security screener. The implementation of an EDSCB would increase the detection of explosives in passenger bags in contrast to an automation as diagnostic aid with human decision (Hättenschwiler et al., 2018). Another article shows that the error rate in the interaction between airport security screeners and automated explosives detection systems is dependent on the self-confidence of the airport security screener (Huegli et al., 2020). Furthermore, various problems are highlighted, including the fact that the interaction between technology and humans can cause errors. One more example for the human-technology interaction is the influence of head-up displays on pilots' situation awareness. The use of enhanced vision systems (EVS) gives pilots more access to relevant information during flight. Information about the terrain around the airplane are displayed via head-up displays. Concerning the situation awareness of the pilot, it was shown that the use of the EVS increases the flight path control accuracy but decreases the system (airplane) awareness of the pilot due to visual distractions (Kim and Kaber, 2014).

The implementation and analysis of security technology at the airport is also addressed in the literature (n = 14). In this context, a luggage control system based on near field communication (NFC) and homomorphic cryptography with wireless communication is analyzed (Álvarez-Díaz et al., 2017) or deep learning-based object detection strategies for threat object detection are evaluated (Dhiraj and Jain, 2019).

More specifically, a number of publications (n = 14) addresses the digitalization of the cockpit. Here, the focus is often on the professional group of pilots, and it is examined, for example, how the flight guardian, which is a platform for monitoring the aircraft and the flight parameters frequently, can improve flight safety and support the pilots in the cockpit (Khan et al., 2018). Other publications analyze the use of head-up displays for pilots (Richards and Lamb, 2016) or test single pilot operations (Brandt et al., 2015; Cummings et al., 2016; Lachter et al., 2014; Liu et al., 2016; Vu et al., 2018).

Ten publications focus on the human factor in relation to the implementation and use of digital technologies at the airport. For instance, changes of visual signals of pilots of different ages are investigated (Pescosolido et al., 2014), changing work practices of safety personnel are addressed (Bassetti, 2018) or the situation awareness of pilots is investigated (Li et al., 2020). For example, the study by Casner and Schooler (2014) was able to support the common assumption that the use of more automation in the cockpit allows the pilot to think less about the actual task. Instead, pilots reflect on the flight at a higher level.

Nine articles are assigned to the sub-topic "Internet of things (IoT)" and address the topic of technical infrastructure at the airport. For example, an article simulates an IoT acoustic monitoring system at an airport (Hilal et al., 2018), in another article 5G-IoT devices to monitor the passengers in real time are tested (Chen et al., 2021) or the development of an adaptive linear activity classification method that uses IoT-frameworks to detect human activities as well as find out who is performing unusual activities is analyzed in one publication (Karthikeswaran et al., 2019).

The topic of technological change and the airport's strategy is addressed in eight articles. For example, Halpern et al. (2021) examine factors influencing digital transformation at airports. Other articles regard the blockchain technology in the supply chain management at the airport (Di Vaio and Varriale, 2020) or the impact of data analytics on passenger experience and operational efficiency (Mullan, 2019).

Eight articles discuss the topic of "technology deployment" at the airport and for example discuss green initiatives for sustainable airport services (Cosgrove, 2018) or presenting an approach that addresses airplane delays and schedule recovery (Lavanya et al., 2017).

The impact of technology on teamwork is investigated by six articles of the literature review. For example, the effectiveness of human autonomy teaming in cockpit applications is being analyzed (Strybel et al., 2018) or the aviation crew resource management is examined (Bennett, 2019). The acceptance of implemented technology at the airport is investigated by six articles. The articles examine the implementation of biometric e-gates (Kim et al., 2020; Morosan, 2016; Negri et al., 2019) and for example analyze factors contributing to passenger resistance to the introduction of biometric e-gate technology in the context of airport security (Kim et al., 2019). Four articles examine the challenges in HRO using the airport as an example for HRO. The problem of rationality of airport security is addressed (Frederickson and LaPorte, 2002), high reliability systems (HRS) are examined (O'Neil, 2011), the structure of HRO are discussed (Rochlin, 2011) and a critical incident stress management (CISM) is analyzed (Leonhardt and Mitchell, 2010). Another four publications examine the air traffic control at the airport and the flight radar technologies, with special focus on the design of an automatic instruction system for air traffic control (Su et al., 2020) and on the automatic dependent surveillance-broadcast (ADS-B) security (Yang et al., 2019).

Two articles refer to the training of professional groups with the investigation of the behavior of security personnel at airports (Kirschenbaum and Rapaport, 2017) and the presentation of an educational model for the evaluation of airport security (Kelemen et al., 2020).

5. Discussion

5.1. State of digitalization at the airport

The aim of this paper was to analyze the relevant impact of digital technologies within the work settings and environments of airports. In the literature review, a number of different digital technologies at the airport were identified and presented. The state-of-the-art of digitalization in air transportation sector refers currently to the professional groups of pilots, security staff and to the airport in general and include technologies like flight radar technologies (Su et al., 2020) augmented and virtual reality (Eschen et al., 2018), self-check in services (Gures et al., 2018; Lee et al., 2014), head-up displays (Kim and Kaber, 2014; Richards and Lamb, 2016; Stanton et al., 2020), baggage security screening (Skorupski et al., 2018; Skorupski and Uchroński, 2018), and x-ray screening (Chavaillaz et al., 2019; Hättenschwiler et al., 2018; Hättenschwiler et al., 2019; Movafeghi et al., 2020). The professional group of cabin crew is not widely represented in the literature regarding digitalization at the airport. One explanation could be that less digital technologies are used in the work context of flight crew members. Another explanation could be that this profession has not yet become the focus of attention for research.

Proposition 1. *Digital systems at airports change job profiles and qualifications, especially for security staff and pilots; future research might analyze how cabin crew members could improve their security awareness* *supported by digital tools.*

For the professional group of pilots, the reviewed literature indicates that applied digital technologies can help to monitor important flight parameters during the flight. It can be assumed that pilots will accept technologies such as eye tracking and augmented reality for gaze-based interactions in future cockpits and that these technologies will also be able to increase the pilot's situational awareness (Rudi et al., 2020). The flight guardian in the airplane also showed convincing results in tests and statistical studies with an improvement of flight safety and as an additional support for the pilot (Khan et al., 2018).

Proposition 2. *Digital technologies in the cockpit are used as additional support for the pilot and increase flight safety, possibly enabling a proposed single pilot cockpit; future research should address more in detail under which framework conditions pilot support and safety increase is actually provided.*

For the airport in general, several factors are investigated to having an impact on the digital change at airports, related to the application and use of digital technologies. The organizational readiness directly effects digital change. Organizational readiness can be defined as the capacity to successfully implement new strategies, programs and procedures. Organizational readiness sports a direct effect on innovation, which in turn affects digital change. Also, airport size affects digital change: Smaller airports are in a weak position to achieve a certain level of digital change compared to larger airports (Halpern et al., 2021).

Proposition 3. *The development of organizational readiness can be used to speed up the rate of innovation needed for digital change at airports; future research could aim to establish supporting factors for organizational readiness in the air transport sector.*

5.2. Human-technology interaction

It is remarkable that the human factor and the human-technology interaction are key research topics in the examination of digitalization at the airport. It might seem counter-intuitive as most digital technologies are aiming at reducing possibly errors by the human factor as a major source of errors within air transportation processes. The literature shows that remarkable precursors of accidents are human-technology conflicts which are caused by insufficient automation design. This can be explained by the fact that there are more than one agent sharing the same resource. For example, modern commercial aircrafts are controlled by a human agent (the pilot or co-pilot) and a technological agent (the autopilot or FMS). These agents share a common resource, in case of the commercial aircraft, the flight guidance. But these agents have different sensors, logics and knowledge to make decisions and take over this common resource from each other. Because of this, conflicts are likely to occur. And even as automation progresses, the human factor will be even more important in a supervising role and therefore essential for safety and efficiency.

Proposition 4. *Remarkable precursors of accidents are human-technology conflicts caused by insufficient automation design; future research should explore which design elements can increase safety through automation less prone for human failure.*

Another problem is that the roles and authorities of the two agents are strictly pre-defined and may fail when it comes to abnormal situation and critical incidents because fixed settings as rules may not work in such situations (Pizziol et al., 2014). Consequently, these considerations lead to the development of dynamic guidelines to prevent conflicts on board. There is a challenge in how to design the interaction between humans and technology in terms of providing safety at the airport as an HRO. Such issues will increase with higher levels of technology implementation and are best solved in advance by integrated design, training, and awareness.

Proposition 5. *Dynamic guidelines for human-technology interaction design in critical situations can provide additional safety; research is warranted to provide the basis and details for human-technology interaction design guidelines supporting humans and increasing safety.*

All propositions are interconnected as depicted in the following figure (see Fig. 8).

6. Outlook

The literature review shows that the number of papers focusing on digitalization at airports has significantly increased in the last decade. As a result of a rising relevance of the topic and the extended use of digital technologies at airports, the application of these technologies is being examined in these papers in particular. New errors can occur as a result of the increased volumes and quantities of human-technology interaction. With regard to the airport as a HRO, which have to avoid errors at all costs, there is an increased relevance in the further investigation and research of the use of technology in HRO under the consideration of the

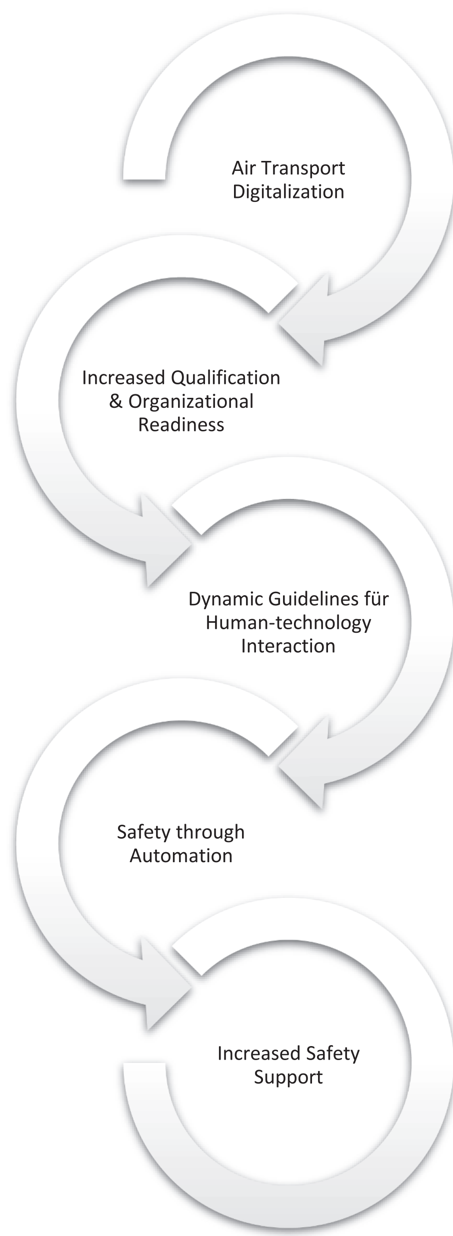

Fig. 8. Propositions regarding increased safety through air transportation digitalization.

human-technology interaction.

For future developments regarding digital technologies cooperating with humans within an advanced working environment in air transportation management, further research of the interaction between humans and digital technologies is necessary. This is due to the fact that coordination between technology and human workers is critical to operational processes as well as safety issues. In particular, the analysis of digital developments in air transportation management is in the interest of further research since airports as organizations are confronted with critical decision-making situations on a daily basis. The question of human-technology interaction is moving into a center position regarding air transport safety and efficiency due to the increased application of technology in the field. This warrants further research into the details of the human factor supervising and collaborating within digital work environments.

Declaration of Competing Interest

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Data availability

No data was used for the research described in the article.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trip.2023.100808.

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