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Identification Of Disruptive Scenarios For Airport Operations: Scoping Review

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Abstract

Airports are a vital transportation infrastructure in our interconnected world. Securing this infrastructure is a top priority of both the industry and politics. Airports are susceptible to various disruptions that can significantly impact operations, potentially leading to prolonged shutdowns. These disruptions can span multiple interdisciplinary research areas, such as cybersecurity, operations research, or risk management, making it difficult to get a comprehensive overview of disruptions and corresponding research activities. To gain an overview of current research activities regarding airport disruptions, we conducted a scoping review. The aim of this review is to identify relevant literature and develop disruption clusters that summarize multiple disruptive scenarios sharing certain characteristics. The results show a large number of current research contributions dealing with diverse disruptions, such as flooding scenarios, Unmanned Aerial Vehicles intrusions, or pandemics. We summarized all identified disruptions into five disruption clusters. The results of this review can be used both for further detailed analyses and as a starting point for comprehensive scenario analyses with airport stakeholders.

Keywords: scoping review, airport operations disruptions, disruptive scenarios, critical infrastructure, transportation sector

1. Introduction

In an increasingly interconnected and interdependent world, critical infrastructures are immensely important for the functioning of societies and the economy (Heino et al., 2019) as they deliver essential resources and services (Sheremet, 2019). Securing these infrastructures against a multitude of threats has consequently emerged as a top priority both at the global and European level (Markopoulou and Papakonstantinou, 2021). Among the broad range of critical infrastructures, the transportation sector, is considered one of the most important (also referred to as a 'lifeline' (Hallegatte et al., 2019)) and deemed essential for ensuring uninterrupted operations as well as for enhancing the daily lives of individuals (UNDRR, 2020). It encompasses various modes of transportation, including aviation and maritime systems, rail, and road, which collectively facilitate the movement of people and goods on a global scale supporting economic activities and fostering globalization. However, the very nature of this sector presents a challenge: On the one hand, there is a need for efficient transportation operations to ensure timely and cost-effective movement of goods and people (Tang et al., 2019). On the other hand, there is a growing concern for sustainability as well as safety and security (Price, 2016; Savych and Shkoda, 2020). This delicate balance between ensuring the safety and security of passengers and transportation infrastructure and maintaining the sector's efficiency is a complex and multifaceted challenge (Beecroft, 2019). In line with the high-level vision of the EU's White Paper and the Flightplan 2050 (cf. European Commission, 2011a, 2011b), European aviation strategy aims to ensure that air transport is smoothly integrated with the rest of the European multi-modal transport network, balancing it with sustainability goals (European Commission, 2023). It aims to reduce capacity constraints and improve efficiency as well as connectivity especially at airports as current research indicates that at least in some regions the "4-hour door-to-door target" is not yet achieved by far (García-Albertos et al., 2020).

Airports, as a fundamental part of the aviation system, are among the most important critical infrastructures in a globally connected society (Alexander, 2013). They serve as dynamic gateways, connecting cities, regions, and countries, and foster the global exchange of ideas, cultures, and commerce (Lunacek et al., 2021). In the context of economic development, airports play a significant role, promoting both regional and national economic growth (Campos, 2023). Consequently, airports are subject to a plethora of disruptions and challenges (Khalid et al., 2016) that can heavily impact their operations (Salotti and Suhir, 2019). These disruptions can have significant negative consequences, including flight delays and cancellations which can ultimately lead to economic losses and decreased customer satisfaction (Cook et al., 2009; Newbold, 2020; Postorino et al., 2020). They may arise from both systemic and contingent sources which can manifest themselves in different aspects (Lee et al., 2020): A limited airport capacity (Malandri et al., 2019) or a shortage of trained staff (Kazda et al., 2022) can be regarded as exemplary systemic disruptions, while contingent disruptions include severe weather events such as heavy rainfall, snowfall, etc. (Janic, 2009), strikes (Malandri et al., 2019), aircraft (also called A/C) maintenance, late crews or passengers, etc. (Lee et al., 2020), and air traffic rerouting or diversions (Pejovic et al., 2009). Therefore, it becomes increasingly important to address the challenges and opportunities within the aviation sector. In this regard, the optimization of airport processes, which is a key factor for ensuring the resilience of aviation systems (Neufville, 2020) and for enhancing the passenger experience (Wattanacharoensil et al., 2017), could be a good means to achieve, albeit limited, improvement (Grimme and Maertens, 2019). Additionally, as the demand for air transport will continue to rise, the need for more efficient airport management systems increases even more (Henke et al., 2022). Consequently, managing an airport requires a comprehensive understanding of these complex processes including possible disruptions to ensure the security, safety, and continuity of airport operations (Yin et al., 2019).

Although there are many studies dealing with various disruptions of airport processes, there is no overview of all the disruptive scenarios that have recently been addressed in the scientific literature and their frequency. To remedy this, a scoping review is conducted within this work to extract current activities and main concerns regarding disruptive scenarios to airport operations in scientific literature.

2. Materials and Methods

A scoping review is well suited for this task as it is used to map the key concepts of a research area, summarize existing literature on a particular topic, and identify research gaps (Arksey and O'Malley, 2005). The conducted scoping review is aligned with the JBI Reviewer's Manual for scoping reviews (Elm et al., 2019; Peters et al., 2020a; Peters et al., 2020b) as well as supplementary recommendations (Arksey and O'Malley, 2005; Levac et al., 2010). To further guide the elaboration, the PRISMA-ScR-checklist (Tricco et al., 2018) is used to guarantee that all necessary criteria are being considered and to minimize the risk of arbitrariness as well as biases during the reviewing process (Shamseer et al., 2015). This checklist is an extension to the PRISMA statement and is congruent with the JBI Reviewer's Manual (Peters et al., 2020b). This strengthens the rigor and reliability of the methodology and ensures the reproducibility of the study (Sarkis-Onofre et al., 2021).

2.1. Eligibility Criteria

Context: Due to the ever-increasing rate at which new information is being disseminated (Pontis et al., 2017), special care must be directed at ensuring that the information used for data analysis is still up to date. Therefore, to guarantee that the considered scenarios are still relevant at this time, only literature published from 2020 onward is considered. Furthermore, as the scoping review aims for a comprehensive list of potential disruptive scenarios for airport operations, neither geographical limitations nor limitations in airport types (regional, national, international, etc.) are set. However, existing literature often does not distinguish between airline or airport operations, but instead considers air transport or aviation in a broader context and includes related components more generally (Li et al., 2021). In these cases, if the disruption of airport operations is not explicitly addressed, the publications are considered ineligible. Moreover, no airport or multi-modal transportation networks (Xu et al., 2022) are considered but only individual airports excluding airlines and other organizations of the secure supply chain (Di Vaio and Varriale, 2020). Furthermore, if other individuals or organizations are negatively affected without an impact on airport operations (e.g., public WiFi Phishing and cybersecurity lacks negatively impacting individual passengers (Hammad and Ati, 2020) or general crime in airport terminals (Feijoo-Fernández et al., 2020)), these scenarios are deemed not eligible in the sense of the scoping review. This perspective extends to disruptions or negative influences caused by airport operations, e.g., the spread of endemics or pandemics such as influenza (Zhou et al., 2021) or COVID-19 (Daon et al., 2020) in specific, or climate damage and noise pollution for neighboring settlements (Ahmadi and Akgunduz, 2023). Moreover, records are classified as not eligible if they primarily focus on process optimization without directly linking it to airport operation disruptions. For example, studies are excluded that aim to improve object detection during security screening without specifically addressing threats posed by the identified objects (cf. Ajagbe et al., 2022). Additionally, research on enhancing crowd-counting techniques in airport terminals (cf. Pevec et al., 2021), or journal articles that assume ongoing operations and aim to optimize operative processes, such as the autonomous vehicle problem for transporting passengers from terminal to the aircraft (cf. Peng et al., 2021), are excluded as well. This also applies to terrorist scenarios or their prevention, such as object detection in airport security screening (cf. Zaliskyi et al., 2022): Records that consider this scenario are only eligible if an acute and well-defined scenario is specified such as an attack in the terminal with a gun or explosives, etc. If only dangerous objects are mentioned and the main concern focuses on methodological optimization, then these records are classified as not eligible. Furthermore, only problems or disruptions are considered that can be addressed and resolved by the airport itself in a short or medium term and that do not have a devastating or fatal effect. Thus, challenges such as sea level rise (Yesudian and Dawson, 2021) is excluded, because the enormous task to find a solution for it is too extensive. Beyond that, the exact delineation of eligible topics is particularly difficult, for example, around runway disruptive processes, as only events that can be influenced by the airport itself are considered. Runway in- and excursion are therefore excluded as they are mainly influenced by pilots and air traffic controllers. Bird strikes on the runway or on airport grounds, however, are considered eligible because the airport is responsible for animal control and can therefore influence and prevent this scenario, whereas bird strikes en-route are not eligible. Additionally excluded are potential issues that address technologies that do not yet exist or are not fully developed for the market, such as vertiports (Bertram and Wei, 2020), or disruptions caused by the planned expansion or construction of airports, such as disagreement with the surrounding population (Zuliyah et al., 2020).

Types of evidence sources: For the conducted review, peer-reviewed journal articles, which may include original research articles, review papers, or other forms of articles, and peer-reviewed conference papers are considered. Grey literature and other non-peer-reviewed literature is excluded from the scoping review as the scientific relevance and significance of the considered scenarios is a crucial part of the scoping review.

Information sources: The information sources are limited to search systems such as literature databases. The identification of relevant search systems was conducted with the help of recommendations from Gusenbauer and Haddaway(2020), which classify fourteen search systems as generally suitable for literature reviews. However, due to restricted access to certain databases, only five recommended search systems could be included and fit within the context of the scoping review: IEEE Xplore, ACM Digital Library, Scopus, TRID, and Web of Science.

Search strategy: The difficulty in formulating the search strategy arises due to the scenarios being primarily considered as secondary aspects in individual research papers. The primary focus of these papers is often on methodologies, and specific scenarios are merely utilized in case studies for illustrative purposes. Consequently, consolidating all relevant scenarios into a single comprehensive search string presents a complex task. To meet these requirements, special emphasis is placed on adhering to the methodological guidelines. According to the JBI Reviewer's Manual (cf. Peters et al., 2020b), the search strategy for evidence-based scientific literature should consist of three steps: ***(1)*** an initial limited search in appropriate search systems relevant to the research question, ***(2)*** subsequent analysis of the terminology in title, abstract, and keywords in the retrieved publications as well as a second comprehensive search across all included search systems, and *(3)* drawing on the literature that was identified as potentially eligible by forward and backward searching.

According to Snyder (2019) it is recommended to directly connect the search strategy to the relevant research objectives. Therefore, to initially identify potential search terms the following initial search terms were used:

- **airport** AND **disrupt*** AND **scenario**

For an initial elaboration of the search terms, the search systems Scopus and IEEE Xplore were used, and potential records were identified. With this strategy, fourteen records could be identified that encompassed one peer-reviewed journal article and thirteen peer-reviewed conference papers. Relevant search terms were extracted from the titles, abstracts, and keywords of the initial records according to four categories (see Table 1).

Table 1: Initial search terms, synonyms, and similar terms.

Area of consideration	Involved entities	Scenario space	Negatively altered status
Aerodrome	Aircraft	COVID-19	Conflict
Air field	Cargo	Cyber	Disruption
Air strip	Crew	Drones	Scenario
Air transportation network	Freight	IT	Threat
Air transportation sector	Gate	Natural hazards	-
Airdrome	Passenger	Terrorism	-
Airport	Pilot	Traffic	-
Airspace	Runway	Weather	-
Complex system	Taxiway	Terminal	-
Hub	-	Supply chain	-

After relevant search terms were extracted from the identified records, the IEEE Thesaurus was used to extend the range of possible search terms. In several extended test searches, using all search terms listed above, most terms could be excluded from the 'Area of consideration' dimension, as they are not frequently used in scientific publications. Solely the terms 'airport', 'hub', 'air transportation network', and 'complex system' are commonly used. As the terms 'hub' and 'complex system' are too loosely defined and network structures were excluded with the eligibility criteria, only the term 'airport' was included into the final search string. Since the goal of the scoping review was to identify the scenario spaces (such as Covid-19, terrorism, or drone intrusions) and the involved entities (such as cargo, crew, and passenger), specific scenarios were not used in the search string. The term 'scenario' was kept as part of the 'negatively altered status' dimension to still be able to identify expressions like 'disruptive scenario' or similar. Furthermore, all terms from this dimension were used regularly, which is why they were all integrated into the final search string. Where possible and necessary, the symbol asterisk was used to automatically include all possible spelling variations, word endings and lexemes, etc. This resulted in the final search string:

- **airport** AND (**conflict** OR **disrupt*** OR **scenario** OR **threat**)

This search string was then used to perform a complete search across the five selected search systems. For this purpose, it was adapted to the respective syntax of the search systems. The final search strings for the individual search systems are listed to demonstrate the differences that had to be considered (see Table 2).

Table 2: Overview of the different search strings used for the chosen search systems.

Search system	Search string
IEEE Xplore	("All Metadata":airport AND ("All Metadata":disrupt* OR "All Metadata":conflict OR "All Metadata":threat OR "All Metadata":scenario) AND ("Publication Title":journal OR "Publication Title":conference)) + Filters publication date 2020 – 2023
ACM Digital Library	[Title: airport] AND [[Title: disrupt*] OR [Title: conflict] OR [Title: threat] OR [Title: scenario]] AND [Abstract: airport] AND [[Abstract: disrupt*] OR [Abstract: conflict] OR [Abstract: threat] OR [Abstract: scenario]] AND [Keywords: airport] AND [[Keywords: disrupt*] OR [Keywords: conflict] OR [Keywords: threat] OR [Keywords: scenario]] AND [E-Publication Date: (01/01/2020 TO 12/31/2023)]
Scopus	TITLE-ABS-KEY(airport AND (disrupt* OR conflict OR threat OR scenario)) AND PUBYEAR > 2019 AND (LIMIT-TO(DOCTYPE, "ar") OR LIMIT-TO(DOCTYPE, "cp")) AND (LIMIT-TO(SRCTYPE, "j") OR LIMIT-TO(SRCTYPE , "p")) AND (LIMIT-TO(LANGUAGE, "English"))
TRID	with abstractsonly: 1, with subject: Aviation, and with result type: Articles and papers, and with language: English, with keywords containing airport AND (disrupt* OR conflict OR threat OR scenario) between dates 2020 – 2023
Web of Science	(((((TI=(airport AND (disrupt* OR conflict OR threat OR scenario))) AND AB=(airport AND (disrupt* OR conflict OR threat OR scenario))) AND LA=(English)) AND DT=(Article OR Proceedings Paper)) AND PY=(2020-2023))

With the retrieved records, forward and backward searching was carried out in accordance with the described methodology. Backward searching involves conducting a literature search within the references of the previously identified publications, while forward searching entails conducting an additional literature search with the objective of identifying further publications that cite the already identified articles (Bandara et al., 2011). Again, litmaps was used for this purpose.

Selection of evidence sources and data collection: Subsequently, all records were exported and collected in Citavi 6, and duplicates were identified and removed manually. This was done by comparing the respective duplicates and selecting the best record according to the quality and availability of the following criteria: DOI, title, abstract, full name(s) of the author(s), publication date, details of the periodical, and full-text. The title and abstract screening of the remaining records was performed with the help of an open source machine learning framework called ASReview to enhance the efficiency of the screening process (van de Schoot et al., 2021). The remaining records' full-texts were then acquired, if possible, and read carefully to extract the addressed disruptive scenario(s).

3. Results

The scoping review literature search was conducted on June 27th and 28th, 2023 and initially resulted in 1610 records. The different search systems produced varying numbers of records. As expected, the interdisciplinary search system Scopus produced by far the most results (1241). Web of Science, in contrast, although considered interdisciplinary as well, contributed only 18 resulting records. The two search systems oriented towards engineering-specific fields (IEEE Xplore - 197) and transportation research (TRID - 153) both contributed some records, while the search system for computer science (ACM Digital Library) provided only a single publication. Additionally, 17 records could be identified through other sources. Figure 1 displays the process of literature search.

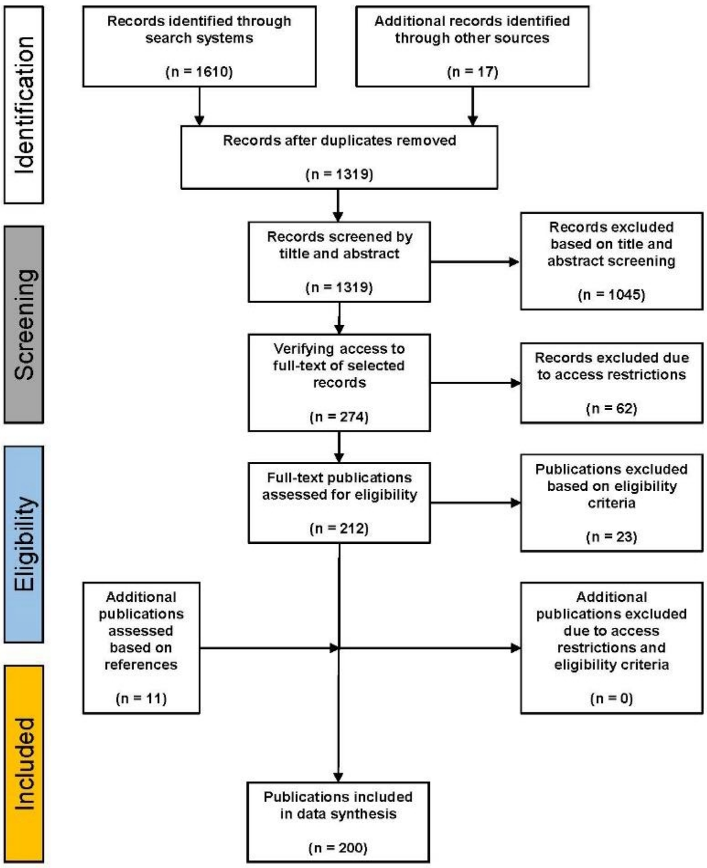

Figure 1: PRISMA flow diagram adopted from Tricco et al. (2018).

The relevant data from the publications classified as eligible were collected as introduced above. The publications contained several different scenarios from very different airport areas. To facilitate the understanding and comprehension of these scenarios, they were divided into five clusters, which in turn exhibit a different number of cluster dimensions. Some publications include several disruptions such as a blackout caused by a wildfire or a thunderstorm (cf. Alruwaili and Cipcigan, 2022). These are then listed in all relevant categories, which is why the total of all scenarios exceeds 200 (number of included publications). Due to the high degree of interconnectedness and interdependencies of the individual scenarios and the underlying processes and structures, the classification may not be optimally suited in certain cases. For example, fires are divided into wildfires (climate cluster) and terminal fires (physical cluster), or strikes are classified in the environmental cluster, while the human resources management (HRM) dimension is placed in the operational cluster. In these specific cases, the fire hazards were separated according to their locations and causes while the HRM dimension addresses the operational safety, e.g., during an A/C turnaround process, whereas strikes are not seen as a direct operational problem but more of a problem concerning the organization and its environment (environment is not exclusively understood as 'natural environment' but organizational and business surroundings and influences, etc. are considered as well). Although this might evoke some confusion, nevertheless, a clear overview of the overall scenario space can be gained, including all possible scenarios. An in-depth overview of all included publications and the scenario clusters can be found at https://www.researchgate.net/profile/Johannes-Duelks/research.

Table 3: Overview of disruptive scenarios for airport operations.

Disruption clusters	Cluster dimensions	records
Climate and weather related	Not explicitly specified	14
	Volcanic eruptions	5
	Limited visibility	3
	Lightning	1
	Extreme temperatures and wildfire	5
	Flooding	10
	Snowfall	2
	Wind shear	3
	Thunderstorms	7
	Earthquakes	3
	Total	**53**
Cyber and IT	combined	**9**
Physical	UAV intrusions	33
	Fire	1
	Power failure or blackout	3
	Terrorism	17
	Foreign Object Debris	5
	Armed conflicts and war	2
	A/C accidents	5
	Total	**66**
Operational	A/C movements	9
	Airport redevelopment	6
	Baggage handling	2
	A/C operating areas	6
	Terminal processes	26
	Human resources management	8
	Total	**57**
Environmental	Pandemic	24
	Wildlife strikes	13
	Strikes	2
	Total	**39**
Total mentions		**224**

4. Discussion

The cluster ‘Climate and weather-related disruptions’ outlines the disruptions that can result from natural hazards. Overall, ‘Climate and weather-related disruptions’ are mentioned third most frequently, accounting for 23.66 % of all listed scenarios. While most scenarios of this cluster are quite clearly determined, at least in this context, some require a more detailed consideration: ‘Not explicitly specified disruptions’ generally include bad weather conditions (cf. Rodríguez-Sanz et al., 2022) and are most commonly related to climate resilience (cf. Ösund-Ireland et al., 2022) and general climate change adaptation (cf. Vogiatzis et al., 2021). ‘Limited visibility’ includes the occurrence of fog, mist, and haze, which disrupt both take-off and landing processes as well as movement on the apron or apron roads, which is essential for processes such as aircraft handling. Under 'Flooding’ several possibilities are combined such as coastal flooding (cf. Lindbergh et al., 2022), glacial lake outburst floods (cf. Chen et al., 2022), pluvial floods (cf. Peng et al., 2020), tsunamis (cf. Kain et al., 2020), or others.

Including nine publications, the ‘Cyber and IT disruptions’ cluster accounts for 4.02 % of all scenario mentions. However, since many different scenarios are addressed that cannot be clustered well, they are presented in a non-specific combined dimension. The scenarios extracted from the relevant publications range from IoT enabled smart boarding pass failures (cf. Madana et al., 2021), or radar and communication jamming (cf. Burchfield et al., 2020) to general cybersecurity and reliability perspectives in smart airports (cf. Koroniotis et al., 2020).

The cluster of ‘Physical disruptions’ includes the most scenarios (66 ≙ 29.46 %) and mainly comprises UAV (mostly drones) movements or attacks onto airport periphery or premises (33 ≙ 50 %) and disruptions due to terrorist attacks (17 ≙ 25.76 %). Furthermore, Foreign Object Debris (FOD), which poses a threat to A/C take-off and landing (Alshammari and Chabaan, 2023), as well as A/C accidents are mentioned. It is striking that other dimensions such as blackouts, which in principle must be regarded as important and could possibly lead to devastating disruptions of airport operations (cf. Sun et al., 2020), are only very rarely (3 ≙ 4.55 %) addressed.

The aggregation of all scenario mentions (57 ≙ 25.45 %) in the cluster ‘Operational disruptions’ proved to be difficult, as different processes are covered in scientific literature that can be considered operational factors or entities. These range from A/C movements (e.g., the allocation of parking positions (cf. Bagamanova and Mota, 2020) or gate allocation and taxiway optimization (cf. Liu et al., 2023)) and the required structures such as A/C operating areas (risk analysis in airport runway maintenance (cf. Cunha et al., 2021), runway friction management (cf. Niu et al., 2021), etc.), or the expansion and conversion of airport areas (cf. Al-Ghzawi and El-Rayes, 2023) to processes in the terminal and HRM, e.g., workforce flexible break assignment problems (cf. Kiermaier et al., 2020) or safety attitude in the workplace (cf. Dobrowolska et al., 2020). The terminal processes dimension includes the most publications of this cluster (26 ≙ 45.61 %). While it can be distinguished well from the processes outside the terminal, this dimension comprises many different topics. Examples include passenger flow and congestion in terminals (cf. Hu et al., 2023; Jenčová et al., 2023), boarding processes (although boarding mainly takes place outside the terminal building, the order and sequence, etc. is already decided at the gate and the process is significantly influenced there) (cf. Schultz et al., 2023), ground service operations such as passport control and passenger transfer security services in terminals (cf. Parkan and Özkır, 2020), overall terminal security (cf. Callaway et al., 2020), security screening processes (cf. Naji et al., 2020), and general airport management decisions (cf. Pohling et al., 2022).

The ‘Environmental cluster' comprises 39 (≙ 17.41 %) scenario mentions and mainly focuses on pandemic events (24 ≙ 61.54 %) and wildlife strikes on airport premises (13 ≙ 33.33 %). Additionally, two (5.13 %) publications address strikes which by their intrinsic nature are designed to slow down and disrupt certain processes.

The statistical assessment of the scoping review indicates that many initially identified disruptions or negative impacts on airport operations had to be discarded because they did not meet the eligibility criteria (only 12.29 % of all publications were included in the analysis and scenario clustering). A common reason for exclusion arose from the fundamental methodological focus of many papers to achieve process optimization without an underlying disruptive scenario. Overall, however, Table 3 demonstrates that a good scope and a comprehensive range of scenarios could be identified that address several aspects of the challenges for air transport outlined by the EU Strategic Transport Research and Innovation Agenda (STRIA) (cf. Bousmanne et al., 2019). However, the results also show that the selected search string can be supplemented and improved with various terms such as ‘hazard’ to identify more relevant records in future applications. Additionally, by applying quality criteria for scenarios in general, as described by Mentges et al. (2023), Spaniol and Rowland (2019), as well as Gausemeier et al. (1998): exhibiting an inherent plausible situation (possibly in the future) that is based on a complex network of influence-factors and possesses an appropriate structure, the results of the scoping review demonstrate the applicability of this description to the identified scenarios as presented above.

From the plethora of topics, that would have to be analysed under the umbrella of infrastructure, passenger, and cargo security, or within the transport strategy of four hours from door to door, only the focal topic of airports and certain disruptions have been selected. Setting this focal topic is necessary because of the multitude of relations and interdependencies of related topics. Given that the European strategy paper has been published in 2011, it also has been observed that very few follow-ups have been issued either by the European Commission or other institutions other than in the private sector and within consulting businesses. The overall topic of improving transportation and its modalities has certainly not decreased, but with an increasing discussion about sustainability and climate change adaptation, the European Commission seems to have shifted the focus to accommodate and balance the perspective of sustainability with security and transportation efficiency. Still, however, air transport will continue being a vital and even critical infrastructure. Considered as a hub that combines and concentrates security aspects of infrastructure and passenger safety and security with main entry points and accessibility between different transportation modes, it is one of the most important critical infrastructure nodes of the transportation sector. This underlines the importance of this study that systematically has analysed which focus has been laid on the topic by researchers so far. The great amount of literature sources in scientific discourse, even in the very limited timeframe from 2020 to 2023 also underlines the relevance.

5. Conclusions

Taking stock of security and transportation in research is important in a world undergoing major transformations in how to deal with climate change and respectively with transportation and risks associated with it. Therefore, a scoping review was conducted to gain an overview of the various research activities in the field of disruptive scenarios for airport operations and many different active research areas were identified. These can be divided into five clusters: 'Climate and weather-related disruptions', 'Cyber and IT disruptions', 'Physical disruptions', 'Operational disruptions', and 'Environmental disruptions'. Although the inherent design of the scoping review did not involve an in-depth analysis of the literature, the number of studies and subjects indicates a great interest in research on increasing the efficiency, safety, and security of airport operations against disruptions. Due to the high criticality of airports and the high demands on their operations, this research field is prone to further increase in the near future. Based on this, the study can serve for future comparisons or more in-depth reviews as great care was taken to make the research and analysis methodology transparent.

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