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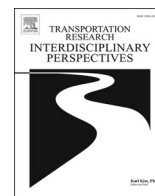
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How can airports prepare for future public health disruptions? Experiences and lessons learned during the COVID-19 pandemic from a systemic perspective based on expert interviews

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ABSTRACT

The COVID-19 pandemic proved to be an existential public health and economic crisis for the airport system. An interview study was conducted using Amsterdam Airport Schiphol as a use case to prepare for future public health disruptions. The study aimed to uncover key experiences and lessons learned by an airport system during the COVID-19 pandemic by interviewing 16 experts from airport operators, airlines, public health agencies, security services, and the government. After thematic analysis, four themes emerged. The first theme addressed the limited readiness of the airport system; the COVID-19 pandemic seemed unimaginable regardless of prior experiences with infectious diseases or weak signals. The second theme depicts an airport system running behind the facts, one that had difficulties implementing operational interventions and had to deal with extensive reorganisations. The third theme illustrated the complex relational dynamics within the airport system, such as the hesitancy of public health stakeholders towards aviation stakeholders and the government utilising a top-down approach. Finally, theme four provides lessons learned for the future whereby actively fostering a systemic approach, sensemaking capabilities, and informal relations are recommended. Current constructions like Crisis Management Teams and the Airport Operations Centre support these learnings. Further reflection and operationalisation of the study's findings are critical to proactively supporting the airport system's transition from a potential pandemic liability to a strategic asset in mitigating public health disruptions.

Introduction

The COVID-19 pandemic triggered an unforeseen existential crisis for the aviation industry, the greatest since the outbreak of the Second World War (IATA, 2020). As COVID-19 spread across the globe, travel restrictions were imposed, and travel demand diminished. Subsequently, the aviation industry reached a *de facto* standstill, as total air traffic decreased by 94 % in April 2020 compared to 2019 (IATA, 2020). In 2020, airlines lost approximately 372 billion USD in revenue while passenger numbers were reduced by 60 % (ICAO, 2022). Meanwhile, airport revenue in the European region declined by 56.7 %, translating to a loss of 37 billion USD in revenue (ATAG, 2020). Currently, the industry is bouncing back as global passenger traffic is expected to reach pre-COVID levels in 2024 (ACI, 2023).

The aviation industry played a crucial role in the spread of COVID-19 across the globe (Arora et al., 2021; Coelho et al., 2020; Sokadjo & Atchadé, 2020; Sun et al., 2022; Zhang et al., 2020), as travel is a vital

facilitator of disease spread. Precedents for the spread of diseases through air transportation are extensive and include MERS (Gardner et al., 2016), Ebola (Bogoch et al., 2015), and H1N1 (Khan et al., 2009). Ozonoff and Pepper (2005) note that air travel is one of the most critical “interconnections” from a public health standpoint. Kuo and Chiu (2021) reaffirm this by stating that the spread of COVID-19 strongly correlates to air connectivity instead of geographic distance. For example, France was affected by COVID-19 before the Philippines, as it had greater connections with China.

Within the aviation industry, by consolidating converging and diverging passenger flows, airports form the central nodes of the air transportation network. The combination of high crowd densities and throughputs in an enclosed space facilitates prime conditions for transmitting infectious diseases (Browne et al., 2016). According to Nicolaidis et al. (2012), airports are especially influential if they are dominated by long-range travel, have strong connections to other airport hubs, and have a strong west-east connection. Ribeiro et al.

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(2020) suggest that imposing strict entrance controls or locking down highly connected airports could significantly slow transmission rates. In other words, airports play an orchestrating role concerning the aviation-related spread of infectious diseases.

In the wake of the COVID-19 pandemic, a wealth of novel research emerged on airports and their role in public health disruptions. When looking into the state-of-the-art, publications can be broadly categorised around operational or organisational aspects. Regarding the operational aspects, research is conducted into airport employees' experiences, passengers' experiences, airport operations, and novel technologies. Based on a literature review, [Paisan and Wan-Chik \(2023\)](#) uncovered nine stress factors (e.g. workload, team conflicts and the pandemic itself) affecting aviation workers. Meanwhile, [Tuchen et al. \(2023\)](#) conducted a web-based survey amongst four airports: Amsterdam Airport Schiphol, Singapore Changi Airport, Taipei Taoyuan Airport, and Zurich Airport. Their main findings centred around the importance of protecting the workforce in terms of job security and against infectious diseases. Shifting towards the passengers, [Ma et al. \(2022\)](#) researched the impact of the airport's physical environment on the perceived safety, satisfaction and travel intentions through surveys. Their results underpin the importance of a clean airport as it improves the passenger experience. Regarding airport operations, [Okulicz and Rutkowska \(2021\)](#) concluded, based on operational data of Chopin Airport, that there is a lack of appropriate procedures to deal with a complete suspension of air traffic. Subsequently, they propose using more real-time data exchange through Airport Collaborative Decision-Making (A-CDM) systems. Concerning technology, [Štimac et al. \(2021\)](#) investigated the future terminal design and emphasised the need to implement contactless technologies, health checkpoints, and redesign in-terminal passenger flows. [Sun et al. \(2021\)](#) reaffirm the importance of contactless technologies while advocating for more interoperable systems amongst aviation stakeholders through Internet of Things (IoT) applications.

Regarding the organisational aspects, research is conducted on airport revenue models, strategies, and policy. [Choi \(2021\)](#) and [Colak et al. \(2023\)](#) focus on airport revenue models. [Choi \(2021\)](#) proposes to repurpose the increased dwell time of passengers, a by-product of health verifications during a pandemic, to boost passenger spending by aligning operational procedures with a commercial revenue perspective. Meanwhile, [Colak et al. \(2023\)](#) conducted an interview study on airport business models concerning the COVID-19 pandemic. They highlight the importance of diversification of revenue streams, cost minimisation, enhanced digitalisation and sustainability focus. Moving towards airport strategies, [Linden \(2021\)](#) investigated how aviation managers could better prepare for uncertain crises. He makes recommendations for short- and long-term planning based on literature and praxis. The recommendations include not exaggerating short-term development, developing a common strategy language, managing uncertainty proactively, making long-term plans by fostering a multidisciplinary dialogue and making the board a co-creation team. In addition, [de Wit \(2022\)](#) researched how airport strategic planners should cope with high-impact and uncertain events and advocated using judgement-based approaches such as scenario building and simulations through serious gaming. Finally, looking at a policy level, [Arora et al. \(2021\)](#) assessed the effects of the COVID-19 pandemic and response mechanisms while proposing a more coordinated global response framework.

Reflecting on previous publications, multiple authors ([Arora et al., 2021](#); [Linden, 2021](#); [Sun et al., 2021](#)) highlight the importance of a systemic or multi-stakeholder approach, usually put forward as a lesson learned for future crises. However, the systemic approach is rarely used as a research lens to investigate airports during the COVID-19 pandemic. Current research seems to focus more on specific operational or organisational aspects rather than the airport system as a whole. Holistically capturing the rich and complex interplay of aviation stakeholders (i.e. the airport operator and airlines) and non-aviation stakeholders (i.e. security services, ministries, and public health agencies) through first-hand accounts seems crucial for practitioners and researchers as they

portray the on-the-ground operational and organisational realities while creating preparedness for airports in the face of future public health disruptions. Subsequently, this study aims to use a systemic approach to investigate learnings and key experiences through primary data collection, with the main research question being: What are the key experiences and lessons learned by an airport system during the COVID-19 pandemic? For this study, the airport system is defined as the combination of aviation and non-aviation stakeholders, as both played a crucial role throughout the COVID-19 pandemic.

Methods

Semi-structured interviews held in a conversational style were used to capture the key experiences and lessons learned by an airport system during the COVID-19 pandemic. This method enabled capturing rich qualitative data (e.g., thoughts, intentions, and ways of organising) from multiple perspectives of a past event ([Patton, 2015](#)). Experts were recruited throughout the airport system to gain systemic insights while allowing for different perspectives. The resulting interviews were thematically analysed using [Braun and Clarke's \(2006\)](#) six-phase approach.

Case study, participants & recruitment

This study was conducted in collaboration with the Royal Schiphol Group, a Dutch airport operator managing Amsterdam Airport Schiphol (AMS). AMS was chosen as the use case for this study due to this collaboration and because it fits [Nicolaidis et al. \(2012\)](#) profile of critical airports during a public health crisis. To illustrate, AMS is dominated by long-range travel; before COVID-19, AMS was the second largest European airport with an annual total of 71.1 million passengers while being a major transfer hub, as in 2021, 43.7 % of its passengers used AMS as a layover ([Royal Schiphol Group, 2022](#)). Second, in 2022, AMS was Europe's most connected airport, ranked third globally ([ACI, 2022](#)). Third, AMS maintains strong connections to Asia and North America, with 6.6 % and 10.7 % of the passenger volumes travelling between these regions in 2019 ([Royal Schiphol Group, 2020](#)).

In preparation for expert recruitment, key stakeholders involved in AMS's system during the COVID-19 pandemic were identified by exploratively interviewing four airport operator employees and co-creating a stakeholder map ([Fig. 1](#)). The resulting map included aviation stakeholders, such as the airport operator and airlines, and non-aviation stakeholders, such as public health services and ministries.

With the key stakeholders identified, primary and secondary inclusion criteria were defined for expert recruitment. As primary criteria, experts had to represent a key stakeholder, to hold a managing or advisory function at the start of the pandemic, and their profession had to be heavily impacted by the COVID-19 pandemic. For secondary criteria, experts ideally had extensive experience in the airport system and had been exposed to other high-impact disruptions (e.g., 9/11 terrorist attacks, SARS, the eruption of the Eyjafjallajökull volcano and/or Ebola). Experts were sourced through a combination of personal networks and snowballing. To ensure diversity, experts from each relevant organisation and internal department were selected. From this point onwards, experts are referred to as participants.

Data collection

Participants were invited for a one-on-one semi-structured interview where they were asked to discuss their key experiences and lessons learned concerning the COVID-19 pandemic in the context of the airport system. An interview guide and timeline supported the interviews. The interview guide provided a set of introductory (7) and reoccurring questions (24) concerning the timeline ([Fig. 2](#)). These questions served as a structure and were introduced conversationally. Questions included, for example, *What were key moments during the first wave of the*

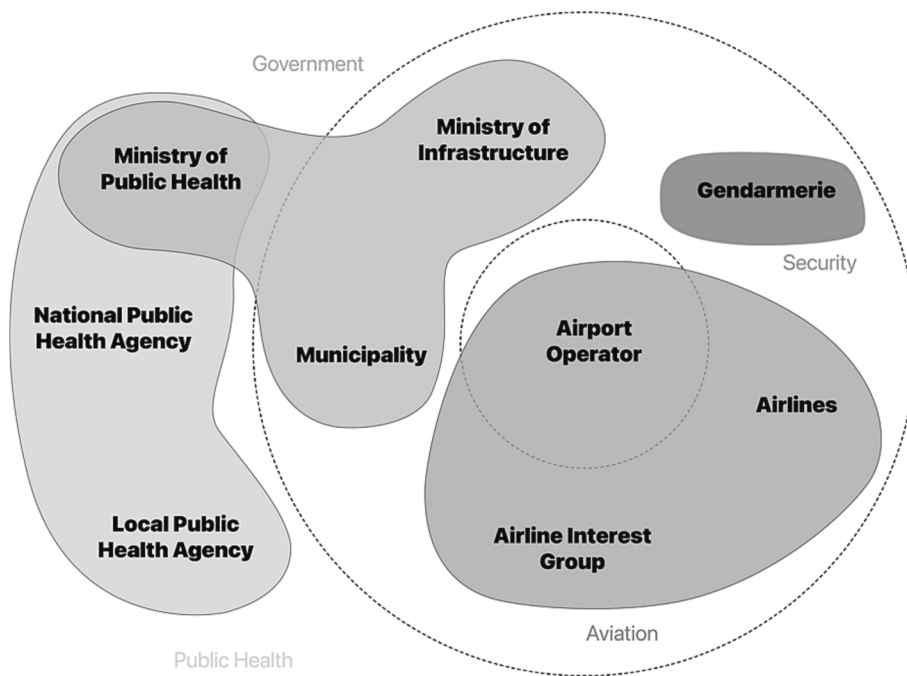


Fig. 1. The stakeholder map used for expert recruitment.

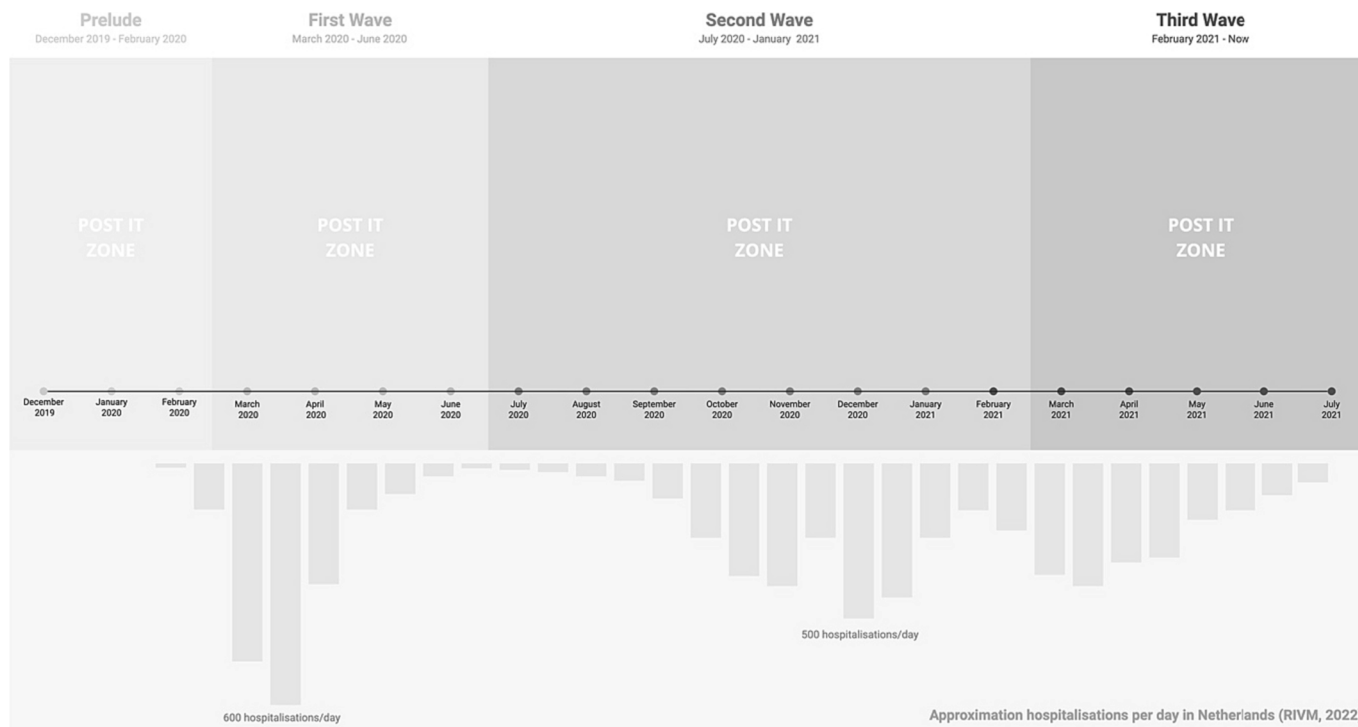


Fig. 2. The timeline used during the interviews presents four pandemic time blocks: prelude, first wave, second wave, and third wave. The graph shows the approximate number of daily hospitalisations in the Netherlands (RIVM, 2022). The grey blocks labelled “Post-it zone” functioned as a space where the interviewer made live notes using digital Post-its in Miro.

COVID-19 pandemic?; How did your organisation react?; What stakeholders were involved?; and What are your key lessons learned from the COVID-19 pandemic?

The timeline (Fig. 2) consists of four COVID-19 pandemic time blocks in the Netherlands: a prelude (December 2019 – March 2020), the period from the first cases in Wuhan (China) until the start of the so-called first wave; the first wave (March 2020 – June 2020); the second wave (July

2020 – January 2021); and the third wave (February 2021 – May 2021). The timeline functioned as a conversation starter and a frame of reference to support the participants in recollecting the order of certain events and their relation to the broader time blocks.

The interviews were in Dutch and held via Microsoft Teams. The interviews lasted between 40 and 120 min. During the interview, the timeline was placed on an online whiteboard (Miro) and shared with the

participants via Microsoft Teams' screen sharing. The online whiteboard allowed the interviewer to make live notes in the "Post-it zone" using digital Post-its. Following Francis et al. (2010), the initial analysis sample required representing the nine key stakeholders. Then, data collection continued until saturation occurred. This study defined the saturation point when three consecutive interviews yielded no new themes, excluding the initial analysis sample.

Data analysis

Inductive thematic analysis was conducted to identify, categorise, and report patterns in the participants' experiences. Methodologically, Braun & Clarke's (2006) six-phase approach was used with a constructionist lens and an emphasis on latent patterns. The six-phase approach consists of (1) familiarising with the data; (2) generating initial codes; (3) searching for themes; (4) reviewing themes; (5) defining and naming themes; and (6) reporting.

Data familiarisation consisted of three steps: listening to the interviews, transcribing the interviews, and reviewing the transcripts. Transcripts were created verbatim and formed the primary data source for the following research steps and were reviewed by the first author. The timelines presented during the interview supported the familiarisation process.

Initial coding occurred in three rounds. In the first round, the primary author coded all transcripts utilising ATLAS.ti software. In the second round, two transcripts were independently coded by the second and third authors and compared to the first-round coding results. Based on this comparison, a third round of coding took place for all transcripts. The goal of these three-round approaches was to ensure the consistency and validity of the coding while reducing interpretation bias.

After coding, the main- and subthemes were searched, developed, and reviewed in collaboration by the first, second, and third authors throughout several workshops. Several codes were discarded as they were deemed irrelevant by the first, second, and third authors. This process used Post-its, a digital (Miro), and an analogue whiteboard.

Defining and naming the main and subthemes was primarily the task of the first author; all authors then reviewed this. To support the themes, illustrative quotes from the participants were translated from Dutch to English and paraphrased to improve readability. The first author translated and paraphrased the quotes; the second and third authors then reviewed these. Finally, the report was drafted and reviewed by all authors.

Ethics

This study was approved by the TU Delft Human Research Ethics Committee (reference number 1630). None of the authors had any hierarchical relation with the participants before the study. All participants were given an informed consent form, which was presented by the first author and signed before the interview. Participants were informed that participation was voluntary and withdrawal could be made at any point. Opinions expressed during the interview were confidential and anonymised, allowing participants to speak freely.

Results

Participants

In total, 16 participants representing all stakeholders in the AMS airport system were interviewed until saturation was achieved. The participants included representatives of the gendarmerie, airport operator, airlines, national government, local government, national public health agency, and local public health agency. In the case of the airport operator and airlines, all participants worked in different departments, allowing for diverse perspectives. More detailed characteristics of the participants are given in Table 1. In general, the participants were eager

Table 1

Interview participants, coded with the first letter of their main area of expertise (S = Security, A = Aviation, G = Government and P = Public Health) followed by a number.

Participant	Function	Affiliation	Area of expertise
S1	Deputy Commander	Gendarmerie	Security
A1	Program Manager Security	Airport Operator	Aviation, Security
A2	Crisis Manager	Airport Operator	Aviation, Security & Public Health
A3	Manager Finances	Airport Operator	Aviation
A4	Lead Operations	Airport Operator	Aviation
A5	Lead Operations	Airport Operator	Aviation
A6	Program Manager Operations	Airport Operator	Aviation
A7	Manager Airline Partnerships	Airport Operator	Aviation
A8	Vice President Operations	Airline	Aviation
A9	Managing Director Health	Airline	Aviation & Public Health
A10	Secretary General	Airlines Interest Group	Aviation
G1	Manager Public Health	Ministry of Public Health	Government & Public Health
G2	Senior Policy Advisor Infrastructure	Ministry of Infrastructure	Government
G3	Manager Security	Municipality	Government & Security
P1	Infectious Diseases Specialist	Local Public Health Agency	Public Health
P2	Infectious Diseases Specialist	National Public Health Agency	Public Health

to share their experiences, giving the interviews a conversational nature. The timeline supported the participants in structuring the interviews and reflecting on their experiences.

Themes

The thematic analysis generated 521 codes, aggregated into four main themes and 12 subthemes. The four main themes are (1) limited readiness in the face of the looming COVID-19 pandemic; (2) constant firefighting; (3) complex relational dynamics; and (4) lessons learned for future public health disruptions. Table 2 provides an overview of each theme, and subthemes supported with illustrative quotes.

Limited readiness in the face of the looming COVID-19 pandemic

While reflecting on the prelude, all participants indicated that the airport system was limitedly prepared for the COVID-19 pandemic. First, prior experiences with public health disruptions (e.g. SARS, H1N1 & Ebola) seem trivialised. Second, the airport system underestimated the weak signals given at the start of the COVID-19 outbreak. Finally, the looming pandemic was unimaginable and approached anecdotally rather than as an existential threat.

A. Trivialisation of pandemics despite prior experiences

Despite prior experiences with public health disruptions (e.g., placing disinfection mats for SARS, preparing AMS regarding H1N1 and quarantining Ebola-infected passengers), the airport system seemed to trivialise the concept of a pandemic. However, participants indicated that knowledge regarding public health was predominantly theoretical. Participant G2 mentioned that pre-COVID models, stating the extreme impact of infectious diseases, were often treated laconically. The models seemed more like a theoretical exercise rather than an actual threat. Participant G1 reaffirmed this sentiment by stating that the pre-COVID experience with infectious diseases was more of an incidental nature, as no recent significant public health disruption had reached the Netherlands. Finally, several participants mentioned feeling that the

Table 2
Overview of the themes and subthemes supported with illustrative quotes.

Limited readiness in the face of the looming COVID-19 pandemic	
A. Trivialisation of pandemics despite prior experiences	<i>And those [models for easily transferable airport diseases] were very serious models, which were treated somewhat laconically at the time. [...] during the initial COVID-19 outbreak there was this sentiment of ‘it won’t come here’. [...] The COVID-19 pandemic seemed more like a theoretical exercise.” (G2)</i>
B. Underestimation of weak signals	<i>“I think we were quite naive in that period, [...] COVID-19 is there [China], and it’ll stay there” (A8)</i>
C. The unimaginable pandemic	<i>“We had an awayday with the management team and then we thought about a few “what-if” scenarios. [...] This included a scenario that we had to close a large part of the airport because the world was closing. We could mostly laugh about that because we just couldn’t imagine it.” (A6)</i>
Constant firefighting	
D. Running behind the facts	<i>“You’re running behind the facts, because the situation is already decided: China is closing, the US is closing, and suddenly there’s a lockdown [...] it just happens” (A2)</i>
E. Operational interventions with mixed success	<i>“[intervention] never got off the ground because time caught up” (A7)</i>
F. Reorganisations in aviation	<i>“Now we’re scaling up with fewer employees [...] but the number of projects hasn’t decreased so then you see a problem.” (A3)</i>
Complex relational dynamics	
G. Hesitant public health stakeholders	<i>“The National Public Health agency was very wary of conflicting interests. So they didn’t want the aviation industry [...] on their emergency committee.” (A9)</i>
H. Difficult government relations	<i>“Yes, all kinds of decision models have been set up, but they still had the function of informing rather than consulting. No public private coordination.” (G2)</i>
Lessons learned for future public health disruptions	
I. Need for a systemic approach	<i>“The pandemic showed [...] that if you do not think more in ecosystems, you will not survive [...] as an airport” (A6)</i>
J. Need for sensemaking capabilities	<i>“[...] you cannot be naive anymore [...] You must arm yourself by making plans and scenarios for the next pandemic” (A10)</i>
K. Indispensable informal relations	<i>“The informal has removed the noise and provided the solutions” (S1)</i>
L. Effective organisational interventions in practice	<i>“In the beginning we were a bit of a stiff mammoth tanker [...] but the tanker moved faster and faster [...] and was increasingly able to quickly anticipate the everyday hustle and bustle.” (A8)</i>

Dutch public health system would be capable of dealing with an infectious disease outbreak; the Netherlands seemed well prepared.

B. Underestimation of weak signals

Many participants quickly became aware of the initial outbreak in China through first-hand channels. Several aviation participants attributed this to having close commercial relations with the Chinese aviation industry. Participant A8 illustrates this by mentioning that their airline had direct connections from AMS to several Chinese cities while their partnering airline maintained a direct connection to Wuhan. The public health participants noted having different channels, referring to an international surveillance network for infectious diseases, a Program for Monitoring Emerging Diseases (ProMED) mailing list, and an aviation health advisory group.

During the prelude phase, a reoccurring sentiment was that COVID-19 was mainly perceived as a regional public health disruption rather than a potential pandemic. Participant A6 mentioned that the focus was

predominantly on the impact on the traffic to and from Asia rather than their system. There seemed to be a certain naivety that COVID-19 would remain in China. Participant A9 illustrated this with an anecdote whereby an airline, in a gesture of friendship, provided medical equipment to China during the prelude. The key assumption was that the Netherlands had plenty of equipment while being unaware of the looming pandemic. Nevertheless, A9 reflected positively on this anecdote, as the Chinese returned this gesture throughout the COVID-19 pandemic.

Throughout the prelude, China reacted rigorously by imposing travel restrictions and lockdowns. Although worrying, most participants were shocked when the US suspended travel with most European countries on the 11th of March 2020. This was viewed as a so-called “showstopper” moment.

C. The unimaginable pandemic

Although the stakeholders of the airport system were generally aware of the COVID-19 outbreak through prior experience and weak signals, actual preparations for a potential pandemic remained scarce. Several participants attributed this to the pandemic being ‘unimaginable’; there were no precedents. To illustrate, participant A6 reflected on a management team day whereby several “what-if” scenarios were developed. One scenario tackled a pandemic and the subsequent closure of a large part of the airport; reactions were fleeting as it seemed unimaginable. Other participants had similar experiences, referring to meetings where they were ridiculed when suggesting the potential impact of a pandemic. However, some preparations were made. Participant A2 referred to setting up an internal crisis team to prepare for a pandemic threat and to explore how flows of potentially infected passengers could be separated.

This unimaginability of the crisis reoccurred throughout the pandemic itself. Participants suggest that this subtheme resurfaced at the end of the first wave, whereby the sentiment of “the crisis is over” was prevalent. This unimaginable aspect is related to the theoretical experiences addressed in subtheme A and the naivety noted in subtheme B.

Constant firefighting

When the first wave hit Europe, the airport system was underprepared. Subsequently, aviation stakeholders were pushed into a position where they had to constantly react to emerging problems due to evolving knowledge of the SARS-CoV-2 virus, government regulations, and travel restrictions. Participant A8 portrayed this theme well with a firefighting analogy:

“It was quite a big fire brigade at one point, putting out fires everywhere.”

This reactive approach is also illustrated by the many diffuse interventions (e.g., health declarations, personnel protective equipment (PPE), and travel corridors) and the reorganisations by aviation stakeholders.

D. Running behind the facts

A reoccurring topic during the first wave was the volatility of the COVID-19 pandemic. Several participants referred to having no sense of control as the situation seems to be ever-changing, something uncommon in the carefully orchestrated aviation industry. Participant A2 mentioned a sentiment of running behind the facts. Events like the closure of China or the first lockdown just happened as “the situation has already been decided for you”. The running behind the fact aspect seemed most apparent during the first wave and then gradually simmered down, but never disappeared entirely. To summarise, the airport system seemed to be in a highly reactive mode throughout the pandemic. A quote from participant A7 captures the overall sentiment

well:

“A lot of running, but actually also a lot of standing still.”

The ‘running behind the facts’ nature was also illustrated by an inability to conduct long-term planning during the pandemic, as the situation constantly evolved. While traditional planning in the aviation sector (e.g., flight routes and gate planning) is developed months in advance, during the pandemic, multiple scenarios had to be continuously developed and adjusted as reality overtook existing plans. To illustrate, participant A7 stated that operational forecasts, traditionally done on a six-monthly basis, were reduced to a bi-daily basis. Subsequently, this added greatly to the workload of the aviation stakeholders’ operational departments.

E. Operational interventions with mixed success

To deal with the COVID-19 pandemic, a wide range of interventions were explored throughout the airport system. These included the use of PPE; social distancing; COVID-19 factsheets; quarantining; repatriations; temperature measuring; analogue and digital health declarations; contact tracing; introduction of homeworking; on-airport testing; cargo-in-cabin; deployment of office personnel in operational functions; travel rules engines; and travel corridors. Implementing these interventions was challenging as they were often “caught up by time”, making them obsolete because of new knowledge or a shifting context. Participants often attributed this to the “running behind the facts” aspect addressed in subtheme D.

Additionally, the effects of the interventions were often subject to discussion. The general ambition was to make the smartest measures with as few operational disruptions as possible. Participants from the aviation, government, and public health sides discussed the careful balancing acts that took place. For example, participant P2 elaborated on the difficulties of giving purely medical advice in a context with many political and economic interests. From the aviation side, scepticism arose as the effectiveness or operational viability of certain interventions was questionable. Participant A1 added that they were occasionally forced to act to maintain appearances.

Interestingly, the standstill of the aviation industry formed an opportunity for the airport system regarding large infrastructure and innovation projects. For example, participant A5 mentioned that due to a minimum of airport operations, research could be done into autonomous taxiing of aeroplanes. Testing these autonomous platforms would have been nearly impossible in a fully operational airport.

F. Reorganisations in aviation

Although COVID-19 was primarily a public health disruptor, the economic fallout for the airport system was immense. As a reaction to the standstill of air transportation, government aid kicked in, and aviation stakeholders were forced to cut jobs to maintain future viability. Although considered proportional, these reorganisations hit the industry hard while creating a brain drain as many experienced personnel left the industry. As a side-effect, informal networks disappeared throughout the airport system. Gradually, the aviation industry recovered, and flight numbers increased. However, the economic pressure and personnel numbers remained constant. This combination led to disproportionate and increased workloads for the already understaffed airport system.

Complex relational dynamics

Throughout the COVID-19 pandemic, complex dynamics emerged within the airport system as stakeholder relations were redefined. These complex dynamics were especially apparent between the public health and aviation stakeholders, as the former maintained a hesitant posture due to fears of conflicts of interest. Concurrently, the government imposed a strong top-down relationship towards the aviation

stakeholders.

G. Hesitant public health stakeholders

Several participants labelled their formal relationship with the Ministry of Public Health and the public health agencies as slow and distant. Participant A9 referred to a fear of conflicts of interest as the main reason. Public health organisations are viewed as neutral and independent entities, so engaging in direct conversation with the aviation sector could tarnish their reputation. Subsequently, aviation stakeholders could not be part of the public health emergency committee. Participant A3 reaffirmed this and spoke of a long-standing mistrust as the Ministry of Public Health has an “allergy” to everything that sounds commercial. Participant A10 nuanced this, mentioning that if public health organisations had direct contact with the aviation sector, they would also have to talk with other sectors, such as hospitality and sport; this seemed impossible during the pandemic.

Another recurring aspect is the knowledge mismatch between the highly complex and specific domains of aviation and public health. Participant A4 illustrated this, stating that while public health is knowledgeable about infectious diseases and reproduction numbers, aviation knows how to manage big crowds in a complex system.

Lastly, the COVID-19 pandemic put public health stakeholders in charge, something completely novel, as traditionally high-impact crises are chaired by the security services. This proved difficult for some participants during the first wave but was gradually accepted.

H. Difficult government relations

Relations between the government, predominantly the Ministry of Infrastructure and Public Health, and aviation stakeholders are generally reported as being problematic. Participants refer to the relations as slow, viscous, siloed, and extremely theoretical. Participant A1 mentioned that the ministries had little understanding of aviation processes. The ministries consistently underestimated the complexities of the airport system and their ripple effects. For example, when the government decided to change the testing regime for passengers entering the Netherlands, the aviation stakeholders were pushed to implement these changes within 24 h. However, implementing this was impossible for aviation stakeholders, as it required inbound passengers, from all around the world, to do novel tests within those same 24 h.

Another reoccurring theme mentioned by aviation, public health, and government participants when referring to the government is its hierarchical top-down mentality. As participant G2 stated, the emphasis was on informing the aviation sector instead of consulting with it. Participant A2 captured this sentiment well, referring to the government’s press conferences and their subsequent regulations as a ‘*diktat*’. Participant A4 stated that this top-down approach made the sector braindead as it prevented people from thinking for themselves; they simply waited for new government orders.

A dynamic which potentially caused these complex relations was the high turnover of governmental personnel. Several aviation participants noted that of those present during the first COVID-19 meeting, no civil servant remained involved. This so-called “carrousel of government” significantly hampered collaboration as the aviation sector had to re-explain the complexities of the airport system to ever-changing civil servants. Subsequently, the government was unable to build adequate domain knowledge.

Lessons learned for future public health disruptions

Four themes emerged when reflecting on the key lessons learned from the COVID-19 pandemic and preparations for future public health disruptions. First, a need was expressed for a more systemic approach by bringing together stakeholders from aviation, public health, and the government. Secondly, the pandemic exposed a shortage of sensemaking capabilities, indicating the need for improved forecasting and decision-

making tools. Thirdly, participants underlined the indispensable value of fostering informal relations as this accelerates decision-making while clearing organisational “noise”. Finally, participants mention three organisational interventions that, to an extent, address the above-mentioned organisational needs.

I. Need for a systemic approach

Many participants expressed the need for a more systemic approach within the AMS airport and international air transportation systems. This desire reoccurred in three contexts. First, participants expressed the importance of harmonisation regarding health entry requirements (e.g., PCR test, antigen test, vaccine). To paraphrase participant A10, a systemic approach is required as a virus does not stop at a border.

Secondly, participants mentioned the need for a more integral, international, and multidisciplinary approach across organisations and countries. Participant A3 stated that it seems extremely difficult to deal with new people during a crisis; hence a more multidisciplinary preparation seems critical. To cite A3, “*There comes a time when we need each other*”. Participant G3’s experiences during the pandemic build on this by referring to a steering committee meeting where roles and responsibilities were misidentified, leading to preconceptions and a degree of friction within the committee.

Thirdly, participants expressed the need for a systemic approach throughout the airport processes, stating that a collective approach is essential as resources such as personnel and money are scarce. To paraphrase participant A6, a siloed system is no longer viable.

J. Need for sensemaking capabilities

Participants indicated the need for more sensemaking capabilities to support long-term planning, decision-making and risk assessment during high-impact disruptions. References to sensemaking came in two contexts. First, participants advocated more extensive and continuous use of scenario thinking and utilising what-if constructions. Participant A2 mentioned that the goal of these scenarios is not necessarily to predict but rather to provide a framework during decision-making. Participant A10 went further, advocating that we should prepare for the next pandemic by making plans and scenarios. Participant P1 agreed, stating that public health guidelines should be revised and include more scenarios related to a long-term pandemic.

Secondly, participants suggested the need for a more risk-based approach. Instead of preventing any infectious disease from spreading, a focus should be on defining acceptable risks. As participant G2 illustrated, passengers’ body temperature could be monitored, adhere to all kinds of hygienic measures, and walk around in a plastic bag, guaranteeing zero transmission, but this is unrealistic. Finding the balance between risks is a more viable option.

K. Indispensable informal relations

Many participants referred to the indispensable value of informal networks in the airport system during the COVID-19 pandemic. These networks supported the participants in bypassing slow, formal structures and avoiding competitive issues. For example, participant A9 referred to the informal and collegial relations with public health agencies regardless of the fear of conflicts of interest.

Informal relations also helped to create clearer information flows while helping participants understand each other’s issues and bottlenecks. To quote participant S1, “*The informal relations removed the noise and provided solutions*”. Maintaining and expanding informal networks is essential in times of crisis.

L. Effective organisational interventions in practice

Participants indicated three interventions addressing prior

organisational needs: the Crisis Management Teams (CMTs), the Airport Operation Centre (APOC) and a cross-organisational steering committee. Many stakeholders started up their CMTs before and during the COVID-19 pandemic. These CMTs were often internal structures with decision-making powers consolidating different departments of a singular organisation. The frequency of meetings was usually based on emerging problems caused by the pandemic, giving it an ad hoc and informal nature. A significant asset of CMTs was their ability to increase the speed of decision-making while reducing organisational complexity. Participant A8 drew the analogy with an accelerating mammoth tanker, as decision-making was slow at the beginning of the pandemic. However, the CMT enabled his organisation to accelerate and even anticipate certain disruptions. As the pandemic became the so-called “new normal”, CMTs became more formalised. This required a shift from a crisis mode to, as participant A2 stated, a novel form of business management. In practice, formalisation mainly occurred by reducing the ad hoc nature of CMTs and giving them a fixed position in the organisation.

The Airport Operation Centre (APOC) emerged as a pre-COVID initiative of the airport operator in reaction to the increasingly congested European airspace. To manage scarce airspace, the APOC consolidates information and data sharing with others, predominantly aviation stakeholders, in one physical control centre to improve the planning and predictability of airport operations. Although the APOC was still in development during the prelude, its implementation was accelerated and repurposed to help manage the first wave of the pandemic. Participants reflected positively on the APOC as it facilitated a systemic approach. Participant S1 noted that it also gave reaction time and helped alignment.

During the first wave, a cross-organisational steering committee representing all major airport system stakeholders except the public health agencies was set up. Several participants referred to this committee as it created a formal platform for stakeholders to discuss, for example, upcoming regulations or operational interventions. No participants reflected on the functioning of this committee.

Discussion

General discussion

The COVID-19 pandemic proved to be an existential economic and public health crisis for the airport system. To be prepared for future public health disruption, this study conducted a series of expert interviews to capture and reflect on the experiences and learnings made by the airport system utilising Amsterdam Airport Schiphol (AMS) as the use case. The subsequent research question was: *What are the key experiences and lessons learned by an airport system during the COVID-19 pandemic?* The study took a systemic approach by consolidating perspectives from aviation and non-aviation stakeholders. After conducting a thematic analysis, four main themes and 12 subthemes emerged, capturing key experiences and lessons learned.

The first theme depicts the limited readiness of the airport system in the face of the looming COVID-19 pandemic. Although infectious diseases were not novel for the airport system and weak signals of the initial COVID-19 outbreak were detected, the actual pandemic’s occurrence appeared to be approached anecdotally rather than as an existential threat. A possible explanation may be the lack of experienced precedents, as the only pandemic comparable to COVID-19 was the Spanish flu in 1918. This concept of a high-impact disruption being unimaginable, often referred to as ‘Black Swans’¹, is not unique and reoccurs throughout history, for example, in the Fukushima nuclear disaster (Piore, 2011), hurricane Katerina (Perla & McGrady, 2011), and the 9/11 terrorist attacks (de Wit, 2022). In the latter case, the National

¹ Taleb (2007) defines Black Swans as rare events with an extreme impact which are only predictable with the benefit of hindsight.

Commission on Terrorist Attacks upon the United States (2004) even explicitly labelled 9/11 as “a failure of imagination”. The aspect of unimaginability continues throughout the COVID-19 pandemic and seems to be a root cause for the constant firefighting addressed in the second theme.

Nevertheless, the unimaginable nature of the COVID-19 pandemic is frequently contested. For example, [de Wit \(2022\)](#) and [Linden \(2021\)](#) argue that the pandemic was indeed imaginable and predictable, referring to a plethora of studies that addressed the dangers of infectious diseases pre-COVID (e.g., [Center for Strategic and International Studies, 2019](#); [Global Preparedness Monitoring Board, 2019](#); [World Economic Forum, 2020](#)), and attributed the limited prepared state of aviation to a lack of proactive risk management. This lack of proactive risk management seems to align with subtheme J, the need for sensemaking capabilities, whereby participants refer to the need for scenario thinking, risk-based approaches, and decision-making frameworks.

To operationalise these sensemaking capabilities, [de Wit \(2022\)](#) advocates for more judgement approaches such as scenario building or simulations through serious gaming, [Linden \(2021\)](#) introduces a framework for strategic thinking in times of shocks, and [Gössling \(2020\)](#) emphasises the need for thinking the unthinkable. An opportunity might also lie in wargaming, a form of serious gaming whereby decisions are made in a synthetic environment of conflict or competition ([Perla, 2022](#)). Instead of a hostile military, the pandemic could then be the adversary of the airport system. Its value goes beyond public health disruptions, as [Perla & McGrady \(2011\)](#) frame wargaming as an antidote against Black Swans. Further investigating these sensemaking practices seems crucial for the airport system.

The pandemic exposed segmented stakeholder dynamics, whereby aviation and public health stakeholders maintained a hesitant relationship, and government stakeholders used a strong top-down approach. These segmented dynamics negatively impacted the inner workings of the airport system as information flows, and feedback loops were fragmented. Additionally, underlying aspects such as fear of conflicts of interest between aviation and public health, large discrepancies in domain knowledge between aviation, public health, and government stakeholders, and the difficulties in knowledge building due to a high employee turnover – predominantly apparent in the ministries – are all issues requiring reflection and must be addressed by the airport system in anticipation of a future public health disruption.

Utilising a systemic approach, as addressed in subtheme I, can mitigate or reduce the complex relational dynamics within the airport system. On the one hand, similar to [Arora et al. \(2021\)](#), this refers to the need for an internationally harmonised and standardised approach between airport systems. On the other hand, as indicated by [Postma and Yeoman \(2021\)](#), this refers to the need for closer collaboration within the airport system. Following [Sun et al. \(2021\)](#), fostering such a systemic approach is crucial, as a siloed approach is undesirable and untenable for managing complex crises. Finally, the importance of informal relations among stakeholders must be highlighted; they are catalysts for a systemic approach.

Constructions like the CMTs and the APOC are crucial for the future, as they operationalised a systemic approach by physically consolidating multiple stakeholders and building informal relations while collectively conducting sensemaking. Further developing and institutionalising these organisational interventions can proactively support the long-term survival of the airport system and possibly transform it from a potential pandemic liability to a strategic asset in mitigating public health disruptions.

Limitations

The participants were asked to reflect on events from December 2019 until July 2021. The study itself took place from July 2021 until March 2022. Subsequently, depending on when the interviews took place, participants had to recollect what had happened one and a half to two

years earlier, which may have resulted in a hindsight bias. The broad data collection interval can predominantly be attributed to the primary inclusion criteria where participants had to originate from a position heavily impacted or focused on the COVID-19 pandemic. As the pandemic left the third and entered the fourth wave during data collection, participants were often busy dealing with the crisis. The participants were sourced through the personal network of the authors and snowballing, which may have resulted in a selection bias.

The study captures experiences and lessons learned until July 2021, but it does not give a complete account of the COVID-19 pandemic. During the data collection, the so-called fourth wave emerged in the Netherlands, leading to another lockdown in December 2021, which lasted until February 2022. Afterwards, the effects of the COVID-19 pandemic quickly simmered down as countries opened again. Although the period from July 2021 until February 2022 was still impactful for the airport system, it is assumed that the key experiences and lessons learned already emerged as the airport system dealt with three prior COVID-19 waves. During data collection, from July 2021 until March 2022, several participants confirmed this assumption in casual conversation.

The study used semi-structured interviews in a conversational style supported by an interview guide. This method is designed to capture rich qualitative data, so conversations were free-flowing, resulting in a general interview duration of about 60 min. Some outliers occurred, where interviews took 40 or 120 min. This variance in duration may have influenced the results; however, the number of codes and findings remained consistent per participant.

Finally, the study used the AMS airport system and the Dutch context as a central use case, thus excluding international bodies or non-Dutch stakeholders. However, the COVID-19 pandemic was a global crisis impacting the whole air transportation network. Subsequently, our findings may only apply to the AMS airport system and the Dutch context.

Conclusions

As the COVID-19 pandemic proved to be an existential crisis for the airport system, expert interviews were conducted to support preparations for future public health disruptions. When looking ahead, airport system practitioners and researchers should consider the following key experiences and lessons learned. First, the airport system was poorly prepared for the upcoming pandemic, as prior experiences with public health disruptions were trivialised, and weak signals were underestimated. During the pandemic, the airport system constantly ran behind the facts, had difficulties implementing operational interventions, and dealt with impactful reorganisations. This limited readiness and constant firefighting is predominantly attributed to the pandemic being unimaginable. An important lesson learned from the unimaginable pandemic is that airport systems must improve their sensemaking capabilities. Practices such as scenario thinking, decision-making frameworks, and simulation through wargaming must be further investigated and operationalised.

In parallel, complex relational dynamics emerged whereby public health stakeholders hesitated to collaborate with aviation stakeholders. Concurrently, the government enforced a strong top-down relationship. To improve the relation between stakeholders, the airport system should move away from a siloed approach and towards a systemic approach. Fostering informal relations among internal and external stakeholders is assumed to be a critical catalyst for facilitating such a systemic approach.

Finally, airport systems should further investigate organisational constructions like CMTs and the APOC, as they embedded systemic sensemaking by physically consolidating multiple stakeholders. Since the emergence of novel public health disruptions is a given, further reflection and operationalisation of this study's findings are critical. They will proactively support the airport system's transition from a

potential pandemic liability to a strategic asset in mitigating public health disruptions.

CRedit authorship contribution statement

Alexander Nieuwburg: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing. **Marijke Melles:** Conceptualization, Formal analysis, Methodology, Supervision, Validation, Writing – review & editing. **Suzanne Hiemstra-van Mastrigt:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Supervision, Validation, Writing – review & editing. **Sicco Santema:** Writing – review & editing, Supervision, Funding acquisition.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Alexander Nieuwburg reports financial support was provided by Royal Schiphol Group.

Data availability

The data that has been used is confidential.

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References

- ACI, 2022. Airport Industry Connectivity Report 2022. <https://www.aci-europe.org/downloads/resources/CONNECTIVITY%20REPORT%202022.pdf>.
- ACI, 2023. The impact of COVID-19 on airports—And the path to recovery. <https://aci.aero/2023/02/22/the-impact-of-covid-19-on-airportsand-the-path-to-recovery-in-dustry-outlook-for-2023/>.
- Arora, M., Tuchen, S., Nazemi, M., Blessing, L., 2021. Airport pandemic response: An assessment of impacts and strategies after one year with COVID-19. *Transp. Res. Interdis. Perspect.* 11, 100449 <https://doi.org/10.1016/j.trip.2021.100449>.
- ATAG, 2020. Aviation: Benefits Beyond Borders—Powering global economic growth, employment, trade links, tourism and support for sustainable development through air transport, despite global crisis. <https://aviationbenefits.org/media/167517/aw-oct-final-atag-abb-2020-publication-digital.pdf>.
- Bogoch, I.I., Creatore, M.I., Cetron, M.S., Brownstein, J.S., Pesik, N., Miniota, J., Tam, T., Hu, W., Nicolucci, A., Ahmed, S., Yoon, J.W., Berry, I., Hay, S.I., Anema, A., Tatem, A.J., MacFadden, D., German, M., Khan, K., 2015. Assessment of the potential for international dissemination of Ebola virus via commercial air travel during the 2014 west African outbreak. *Lancet* 385 (9962), 29–35. [https://doi.org/10.1016/S0140-6736\(14\)61828-6](https://doi.org/10.1016/S0140-6736(14)61828-6).
- Braun, V., Clarke, V., 2006. Using thematic analysis in psychology. *Qual. Res. Psychol.* 3 (2), 77–101. <https://doi.org/10.1191/1478088706qp0630a>.
- Browne, A., Ahmad, S.-S.-O., Beck, C.R., Nguyen-Van-Tam, J.S., 2016. The roles of transportation and transportation hubs in the propagation of influenza and coronaviruses: A systematic review. *J. Travel Med.* 23 (1), tav002. <https://doi.org/10.1093/jtm/tav002>.

- Center for Strategic and International Studies., (2019). Ending the Cycle of Crisis and Complacency in U.S. Global Health Security.
- Choi, J.H., 2021. Changes in airport operating procedures and implications for airport strategies post-COVID-19. *J. Air Transp. Manag.* 94, 102065 <https://doi.org/10.1016/j.jairtraman.2021.102065>.
- Coelho, M.T.P., Rodrigues, J.F.M., Medina, A.M., Scalco, P., Terribile, L.C., Vilela, B., Diniz-Filho, J.A.F., Dobrovolski, R., 2020. Global expansion of COVID-19 pandemic is driven by population size and airport connections. *PeerJ* 8, e9708.
- Colak, O., Enoch, M., Morton, C., 2023. Airport business models and the COVID-19 pandemic: An exploration of the UK case study. *J. Air Transp. Manag.* 108, 102337 <https://doi.org/10.1016/j.jairtraman.2022.102337>.
- de Wit, J., 2022. Black swans or gray rhinos on the runway? The role of uncertainty in airport strategic planning. In: *The Air Transportation Industry*. Elsevier, pp. 225–245. <https://doi.org/10.1016/B978-0-323-91522-9.00005-1>.
- Francis, J.J., Johnston, M., Robertson, C., Glidewell, L., Entwistle, V., Eccles, M.P., Grimshaw, J.M., 2010. What is an adequate sample size? Operationalising data saturation for theory-based interview studies. *Psychol. Health* 25 (10), 1229–1245. <https://doi.org/10.1080/08870440903194015>.
- Gardner, L.M., Chughtai, A.A., MacIntyre, C.R., 2016. Risk of global spread of Middle East respiratory syndrome coronavirus (MERS-CoV) via the air transport network. *J. Travel Med.* 23 (6), taw063. <https://doi.org/10.1093/jtm/taw063>.
- Global Preparedness Monitoring Board. (2019). A World at Risk: Annual Report on Global Preparedness for Health Emergencies. https://www.gpmb.org/docs/librariesprovider17/default-document-library/annual-reports/gpmb-2019-execsum-annualreport-en.pdf?sfvrsn=660402fa_28.
- Gössling, S., 2020. Risks, resilience, and pathways to sustainable aviation: A COVID-19 perspective. *J. Air Transp. Manag.* 89, 101933 <https://doi.org/10.1016/j.jairtraman.2020.101933>.
- IATA. (2020). Annual Review 2020 (p. 56).
- ICAO, 2022. Effects of Novel Coronavirus (COVID-19) on Civil Aviation: Economic Impact Analysis. https://www.icao.int/sustainability/Documents/COVID-19/ICAO_Coronavirus_Econ_Impact.pdf.
- Khan, K., Arino, J., Hu, W., Raposo, P., Sears, J., Calderon, F., Heidebrecht, C., Macdonald, M., Liauw, J., Chan, A., Gardam, M., 2009. Spread of a novel influenza A (H1N1) virus via global airline transportation. *N. Engl. J. Med.* 361 (2), 212–214. <https://doi.org/10.1056/NEJMc0904559>.
- Kuo, P.-F., Chiu, C.-S., 2021. Airline transportation and arrival time of international disease spread: A case study of Covid-19. *PLoS One* 16 (8), e0256398.
- Linden, E., 2021. Pandemics and environmental shocks: What aviation managers should learn from COVID-19 for long-term planning. *J. Air Transp. Manag.* 90, 101944 <https://doi.org/10.1016/j.jairtraman.2020.101944>.
- Ma, G., Ding, Y., Ma, J., 2022. The impact of airport physical environment on perceived safety and domestic travel intention of Chinese passengers during the COVID-19 pandemic: the mediating role of passenger satisfaction. *Sustainability* 14 (9), 5628. <https://doi.org/10.3390/su14095628>.
- National Commission on Terrorist Attacks upon the United States. (2004). *The 9/11 Commission Report: Final Report of the National Commission on Terrorist Attacks Upon the United States (9/11 Report)*. National Commission on Terrorist Attacks Upon the United States. <https://www.govinfo.gov/app/details/GPO-911REPORT>.
- Nicolaides, C., Cueto-Felgueroso, L., González, M.C., Juanes, R., 2012. A metric of influential spreading during contagion dynamics through the air transportation network. *PLoS One* 7 (7), e40961.
- Okulicz, M., Rutkowska, P., 2021. The impact of covid-19 on airport operations. In: Kwasiborska, A., Skorupski, J., Yatskiv, I. (Eds.), *Advances in Air Traffic Engineering*. Springer International Publishing, pp. 86–105. https://doi.org/10.1007/978-3-030-70924-2_8.
- Ozonoff, D., Pepper, L., 2005. Ticket to ride: Spreading germs a mile high. *Lancet* 365 (9463), 917–919. [https://doi.org/10.1016/S0140-6736\(05\)71058-8](https://doi.org/10.1016/S0140-6736(05)71058-8).
- Paisan, N. I. S., & Wan-Chik, R. Z. (2023). Stress Factors and the Impacts of COVID-19 Pandemic: A Review on the Aviation Industry. In A. Ismail, F. Nur Zulkipli, J. Jaafar, & A. Öchsner (Eds.), *Industrial Revolution in Knowledge Management and Technology* (pp. 51–59). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-29265-1_7.
- Patton, M.Q., 2015. *Qualitative research & evaluation methods: Integrating theory and practice* (Fourth edition). SAGE Publications Inc.
- Perla, P., & McGrady, E. (2011). Why wargaming works. *Naval War College Review*, 64 (3), 111–130. JSTOR.
- Perla, P. (2022). Wargaming and The Cycle of Research and Learning (1). 5(1), Article 1. <https://doi.org/10.31374/sjms.124>.
- Piore, A., 2011. Planning for the Black Swan. *Sci. Am.* 304 (6), 48–53. <https://doi.org/10.1038/scientificamerican0611-48>.
- Postma, A., Yeoman, I.S., 2021. A systems perspective as a tool to understand disruption in travel and tourism. *J. Tour. Fut.* 7 (1), 67–77. <https://doi.org/10.1108/JTF-04-2020-0052>.
- Ribeiro, S. P., Castro E Silva, A., Dáttilo, W., Reis, A. B., Góes-Neto, A., Alcantara, L. C. J., Giovanetti, M., Coura-Vital, W., Fernandes, G. W., & Azevedo, V. A. C. (2020). Severe airport sanitarian control could slow down the spreading of COVID-19 pandemics in Brazil. *PeerJ*, 8, e9446. <https://doi.org/10.7717/peerj.9446>.
- Royal Schiphol Group. (2020). *Annual Report 2019—Royal Schiphol Group* (p. 255).

- Royal Schiphol Group, 2022. Annual Report 2021—Royal Schiphol Group (p. 231).
- Sokadjo, Y.M., Atchadé, M.N., 2020. The influence of passenger air traffic on the spread of COVID-19 in the world. *Transp. Res. Interdis. Perspect.* 8, 100213 <https://doi.org/10.1016/j.trip.2020.100213>.
- Štimac, I., Pivac, J., Bračić, M., Drljača, M., 2021. The impact of COVID-19 pandemic on the future airport passenger terminals design. *Int. J. Traffic Transp. Eng.* 11 (1) [https://doi.org/10.7708/ijtte.2021.11\(1\).08](https://doi.org/10.7708/ijtte.2021.11(1).08).
- Sun, X., Wandelt, S., Zhang, A., 2021. Technological and educational challenges towards pandemic-resilient aviation. *Transp. Policy* 114, 104–115. <https://doi.org/10.1016/j.tranpol.2021.09.010>.
- Sun, X., Wandelt, S., Zhang, A., 2022. COVID-19 pandemic and air transportation: summary of recent research, policy consideration and future research directions. *Transp. Res. Interdis. Perspect.* 16, 100718 <https://doi.org/10.1016/j.trip.2022.100718>.
- Taleb, N.N., 2007. *The black swan: The impact of the highly improbable* (1st ed). Random House.
- Tuchen, S., Nazemi, M., Ghelfi-Waechter, S.M., Kim, E., Hofer, F., Chen, C.-F., Arora, M., Santema, S., Blessing, L., 2023. Experiences from the international frontlines: An exploration of the perceptions of airport employees during the COVID-19 pandemic. *J. Air Transp. Manag.* 109, 102404 <https://doi.org/10.1016/j.jairtraman.2023.102404>.
- World Economic Forum, 2020. Global Risk Report 2020. https://www3.weforum.org/docs/WEF_Global_Risk_Report_2020.pdf.
- Zhang, Y., Zhang, A., Wang, J., 2020. Exploring the roles of high-speed train, air and coach services in the spread of COVID-19 in China. *Transp. Policy* 94, 34–42. <https://doi.org/10.1016/j.tranpol.2020.05.012>.