Digital transformation: An analysis of the current state within Europe's top five digital airports

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Abstract

This paper showcases the current stage of implementation of various selected digital transformation initiatives at the top five European airports in this regard. Applying a recent theoretical framework (technology adoption framework for airports [TAFA]), the overall current level of technology adoption projects in various stages of implementation at these airports is analysed. The study's approach is based on qualitative data which was collected through interviews with airport representatives and industry experts as well as from publicly available sources. The study shows that the targeted airports understand digital transformation as the process of enhancing their passenger experience and their cost base via improved service quality and operational efficiency. The findings reveal that Europe's top five airports currently share the characteristics of Airport 3.0 and that they are progressively beginning solutions based on Industry 4.0 technologies. The outlook on current trial and pre-trial technologies shows a common trend of transformation towards Airport 4.0. There is, however, no common approach applied to this that would be coordinated either by ACI, ICAO or even IATA, leaving a patchwork of isolated technology solutions with widely divergent user experiences to be expected. In the nearer future, airports are likely to remain technological islands with no common approach to a seamless integration between them and, ideally, also between airlines and other transport providers to improve travellers' physical and digital journey. The study can serve as a guideline for airport managers and will support their decision-making processes by providing information on the strategies taken by the top five European airports.

Keywords:

digital transformation, industry 4.0, airports, technology adoption, innovation

INTRODUCTION

Due to their fundamental role in the air travel journey, airports have been striving to keep up with the changing needs of their diverse customers and have progressively abandoned an approach of 'one-size-fits-all'.[1] Airport operators nowadays are innovating their business models by differentiating and personalising offers, together with frequently introducing new digital solutions.[2] Despite the fact that these initiatives often focus on providing a seamless passenger journey locally, the ultimate goal of digital transformation at airports is much broader. It includes various improvements in operational efficiency alongside an increase in sales and ancillaries to enable improved revenue streams.[3] With air traffic just recovering from the COVID-19 pandemic, European airports now find themselves in need of more efficient and automated processes to accommodate rapid growth in demand, and investments in digital transformation initiatives are a key to this. Some well-known technologies such as smart check-in kiosks, e-gates, biometric authentication, self-bag drop, indoor navigation services and airport mobile apps are examples of such digital technology adoption.[4] Not only the rate at which the various market players implement innovative technologies, but also their capacity to enhance profits determines their performance in a highly competitive environment.

As a result, the most recent challenge for airports' digital transformation is to innovate quickly and effectively. The managerial interest is now shifted towards prioritising projects that can be easily implemented, that do not require large investments and that can generate good returns,[5] rather than requiring complex and long-term changes. An additional current issue for airports is to select which specific technologies to

implement to deliver concrete benefits for their stakeholders. To do so, it is necessary to adopt technology with a problem-centred approach and to first understand the key objectives of digital transformation.[6]

Many airports across Europe are now progressively introducing new technologies in their daily operations, with varying degrees of promotion to the public. Therefore, the study underlying this paper aims to deliver an overview of the current levels of digital transformation achieved by five leading European airports, by providing a detailed picture of the current stage of implementation of various technology adoption projects or initiatives.

To fulfil the stated objective, the study aims to answer the following questions:

1. Which project initiatives and expected benefits are the top five European airports pursuing to digitally transform their business?
2. How can these digital transformation initiatives be allocated within the technology adoption framework for airports?

INDUSTRY 4.0

The concept of Industry 4.0 (I4.0) was coined for the first time in Germany in 2011 as a strategic initiative of the Federal Government's Industry — Science Research Group aiming at digitally refining and strengthening the country's production facilities.[7] The term is used practically to define the ongoing Fourth Industrial Revolution, which is shaping the future of manufacturing through the development, commercialisation and operation of new self-regulating, autonomous and sensor-based digital systems.[8] However, the industrial and manufacturing sectors are not the only ones being affected by the changes brought upon by digital transformation. As indicated by Kagermann *et al.*[9] in the German initiative, the business potential of I4.0 also lies in the optimisation of services, which enable a wider range of applications.

As a key player in international transport, the aviation industry has been a driving force for technological development.[10] Due to the highly competitive nature of air travel, the different players are in constant need of innovative solutions to improve their economic performance. As a crucial step in the passenger journey, airports are progressively innovating their service offering with the adoption of new technologies on both the land and airside. A survey of 6,000 global passengers from Airport Dimensions and Connecta[11] has revealed an increase in demand for a variety of digital technologies and services that travellers believe would enhance their airport experience. For instance, according to 68 per cent of Gen Z passengers, the ability to order and pick up meals via an app will enhance their airport experience. A single app to simplify travel and paperwork was requested by 71 per cent of all passengers.[12] The current reality is far from this — a traveller flying from Amsterdam Airport Schiphol (AMS) via Frankfurt Airport (FRA) to John F. Kennedy Airport (JFK) would need to download each of the three airports' individual apps to benefit from their functionalities on ground, while probably using an unconnected fourth airline app to manage check-in and the airborne part of their journey — and much potential remains to be harvested from better interconnectivity for the passenger. The situation of airports to improve key operational processes — passenger-related or purely internal — is much simpler. Keeping in mind regulatory (eg passenger security or data privacy

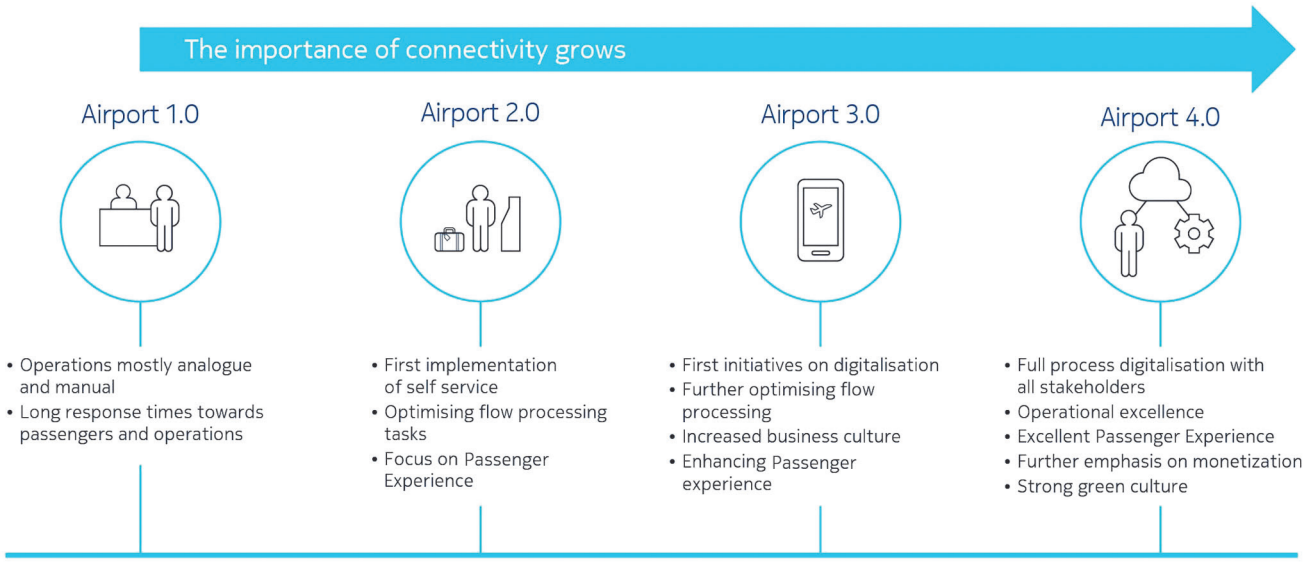

Figure 1 The four stages of airport digital maturity
Source: Adapted from Nokia

related) restrictions, airports are relatively free to innovate performance-enhancing digital solutions in test settings, pilots, and later full-scale implementation (Figure 1).

THE TAFA FRAMEWORK

Despite airport digital transformation being a common theme nowadays, only a few academic works embrace the topic's significance and support it with theoretical models. According to Nordqvist,[13] given the issues that the aviation sector is currently experiencing, it is not surprising that most studies focus on operational and cost-efficiency. However, research from Tan and Masood[14] focused on developing a broad technology adoption framework for airports seeking to implement new technology. The framework was named the technology adoption framework for airports (TAFA), displayed in Figure 2, and was applied in a case study for a major Asian Airport. The core section is the technology adoption process, and it involves three steps, which are utilised to categorise the maturity level of technologies that airports intend to implement.

- The first step is the pre-trial phase, which consists of taking a problem-based method to develop tangible solutions for a specific challenge. This solution must be checked in three phases called proof of technology, proof of business and proof of operations.
- Next, the trial phase is characterised by the execution of a proof of concept (PoC) and pilot testing for the ideated technology. Given a satisfactory outcome of this phase, the last phase is the successful implementation, connected to the framework's section 'Important I4.0 technologies for Airport 4.0', which lists a variety of core systems and I4.0 tools that are at the base of the development of different innovations in the airport context. The upper part of the TAFA is named objectives for digital transformation and consists of a series of outcomes that the implemented technologies should aim for.

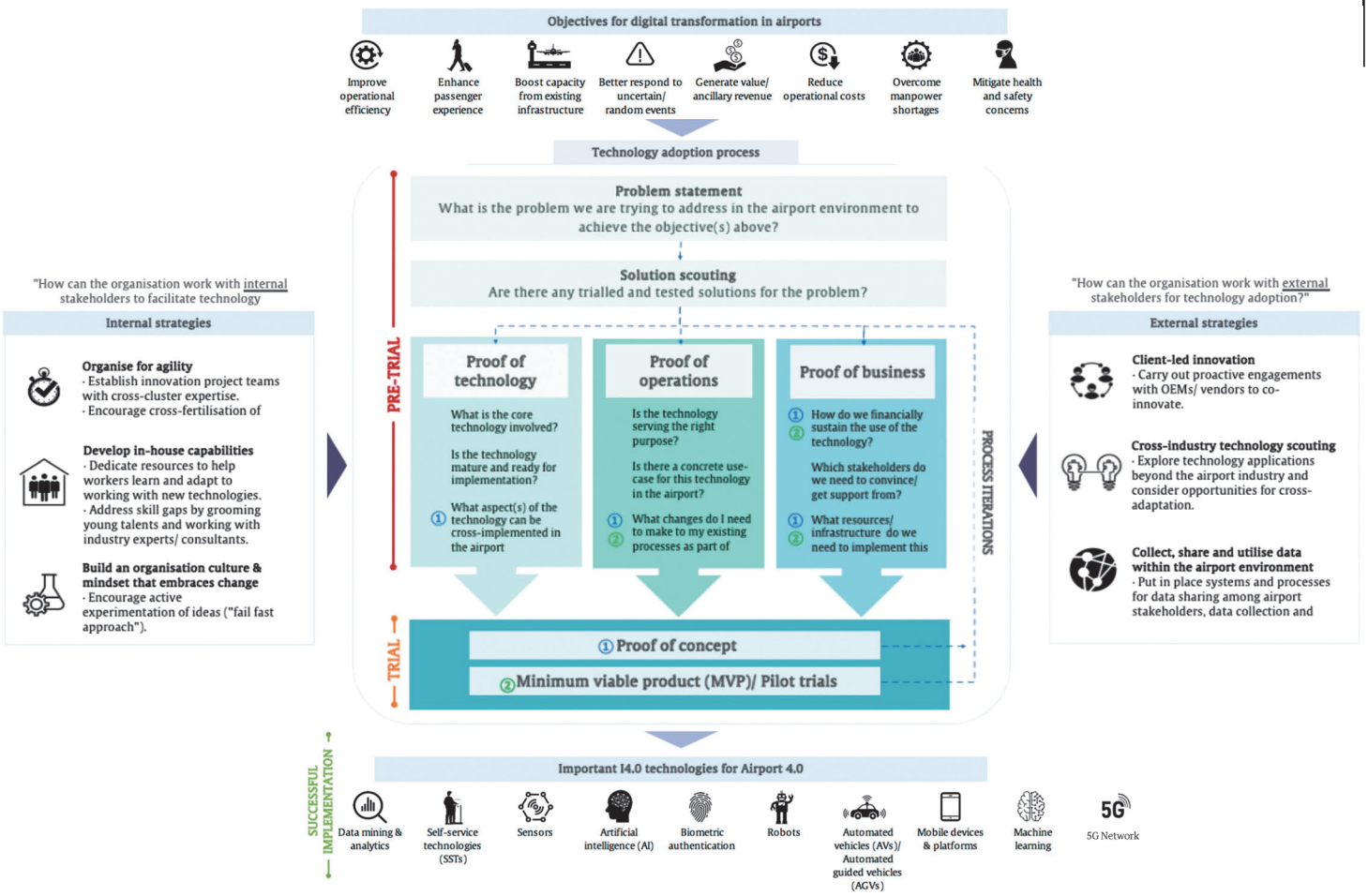

Figure 2 Technology adoption framework for airports (TAFA)
Source: Adapted from Tan & Masood

- Last, the framework includes the strategies to facilitate the technology adoption process, further divided into two sections outlining internal and external practices that support airports in successfully embracing innovation.[15] Due to the sensitive nature of these practices of airports, they were excluded from the scope of our study to avoid potential conflicts of interest for our interview partners in the collection of primary data.

RESEARCH DESIGN AND METHOD

As the exploratory study aims at clarifying the understanding of digital transformation and technology adoption in the context of European airports, a research approach based on qualitative data was chosen for the study. The authors performed semi-structured interviews in combination with secondary data analysis. The study followed three steps: In the first step, the five airports were selected according to a weighted combination of variables such as number of airlines, number of annual passengers, digital transformation initiatives, and awards received. The resulting target population of this research consists of:

1. Amsterdam Schiphol Airport (AMS);
2. iGA Istanbul Grand Airport (IST);
3. Rome Fiumicino Airport (FCO);
4. Munich Airport (MUC);
5. Paris Charles de Gaulle (CDG).

Readers familiar with the European airport infrastructure may consider major airports to be missing from this top five list, such as Frankfurt (FRA) or London Heathrow (LHR). Even though they are far larger in many traffic-related key performance indicators (KPIs) than eg FCO, the criteria weighting for technological leadership in the chosen methodology simply outweighs the size or traffic-related scores. Only five airports were chosen to limit the scope of data collection for the benefit of a sound balance of timely results versus a comprehensive picture covering all major European commercial airports.

The second step was the comprehensive collection of available secondary data from public source as well as primary data from a series of interviews. All interview partners were either directly employed by the airports in the field of digital transformation, or previously/currently supporting them as contracted third parties and were assured they would remain anonymous.

In the third step, the collected data was examined using a thematic analysis approach. Both the primary and secondary data were summarised in separate tables. After coding the information generated from interviews and secondary data analysis, it was possible to cluster the initiatives into the categories found in the following sections.

RQ1: TRANSFORMATION PROJECTS

The results from the conducted study have identified ten categories defining the various digital transformation projects at the top five European airports. Six categories are further divided into subcategories containing case-specific transformation projects which are characterised by common underlying 4.0 technologies and objectives.

Digital passenger information

The first identified category is digital passenger information, outlining the solutions that airports utilise to communicate travel-related information to passengers. Digitally informing travellers regarding the state of their journey was understood by the researched airports as an essential factor in enhancing the passenger experience, reducing operational costs and overcoming staff shortages. This category was further divided into three subcategories, namely airport app, self-service unit/totem and chatbot/virtual assistant. The development of a dedicated airport app for passengers has the purpose of sharing information such as flight status, parking information, waiting times at security checkpoints and relevant health-related policies, together with easing wayfinding within the terminal infrastructure. Other similar digital information platforms are identified as physical self-service units or totems for passenger support in the terminal — an interim solution designed for the non-digital passenger. At AMS for example, these self-service units consist of interactive touchscreens deployed around the landside where passengers can seek help and access a range of information according to their needs, such as wayfinding, walking distance/times and gate information.[16] Lastly, the deployment of an automated chatbot on the airports' main web page, also known as a virtual assistant, was mentioned as a possible digital initiative to automatically answer the most recurring customer enquiries while reducing the need for human customer support.

Self-service check-in and bag drop kiosks

The second category identified, self-service check-in and bag drop kiosks, is

widely considered effective in the context of capacity enhancement and queue reduction generating improvements in the passenger experience and significant cost reductions for the airport. These can be distinguished into two different types, namely, common-use kiosks and airline (or alliance)-specific kiosks. When evaluating the collected information, a pattern was noticed in the choice of which type of self-service station to adopt according to the airport volume of traffic. Specifically, it was found that the biggest hubs such as AMS, CDG and IST mention common-use self-service kiosks, while the medium sized airports such as MUC and FCO refer to airline (or alliance)-specific stations when inquired about their self-service check-in and bag drop offering.

Automated border control

Common to all five airports, the category automated border control (ABC) is deemed to fulfil multiple airport objectives, such as the improvement of operational efficiency in parallel with a reduction in operational costs, resilience against staff shortages, and a boost in capacity from existing infrastructure. As depicted in Figure 3, the airports indicate enhancement of passenger experience as another objective of ABC, which yields significantly shorter waiting times at checkpoints for eligible passengers.

Biometric journey

This is the fourth category identified by the study and indicates the entirely touchless and passport-less passenger journey from origin to destination based on biometric technology. This category is further divided between niche and large-scale biometric journeys. The term niche biometric journey is used to describe the touchless and passport-less airport experience when restricted to a specific share of passengers. At MUC, for example, a fully biometric journey is already available for Star Alliance passengers flying with selected airlines such as Lufthansa and SWISS.[17] Contrarily, large-scale biometric journey is understood as a wide-ranging, multi-use touchless and passport-less airport experience that any passenger can access and benefit from, irrespective of the airline, alliance or route.

PROCESS AUTOMATION

Three airports identify transformation projects that include the category of process automation in their development. The subcategory automated turnaround checks, mentioned by two airports, is a technological initiative that enables the automatic detection of different ramp activities thanks to smart sensors and cameras installed in the apron. Implementing this initiative allows the monitoring of single operations, understanding of critical pain points and improvement of the aircraft handlers' on-time performance, leading to an overall improvement of operational efficiency. Additionally, one interviewee explained how an automated turnaround check could be of support to, and eventually culminate with the substitution of, staff in turnaround coordination and surveillance of ramp operations. Another technological initiative for smart operations on the apron is automated bag transport. This project category involves the deployment of self-driving baggage carts that transport checked luggage between the baggage handling facility and the airplane. As presented in Figure 3, this initiative aims at further reducing any delays in the baggage reclaim or transfer process, again improving operational efficiency, and overcoming staff shortages.

Two studied airports identified cleaning robots as the third subcategory for process automation. They are described as intelligent machines equipped with sensors that recognise which type of dirt is found on the ground and apply the appropriate method of cleaning it.

Smart commercial activities

The next category is characterised by the underlying goal of generating ancillary revenue for the airport and consists of two transformation initiatives, namely personalised commercial offerings and social media sales. The first concentrates on expanding the airport's commercial offering according to the different requirements of passengers and pursues the possibility of commercially leveraging the time travellers spend inside the terminal. For example, IST has diversified offerings and entertainment experiences based on 'segment-specific needs', identified through the tracking of current passenger trends within the airport.[18] Similarly, one interviewee highlighted the possibility of increasing ancillary revenues through the use of social media. The goal of this initiative is for passengers to be able to order existing duty-free products and food directly from commonly used smartphone apps, such as WhatsApp.

Intelligent surveillance

This category is defined by three underlying transformation project categories and is characterised by the goal to improve operational efficiency while strengthening resilience to unforeseen or random events. First, intelligent dirt recognition consists of a smart system that can detect any type of dirt on the airport's solar panels and subsequently clean them automatically. Secondly, digital token for bag tracking is an initiative that aims at completely substituting printed baggage tags and making it possible for passengers to always keep track of their luggage while at the airport (not connected to tracking requirements for airlines under IATA Resolution 753). Last is a highly innovative 3D system, capable of recognising sharp objects at security controls, which allows passengers to leave all their belongings inside their hand luggage and to avoid time-consuming bag re-checks from staff, thus significantly improving the capacity of each checkpoint.

Other categories

The drones and vertical take-off and landing (VTOLs) category is common to three of the studied airports. For example, CDG plans on enabling drone flights between CDG airport and Paris city centre by 2024.[19]

Another category identified is intelligent route tracking. It aims at ultimately improving the passenger journey, boosting operational efficiency and the use of existing capacity. The initiative consists of a common system allowing airports to follow travellers from door to door, predict their needs, and accordingly interact with them.

A fully autonomous apron is the last category identified by the study, which primarily aims at improving operational efficiency, together with better preparing the airport for future events and overcoming staff shortages. The initiative described by one interviewee includes the deployment of automated vehicles and passenger loading bridges throughout the apron, in combination with automated turnaround checks.

		Objectives for Digital Transformation at the Top Five European Airports							
		Improve Operational Efficiency	Enhance Passenger Experience	Boost Capacity from Existing Infrastructure	Better respond to uncertain/ random events	Generate ancillary revenue	Reduce Operational Costs	Overcome Manpower Shortages	Mitigate Health & Safety Concerns
Successful Implementation	Digital Passenger Information		X	X			X	X	X
	Airport App		X						X
	Self-Service Unit / Totem		X	X			X	X	
	Chatbot / Virtual Assistant		X				X	X	X
	Self-service Check-In & Bag Drop	X	X	X			X	X	
	Common use self-service kiosks	X	X	X			X	X	
	Airline-specific self-service kiosks		X	X			X	X	
	Automated Border Control	X	X	X			X	X	
	Niche Biometric Journey	X	X	X			X	X	X
Trial Phase	Process Automation	X			X		X	X	
	Automated Turnaround Check	X			X		X	X	
	Autonomous Cleaning Robots		X				X	X	X
	Automated Bag Transport	X			X			X	
	Smart Commercial Activities		X			X	X		X
	Personalised Commercial Offerings		X			X			
	Social Media Sales		X			X		X	X
	Intelligent Surveillance	X	X		X		X		
	Intelligent Dirt Recognition	X			X				X
	Digital Token for Bag Tracking	X	X		X		X		
	Recognition of Sharp Objects	X	X	X	X			X	X
	Large-Scale Biometric Journey	X	X	X			X	X	X
Pre-Trial	Drones/VTOLs	X						X	
	Intelligent Passenger Route Tracking	X	X	X	X				
	Autonomous Apron/ Passenger Loading Bridges	X			X		X	X	

Figure 3 Current state of technology adoption at the top five European airports

RQ2: APPLICATION OF THE TAFA FRAMEWORK

The categories identified above are allocated, according to their stage of implementation, to a three-step process diagram based on the TAFA framework, presented in Figure 3, and further examined following the framework's 'Important I4.0 technologies for Airport 4.0' guidelines, highlighted in Figure 4.

Implemented categories

The information presented in Figure 3 represents the core results of this research. Digital passenger information has been implemented by all the researched airports when defined by its subcategory airport apps. Similarly, self-service units/totems are, for the time being, in use at four airports, while chatbots/virtual assistants are currently available on three airport websites. Self-service check-in and bag drop is likewise a well-established technology at all the interviewed hubs, with AMS, IST and CDG operating common-use kiosks, and airline (or alliance)-specific stations in use at MUC and FCO. The category biometric journey is only partially implemented at two major European airports, namely MUC and FCO, as a niche initiative, targeting a limited segment of passengers. Lastly, automated border control was found to be a fully implemented technology at all five top European airports. As is observable from Figure 4, the successfully completed initiatives present several commonalities, such as the widespread use of data mining and analytics, self-service technology,

biometric authentication and the use of mobile devices. This suggests that airports have proactively engaged existing technologies from other industries and adapted them to the passenger journey.

Trial and pre-trial categories

Large-scale biometric journey is placed in the trial phase of the TAFA framework and is currently examined by two airports, as depicted in Figure 3. The category smart commercial activities is placed in the same phase due to the reported ongoing tests being executed by two airports in terms of personalised offerings, while social media sales are currently trialled at solely one major airport, FCO. Similarly, the different initiatives defining the category intelligent surveillance, namely intelligent dirt recognition, recognition of sharp objects and digital token for bag tracking are currently tested by only one hub each. Process automation is in a developmental phase at three different airports, with automated turnaround check and cleaning robots being the most common subcategories to most. Moreover, Figure 4 portrays relatively new technologies that are yet in an early adoption stage, such as machine learning, artificial intelligence, robots and sensors as the main tools enabling most initiatives that airports are currently testing.

Lastly, I4.0 technologies such as advanced robots, sensors and autonomous technologies based on machine learning constitute the basis for several categories located in a pre-trial phase. Intelligent passenger route tracking and autonomous apron are undergoing the necessary proof of technology, operations and business at two different major airports, while three major European hubs are currently pre-trialling the commercial deployment of drones and VTOLs.

		Data Mining & Analytics	Self-service Technologies	Sensors	Artificial Intelligence	Biometric Authentication	Robots	Automated Vehicles (AVs)	Mobile Devices and Platforms	Machine Learning	5G Network
Successful Implementation	Digital Passenger Information	X							X		
	Airport App	X	X						X		X
	Self-Service Unit / Totem	X	X		X						
	Chatbot / Virtual Assistant	X			X				X	X	X
	Self-service Check-In & Bag Drop		X								
	Common use self-service kiosks		X								
	Airline-specific self-service kiosks		X								
	Automated Border Control	X	X			X					
	Niche Biometric Journey	X	X			X					
Trial Phase	Process Automation			X						X	
	Automated Turnaround Check			X	X		X			X	
	Autonomous Cleaning Robots			X	X		X			X	
	Automated Bag Transport				X		X	X		X	
	Smart Commercial Activities	X							X		X
	Personalised Commercial Offerings	X							X	X	X
	Social Media Sales	X	X						X		X
	Intelligent Surveillance				X						
	Intelligent Dirt Recognition	X		X	X					X	
	Digital Token for Bag Tracking	X		X	X					X	
	Recognition of Sharp Objects	X			X					X	
	Large-Scale Biometric Journey	X	X			X					
Pre-Trial	Drones/VTOLs						X	X			
	Intelligent Passenger Route Tracking	X		X					X	X	
	Autonomous Apron/ Passenger Loading Bridges			X	X		X	X		X	

Figure 4 Important I4.0 technologies for digital transformation at the top five European airports

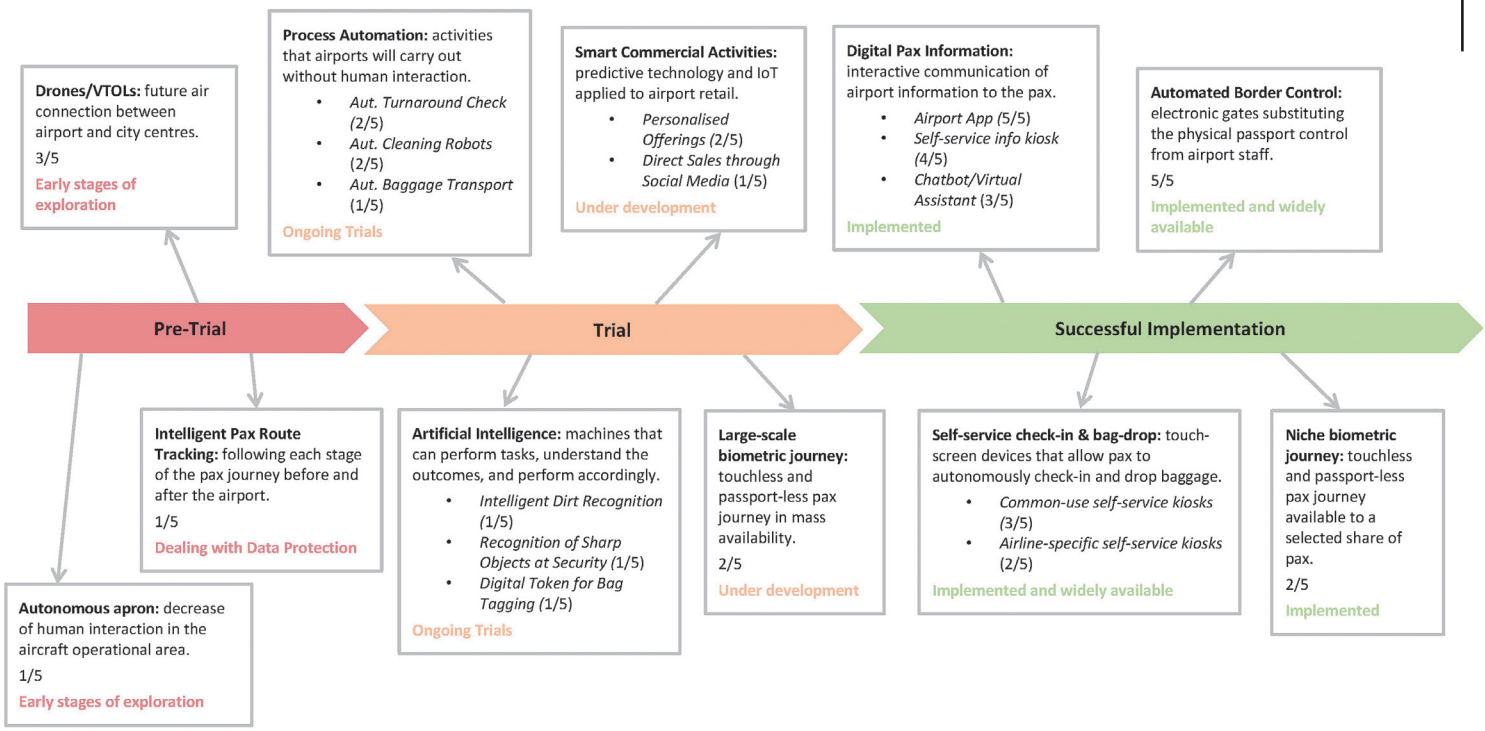

Figure 5 Current state of technology adoption at top five European airports

DISCUSSION AND RECOMMENDATIONS

Passenger-centric concepts

The study demonstrates that I4.0 technologies are a core component of airport operations at the technologically leading airports in Europe, with a focus on enhancing passenger experience (unlike the focus of academic studies on the matter, as mentioned initially). While humans still play a role in the airport environment, the study found that an increasing number of tasks is being progressively executed by machines that directly interact with customers, such as boarding card and passport control gates, passenger information services, self-service check-ins and bag drop kiosks. Further, the industry focus is shifting towards passenger needs and airports are now striving to offer a 'seamless, uncomplicated, safe, and secure travel experience',[20] while apparently applying this adjective only to the on-airport portion of the experience. However, a fair share of other digitalisation initiatives is not directly visible for or directed at the passenger journey, and they target, for example, operational efficiency improvements. While Figure 3 showed that most initiatives aim to achieve multiple objectives, Figure 4 demonstrates the same for the combination of different technologies. Figure 3 clearly demonstrates that passenger-related, efficiency-enhancing technical concepts are the most common and mature, while the implementation of other initiatives is only just beginning to take concrete shape.

Pandemic as accelerator

A bit surprisingly, in most interviews, the recent COVID-19 pandemic was described as an accelerator rather than an impediment to digitalisation initiatives. Even though lockdowns and travel restrictions in many cases still affect air traffic volumes and have crippled financial resources of airports,

digitalisation is seen as more important than before the pandemic. The underlying reason is that the elimination of the human factor often has the effect, despite heavy investments for the airport, to allow faster, more cost-effective, and even resilient service delivery in direct combination with better health protection for passengers and staff alike.

Organisational acceptance

Another point raised by most interviewees was the importance of organisational acceptance in the digital transformation process. Namely, two airports mentioned how the acceptance of new projects is often challenged by the organisation itself. One interviewee explained how top management often expects to receive fully tested and ready-to-use projects before approving their implementation, which runs counter to the 'fail fast on a smaller scale' strategy followed by innovation teams. To tackle this challenge, another interviewee suggests the creation of small digital working groups, each with partial decision-making powers, to enable the initial stages of technology development without long lead times for approvals.

Missing coordination between airports or airlines

A second, and rather unexpected, finding from the interviews is that there seems to be no coordinated effort between airports in this digitalisation journey. Both authors and interview partners are unaware of the existence of national initiatives of the kind, let alone international (with possibly one rare exception of the digital passenger route tracking that one airport is engaging in). One would assume that Airports Council International (ACI), the International Civil Aviation Organization (ICAO) or maybe the International Air Transport Association (IATA) would drive and sponsor these initiatives to harmonise customer journeys and the use of digital technology for reasons of both investment effectiveness and efficiency. Although IATA and ACI launched the NEXTT (new experience travel technologies) vision, to promote innovation among airports through open knowledge of industry best practices, the initiative appears to have been entirely halted in 2021 with a few isolated single-airport case studies, yet far from the needed industry-wide collaboration.

While all airport interviewees remarked that it is only through coordination between stakeholders that the benefits brought about by IT solutions can be achieved, it was noticed that a unified understanding and application of the term is absent as yet. For example, the interviews revealed that while one airport describes coordination as the exchange of data with sector partners such as aircraft handlers, another understands it as the investment in start-ups to harmonise research and boost mutual growth. Even though single airports make extensive use of their network of suppliers, customers and technology partnerships in their digitalisation programmes, such coordination is missing between airports and airlines. It seems obvious that this absence of coordination will lead to problems in the long term regarding interoperability between airports and with airlines, losses in customer friendliness and generally unleveraged technological potential. Despite the obvious challenge of inter-airport competition, the potential benefits of a coordinated approach to improvements in the global airport community should be given more serious consideration — not least to improve the benefits for travellers, airline

customers, concessionaries and other business partners along the value chain.

The app dilemma

The fact that each of the top five airports has their own passenger app shows self-centricity in lieu of traveller-centricity. While travellers are longing for a single mobility app[21] that guides them from doorstep to doorstep regardless of the transport modes involved, the reality today is a multi-app world bound to single companies or modes of transport. For our mentioned example flight AMS–FRA–JFK, a total of four apps would be needed (or potentially useful) for the passenger — a major usability challenge. It stands to reason airlines and airports alike, and with them the entire aviation community, would benefit from a more coordinated approach to investments into digital technology and data exchange. Recent major struggles of European airports in the summer of 2022 to deliver high-quality service in peak season and the ensuing struggles of airlines are prime examples for the need of such networked cooperation. Further research on the topic of digital airport transformation might not only include a globally broader population of airports with eg non-hub or regional airports, but also focus on the potential benefits and existing barriers to more global coordination in this vital transformation effort of airports around the globe.

References

(1) Graham, A. (2014), 'Airport Operations', in: 'Managing Airports: An International Perspective', 4th ed., Routledge, Abingdon and New York, pp. 137–65.

(2) Zaharia, S. and Pietreanu, C. (2018), 'Challenges in Airport Digital Transformation', *Transportation Research Procedia*, Vol. 1, No. 35, pp. 90–9.

(3) Gardy, A. (2016), 'Digital Trends & Opportunities for Airports', available at https://silo.tips/download/digital-trends-opportunities-for-airports-alexis-gardy-roland-berger-canada (accessed 21st July, 2021).

(4) Kovacikova, M., Janošková, P. and Kováčiková, K. (2021), 'The Comparison of Digitalization of Slovak Airports within the Digital Transformation of European Union Countries', *Transportation Research Procedia*, Vol. 55, pp. 1281–128.

(5) Dimitrova, M. (2022), 'How Airports and Airlines are Harnessing New Technologies to Improve Operations and CX', Future Travel Experience, available at https://www.futuretravelexperience.com/2022/04/how-airports-and-airlines-are-harnessing-new-technologies-to-improve-operations-and-cx/ (accessed 21st July, 2021).

(6) Tan, J. H. and Masood, T. (2022), 'Airport 4.0 — Technology Adoption Framework for Airports (TAFA)', available at https://pure.strath.ac.uk/ws/portalfiles/portal/137035900/Tan_Masood_engrXiv_2022_technology_adoption_framework_for_airports.pdf (accessed 21st July, 2021).

(7) Kagermann, H., Lukas, W. D. and Wahlster, W. (January 2011), 'Industrie 4.0: Mit dem Internet der Dinge auf dem Weg zur 4. Industriellen Revolution', *VDI Nachrichten*, Nr. 13-2011, p. 2.

(8) Hofmann, E. and Rüsch, M. (2017), 'Industry 4.0 and the Current Status as well as Future Prospects on Logistics', *Computers in Industry*, Vol. 89, pp. 23–34.

(9) Kagermann, *et al*., ref. 7 above.

(10) Nokia (2021), 'The Time for Airports to Digitalize is Now', available at https://www.nokia.com/about-us/newsroom/articles/the-time-for-airports-to-digitalize-is-now/ (accessed 24th August, 2022).

(11) Airport Dimensions and Connecta (2021), 'Airport Experience Research: Understanding Tomorrow's Traveler', available at https://asianaviation.com/wp-content/uploads/Airport-Experience-Research-Understanding-Tomorrows-Traveler.pdf (accessed 24th August, 2022).

(12) *Ibid*.

(13) Nordqvist, M. (2022), 'The Future Digital Airport Experience', Uppsala University, available at http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-478420 (accessed 24th August, 2022).

(14) Tan and Masood, ref. 6 above.

(15) *Ibid*.

(16) Schiphol, 'Self Service Units', available at https://www.schiphol.nl/en/innovation/blog/self-service-units/ (accessed 29th December, 2022).
(17) Flughafen München GmbH (2020), 'What a Difference: Munich Airport Integrated Report 2019', pp. 50–55, available at https://report2019.munich-airport.com/three-challenges-for-the-future/digital-transformation.html (accessed 12th September, 2022).
(18) Inankul, E. (2022), 'The Impact of Digital Transformation at iGA Istanbul Airport', International Airport Review, available at https://www.internationalairportreview.com/article/176328/digital-transformation-at-iga-istanbul-airport/ (accessed 12th September, 2022).
(19) Groupe ADP (2018), 'Designing the Airport of the Future' available at https://www.parisaeroport.fr/en/group/strategy/innovation/connect/smart-airport (accessed 12th September, 2022).
(20) Flughafen München GmbH, ref. 17 above.
(21) Airport Dimensions and Connecta, ref. 11 above.