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Towards Airport 4.0: Airport Digital Maturity and Transformation

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Abstract

Based on a review of literature, this paper applies the concept of maturity models to airport digital transformation, focusing mainly on a passenger experience perspective. The paper shows how airport digital maturity ranges from the mere replacement of analogue processes through to the more progressive and innovative adoption of digital technologies for adding value to specific processes. Ultimately, the industry is undergoing a progressive digital transformation, a paradigmatic shift in the way digital technologies are adopted and used, but also in terms of how airports address organisational challenges associated with transforming their business. Key factors that airports need to consider when transforming their business are illustrated in an airport digital transformation model. The model also provides a conceptual framework for researchers interested in conducting future studies in this area.

Keywords: Airports; Maturity models; Digital transformation.

1. Introduction

Modern society has been fundamentally changed by three industrial revolutions. Firstly, the Age of Mechanical Production, from the 1780s, based on advancements in the use of water and steam power and mechanical production equipment. Secondly, the Age of Science and Mass Production, from the 1870s, based on advancements with electricity and mass production. Thirdly, the Digital Revolution, from the 1970s, based on advancements with electronics, information technology and automation. A fourth industrial revolution, commonly refered to as Industry 4.0 or the Age of Cyber-Physical Systems, is now underway. This fourth revolution builds on previous technologies developed during the Digital Revolution, but also utilises so-called smart systems to monitor digital processes, replicate physical with virtual worlds, and make decentralised decisions in real-time. In turn, this trend is being powered by a range of technologies and concepts associated with automation and data exchange, such as the Internet of Things (IoT), big data analytics, cloud computing, cognitive computing (e.g. based on artificial intelligence), additive manufacturing, blockchain, cybersecurity, virtual modelling and simulation, augmented reality, and systems integration.

Generally speaking, airports have been quick to embrace the Digital Revolution; replacing manual and analogue processes with automated and digital processes (known as digitisation). For instance, self-service kiosks and automated bag drop facilities are now commonplace at airports worldwide. More recently, wider industrial shifts towards Industry 4.0 have prompted many airports to adopt a more progressive and innovative approach to the way they use digital technologies for adding value to specific processes (known as digitalisation). For instance, this can include personalised digital wayfinding via mobile applications tailored to a passenger´s travel itinerary, or innovative retail solutions offered via various digital platforms, where passengers can pre-order airport meals or enjoy click-and-collect style shopping. While there may be advantages to such initiatives from a passenger experience and commercial perspective, transitions towards Airport 4.0 inevitably pose considerable challenges for airport operators. Crucially, the disruptive potential of Airport 4.0 extends beyond merely implementing technology to address specific functional processes at an airport. Ultimately, it describes the process of undergoing a digital transformation, a paradigmatic shift in the way digital technologies are adopted and used from a strategic standpoint at an organisational level. How airports address organisational challenges associated with transforming their business will likely go some way to determining the success of airports attempting to embrace Airport 4.0 philosophies.

In terms of current literature, the concept of airport digital transformation is covered extensively in grey literature, with a range of publications by industry associations and management consultancy firms in recent years (e.g. ACI, 2017a; ACI, 2017b; Amadeus, 2012; Arthur D. Little, 2018; Boutin et al., 2016; Fattah et al., 2009; Nau and Benoit, 2017; Zmud et al., 2018). The concept is covered to a small extent in published conference proceedings (e.g. Zaharia and Pietreanu, 2018). In addition, there are a growing number of academic papers that are focused on digitalisation, often regarding initiatives with specific technologies (Table 1). However, airport digital transformation has barely received any attention from published academic journal articles, and it is hoped that this paper will spur new academic research in what is likely to be an area of growing interest and importance.

Based on a review of literature, this paper applies the concept of maturity models to digital transformation at airports. The aim is to develop a conceptual framework of airport digital maturity and of key factors associated with airport digital transformation. In terms of structure, this paper begins by providing background on the role of digital technologies at airports including the benefits and challenges associated with investing in digital technologies. Maturity models are then introduced and applied to the airport industry. Using the passenger journey as an example, the paper then considers technological transformation required to reach maturity, including the importance of data. The paper then considers organisational transformation. Based on the topics discussed in this paper, an airport digital transformation model is presented to illustrate key factors that airports need to consider when digitally transforming their business. The final section provides concluding remarks.

Table 1. Academic research on the use of digital technologies at airports.

Technology	Example studies
Airport information systems	Brida et al. (2016)
Augmented and virtual reality	Eschen et al. (2018)
Biometric systems	del Rio et al. (2016); Haas (2004); Kalakou et al. (2015); Morosan (2016)
Digital channels	Halpern (2012); Halpern and Regmi (2013); Florido-Benítez (2016); Florido-Benítez et al. (2016); Inversini (2017); Martin-Domingo and Martín (2016); Straker and Wrigley (2018); Wattanacharoensil and Schuckert (2015)
People tracking	Adey (2004); Bouma et al. (2016)
Queue prediction	Chiti et al. (2018)
Self-service technologies	Bogicevic et al. (2017); Castillo-Manzano and López-Valpuesta (2013); Gures et al. (2018); Lee et al. (2014); Wittmer (2011)

2. The role of digital technologies at airports

Digital transformation has contintinuos optimisation as a goal, where companies should be able to sense shifts in the market and respond quickly. This level of transformation does not happen by accident and rarely occurs organically. Instead, digital transformation is often seen as a journey that needs a strategic roadmap (Gobble, 2018) and requires strong investment across the organisation, especially from a technology point of view. In this regard, expenditure on technology at airports continues to grow. SITA (2018) estimate that airports invested US$8.6 billion on technology in 2017 (up from US$7.0 billion in 2016). Technology spend as a proportion of total revenue at airports has more than doubled from 2.7 per cent in 2008 to 5.7 per cent in 2017 (SITA, 2010; SITA, 2018).

There are many reasons why airports are investing in technology. Based on interviews with over 15 major airports worldwide, the management consultancy firm Arthur D. Little (2018), find the main reasons are to improve operational efficiency (by making better use of capacity and enhancing operational resilience and agility) and to improve cost efficiency (by reducing capital expenditure requirements and operating expenditure). This reflects how larger airports in many countries face capacity constraints and subsequent problems relating to delays, overcrowding and pressure on service levels, and in an industry that is capital intensive and increasingly competitive.

The industry expects future growth. Airports Council International (ACI, 2018) estimates that 8.3 billion passengers travelled through airports worldwide in 2017. They forecast a compound annual growth rate of 3.5 per cent for the 2017 to 2040 period. Such growth will create further challenges relating to capacity at many airports and further emphasise the need to invest in technologies that improve operational and cost efficiency.

But digital transformation is not only about creating value through efficiency gains. It is also about improving customer service by redesigning the customer experience and rethinking the purchasing process. Gathering and analysing customer data allows businesses to know their clients better and personalise their experience with the objective of creating value by reinforcing together the service and the core business of the organisation. For airports, simultaneously enhancing the passenger experience and generating additional revenue has become paramount, as passengers have high levels of technology adoption, and increasingly demand and expect digital interactions at all stages of their journey (IATA, 2018; SITA, 2016). In addition, satisfaction rates with key airport processes are higher among passengers that use technologies versus those that do not (SITA, 2019). This is important from a service quality perspective but also because studies suggest that happier passengers spend more (Jarrell, 2014).

As with most studies, Arthur D. Little (2018) focuses on larger airports, even though 81 per cent of the world´s airports are small (serving less than one million passengers per annum). A further 12 per cent serve one to five million (ACI, 2014). The benefits of investing in technologies at smaller airports with low passenger throughput are less certain. However, given that the vast majority of them are inherently loss-making due to their cost structure, the effective implementation of technology is likely to offer significant cost efficiency benefits by making better use of operating and capital expenditure.

Despite the potential benefits, there are also many challenges associated with investing in technology. It can be costly to implement and there may also be high running costs once implemented. It can be difficult to keep up with new versions and updates, which could potentially create system level vulnerabilities, and there may be a need for additional technical support or staff training, especially if there are knowledge limitations of the workforce. From the workforce and organisational perspective, digital transformation can be considered as a horizontal process, and cannot be defined or delivered by a classic independent IT department. Digital strategy and its implementation typically requires an organisational model in which the Chief Digital Officer (or equivalent position) has influence in all departments of the organisation through managers present in each department.

Ideally, new technologies should fit into existing infrastructure and services to keep costs down, especially early on before they can be scaled up with dedicated infrastructure and services. However, it may be difficult to fit new initiatives into existing infrastructure and services. Technologies change rapidly so there is a great deal of uncertainty regarding their lifespan. There are also potential lock-in effects, for instance, of being tied-in to a specific technology or supplier. Any new initiatives will need to receive support from senior managers but also from industry partners and stakeholders such as investors, which may themselves have limitations. Airports will need to quantify potential benefits and returns on investment in order to get industry partners and stakeholders to buy-in to any new technologies, which can be difficult, especially for new technologies that have not been trialed much before in an airport setting. Increasingly, the implementation of new technologies is also challenged by concerns regarding data privacy and other ethical considerations.

Despite the challenges, airports continue to respond to the digital world that we now live in. According to Arthur D. Little (2018), the risks of non-adoption of digital technology, in order of priority, are: a non-competitive operational performance and business model; inferior operational performance; long-term structural cost disadvantages; sunk costs, losses and failed investments; environmental benefits/legislative compliance. There is therefore a growing interest in the digital transformation of airports with the ultimate goal being to reach digital maturity.

3. Airport digital maturity

Maturity models are well established in management science. According to Chaffey (2010), they can help to review current approaches and identify areas for improvement, benchmark against competitors, identify good practice from more advanced adopters, set targets and develop strategies for improving capabilities (e.g. by assessing resource needs and deployment), and create a roadmap of future improvements. Indeed, as highlighted by Kane et al. (2015), the digital strategy roadmap drives digital maturity.

Models typically identify a series of levels that are passed as certain capabilities are reached. Nolan (1973) presents a model consisting of four stages that an organisation can go through when planning, organising and controlling activities associated with managing computer resources: computer acquisition, intense system development, proliferation of controls, and user/service orientation. He describes each stage and the tasks needed in order to reach each stage. His initial model does not refer specifically to maturity and is instead based on stage theories. However, he published a later model in Nolan (1979) related to data processing within organisations. The model added two stages; data administration and maturity. The six stages therefore reflect data processing growth within organisations from acquiring a computer through to the mature management of data.

One of the earliest conceptualisations of maturity models in management science was by Crosby (1979). His Quality Management Maturity Grid (QMMG) allows organisations to assess how mature their service or product quality management processes are, and how well those processes are embedded in the culture of the organisation. The QMMG describes five levels that an organisation can go through: uncertainty, awakening, enlightenment, wisdom and certainty. Crosby´s work was popularised by the Capability Maturity Model (CMM) that was developed by Carnegie Mellon University to improve software development processes and therefore also followed on from the computer resources and data processing models of Nolan (1973; 1979). CMM´s five levels of maturity are: initial (processes are fairly ad-hoc and rarely documented), repeatable (some processes are repeatable), defined (processes are defined and documented), managed/capable (processes are monitored and controlled), and optimising/efficient (processes are continually improved through feedback resulting in incremental and innovative improvements to process performance).

Although early models focused on software development or computer resources and data processing, they have also been applied widely as a tool for improving processes in other fields such as management science. For instance, see Röglinger et al. (2012) for an in-depth review of maturity model literature relating to business process management.

It is worth noting that there are several challenges associated with the use of maturity models. For instance, Mullaly (2014) criticises their linear assumption that progression is sequential and results in improved performance. Also, that stages are characterised by practices based largely on anecdotal observations of what one would expect to see in a more mature company. This may be conceptually reasonable but not necessarily conducted rigourously.

Despite the challenges associated with them, maturity models are commonly used in airport digital transformation studies. For instance, Nau and Benoit (2017) identify what they call four waves of digitisation at airports: Airport 1.0 where all processes are done manually; Airport 2.0 where some processes are automated for cost reduction; Airport 3.0 where automated processes are fully deployed; Airport 4.0 where airport systems are fully integrated within the airport ecosystem (e.g. using open Application Programming Interfaces (APIs) and big data).

Similarly, Arthur D. Little's (2018) digital airport maturity model identifies four levels: Airport 1.0, which is characterised by manual and analogic processes and long lag times between resource specification and airport response; Airport 2.0, which is characterised by the implementation of self-service thanks to the automation of some key flow processing tasks such as for bag drop and passport control; Airport 3.0, which is characterised by several focused initiatives to leverage digitalisation to optimise flow monitoring and passenger processing; Airport 4.0, which is characterised by airports that are fully connected with all stakeholders, and superior proactivity and reactivity to adapt to real-time airport requirements (e.g. operational needs and customer requests).

Although they do not refer specifically to digital maturity, ACI (2017a; 2017b) describe three levels of a digital airport in their Airport Digital Transformation White Paper. The three levels are: Digitally enabled – the airport has the basics in order such as infrastructure and cyber-resilience to be able to become a digital airport in order to reach customers; Fully digital – the airport has implemented all the options that create a fully digital airport based on mainstream and commonly available technologies; Next-generation digital – the airport has implemented all the advanced digital concepts that are not commonly available and tested in the aviation industry, such as seamless travel with single-token biometric touchpoints, new business models based on digital services such as blockchain, and personal and context-aware services for passengers.

The maturity model developed for this paper draws upon those presented by previous studies. It consists of four levels (Fig. 1). Airport 1.0 is the lowest level of digital maturity. In fact it can be argued that Airport 1.0 is not at all digital. However, key processes may be supported by computers, for instance, at check-in and boarding, although it is likely that manual intervention is still required by staff. The ability to reach passengers is limited. There are likely to be long lag times between the capture of data and its use.

Airports that have progressed to Airport 2.0 have begun to digitise by replacing key manual and analog processes with automated and digital processes. This is supported by the initial deployment of self-service facilities and automated gates (i.e. at check-in and bag drop, security, passport control and departure gates), with the main focus being to reduce costs. There may also be an initial deployment of technologies that seek to enhance the passenger experience, for instance, with digital channels and free one-click wifi that provide several opportunities to reach the passenger. Electronic data may be captured and used to inform decision making, and there may also be several open data initiatives to share data with key stakeholders.

Airports that have progressed to Airport 3.0 have begun to digitalise key processes. This involves using digital technologies to add value to existing processes. Self-service and automation is fully deployed, and all touch points are digitally enabled by a full range of mainstream technologies. The airport can now easily reach the passenger, for instance, via a dedicated airport mobile application and/or a registered passenger profile or CRM database. Data that is captured is used to inform decision-making, and there is extensive sharing of data with key stakeholders. There is still a focus on reducing costs but also on improving operational efficiency and the passenger experience (e.g. with location-based services and an omnichannel content strategy). There is also a focus on revenue generation (e.g. using the airport´s own e-Commerce platform).

Moving on to Airport 4.0 involves digital transformation. A paradigmatic shift in the way digital technologies are adopted and used. Value is created from data that is captured and shared with a range of stakeholders in real-time using smart data capabilities. Airport systems and processes are integrated within the wider digital ecosystem that connects all stakeholders. Biometric touch points provide passengers with a seamless travel experience. The passenger is easily reached, and the airport is able to deliver customised notifications to passengers, along with personalised and context aware offerings. A range of Industry 4.0 technologies are used.

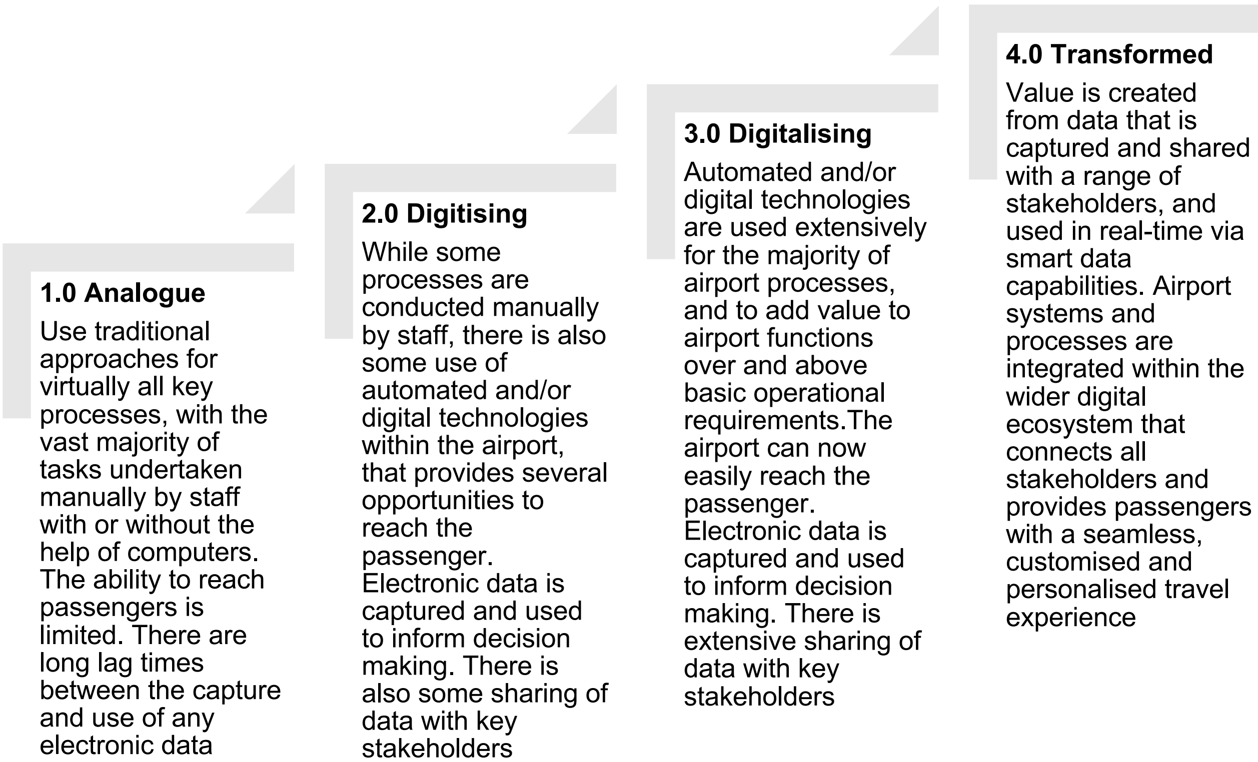

Fig. 1. Airport Digital Maturity Model (ADMM).

4. Airport digital transformation

4.1 Technological transformation

As an example of the role played by technologies at each stage of maturity, consider example technologies used for several mandatory and optional touch points during the passenger journey (Table 2). While the technologies included in Table 2 provide just a few examples, Industry 4.0 technologies offer a vast range of opportunities for airports and other stakeholders to innovate across the passenger journey. For instance, in the future it may be common for passengers to check-in and access pre-trip information by having a two-way conversation with an artificial intelligence powered Airport Assistant accessed via mobile or smart home devices. For getting to the airport, passengers may be able to buy a single intermodal ticket for their trip via an airport mobile application, allow valet robots to park their car on arrival at the airport, arrive in self-driving cars, or use automated (driverless and autonomous) transport systems. A great deal of attention is currently focused on biometric identification, which is being introduced at a growing number of airports. Alternatively, passengers may simply use body-embedded identification.

For baggage, items may be collected and delivered to passenger homes by drones or robots. There may be ambient security scans on arrival at the airport instead of needing to go through security screening. When shopping, passengers may encounter robotic shop assistants, acceptance of virtual currencies (e.g. Bitcoin), personalised retail and nutrition options for food and drink based on passenger profiles, experimental food centres (e.g. with 3D printed food), and the 3D printing of goods. There may also be intelligent data mining to pre-empt passenger mood and behaviour at the airport. While some of these innovations may seem far off, the rapid pace of change and technology adoption in the sector means that initiatives such as these may be closer to be being realised than one might think.

Table 2. Example technologies deployed at different stages of the passenger journey.

Stage	Airport 1.0	Airport 2.0	Airport 3.0	Airport 4.0
Airport car parking	Pre-book by phone or book and pay on arrival or departure	Book online and pay on arrival or departure	Book and pay online	Book online and pay automatically (e.g. using Autopay)
Check-in	With staff at a check-in desk	Online or via a dedicated self-service check-in kiosk	Online or via a common-use self-service check-in kiosk	Register biometric and travel details at check-in or before arriving at the airport
Bag tag and drop	With staff at a check-in desk	Print the tag at a self-service check-in kiosk and deliver the bag to a staffed bag drop	Self-service bag tag and drop	Permanent digital bag tag with journey tracking via a mobile app
Security	Metal detectors and pat downs	X-ray scanners	Full body and computed tomography (CT) scanners	Biometric walk through (e.g. using highly sensitive infra-red cameras and facial recognition) without the need to remove items
Departure gate	Paper boarding pass checked by staff	Electronic boarding pass checked by staff	Self-scanned electronic boarding pass	Biometric single-token travel
Commercial	Information and services accessed physically at the airport	Digital information available about services at the airport	e-Commerce opportunities (e.g. pre-order car parking, click and collect retail)	Personalised / context aware offerings
Information and wayfinding at the airport	Brochures, analogue signage, and staffed information desks	Digital channels and digital signage	Digital self-service information and location-based services	Augmented and virtual reality experiences and personalised notifications

Contact the airport	Phone or post	Email or online feedback form	Messaging application or live chat service	Artificial intelligence (e.g. Chatbot)

Despite the many opportunities for technological innovation, Airport 4.0 recognises that technologies alone cannot create significant value; this happens only when there is an overall cohesive architecture – a smart airport, which is the key premise of Airport 4.0. Zmud et al. (2018) refers to this as the Connected Airport, based largely on the concept of IoT. IoT can be defined as a system where a network of digitally connected physical objects (e.g. passengers, baggage, cargo, aircraft, staff, or equipment such as vehicles, elevators, people movers, heating systems) collect digital information via sensors such as those listed in Table 3. Information from sensors can then be communicated across the network to help aid decision making.

Table 3. Types of sensors used at airports.

Category	Examples
Proximity	Parking space sensors, radio-frequency identification (RFID) smart baggage tracking, asset or workforce tracking, passenger tracking via beacons, Bluetooth, near field communications (NFC) or wifi
Pressure	Sensors for smart energy monitoring, building maintenance, waste management
Optical	Cameras or other sensors for biometrics, security screening, flow or throughput management, or monitoring equipment such as kiosks and bag drop stations
Motion	Access control sensors for intrusion detection, video surveillance, automatic doors or barriers

In Zmud et al. (2018), IoT is regarded as the technology architecture for a digital airport future. Based on five key stages of what Deloitte call the information value loop (e.g. see Holdowsky et al., 2015): (1) Physical objects (2) Instrumentation, which is the sensor or smart component; (3) Connectivity via a network that allows the digital interaction between objects; (4) Aggregator that gathers and stores data, taking into account any standards and legal/regulatory or social and ethical requirements – collects related items of content and displays them or links to them; (5) Analytics that provide actionable information from the data generated in order to improve performance.

Therefore, although based on the concept of IoT, the information value loop is dependent on a full range of Industry 4.0 technologies. For instance, data is collected from sensors and may be stored in the cloud using cloud technologies or some kind of unified digital platform. Here, big data analytics can be leveraged to drive Airport 4.0 initiatives, while artificial intellegence or machine learning can help to transform data into information that provides insights and allows for decisions and actions to be taken. The data also allows for modelling and simulation to be carried out (e.g. using Digital Twin technologies). There are a range of potential uses for Industry 4.0 technologies that often fall under clusters of solutions (see Blondel et al., 2015). For instance, for passengers, key clusters include flow monitoring and management, process automation, and customer engagement. Other solutions include intelligent building management (e.g. for energy management, preventative maintenance and asset management), predictive solutions (e.g. for the automated management of airport resources), and collaborative decision making for air and ground operations (e.g. for operations management and total airport management). Regardless of which cluster is being addressed, digital transformation relies on the ability to use information in (near) real-time, and this typically requires integrating information feeds with a range of stakeholders.

Each stakeholder has their own responsibilities and priorities and are often inclined to protect their own information. However, there are also common goals that can enhance the overall functioning and performance of an airport and subsequently enhance the passenger experience. Sharing data has therefore become one of the most important tools for digital transformation, and relies on having an effective stakeholder communication, coordination and engagement framework (ACI Europe, 2018). Increasingly, there are cybersecurity and ethical issues to take into account (e.g. regarding personal data privacy).

When considering data exchange, there needs to be a clear understanding of who the stakeholders are, what challenges they face, and the data that they require. This includes data that they require themselves but also data that can come from shared sources (Table 4). According to ACI Europe (2018), benefits of such data exchange include: passenger satisfaction increases because rather than being bounced between different stakeholders, services are more seamless; it might result in a reduction in the number of complaints, and a reduction in extra costs for airlines and airports because of no need for extra staff, counters/desks, and overtime. Also, staff are likely to be under less pressure, and airports and airlines may be able to prevent and avoid poor service instead of patching up services because there will hopefully be less overbooking, reduced layover expenses, and less re-scheduling/re-routing of passenger flights. There might be greater revenue generation because a satisfied passenger spends more money (up to 45 per cent more than an unhappy passenger). Although not covered by ACI Europe (2018), it may also mean that staff are more free to provide assistance to those that need it, while those that do not need it can be in more control of their own journey.

As alluded to already, capturing and then leveraging useful passenger information is key to an Airport 4.0 philosophy. This information can be generated at different stages of the passenger journey, as shown in Table 5. While currently this information may reside with different stakeholders in the value chain, sharing of this data in a secure, controlled and anonymous way is generally seen as being vital to addressing some of the challenges in the passenger journey, as outlined in Table 4.

Table 4. The aviation stakeholder data exchange matrix.

Stakeholder	Challenges	Required data	Shared data
Airport	• Keep SLAs • Increase non-aeronautical revenue • Improve operational workflow	• Passenger information	• Location of passenger in the terminal • Terminal situation and environment • Retail offers
Airline	• Meet target off-block time	• Location of passenger in the terminal	• Passenger information
Passenger	• Improve travel experience • Find best deals in retail	• Travel updates • Live information at the airport • Guidance • Retail vouchers	• Passenger information • Current status and location of passenger
Border control	• Keep SLAs • Reduce operational costs	• Current and expected passenger flow information	• Resource allocation
Security	• Keep SLAs • Reduce operational costs	• Current and expected passenger flow information	• Resource allocation
Ground handling	• Keep SLAs • Reduce operational costs	• Baggage information	• Current status and location of baggage

Source: adapted from ACI Europe (2018).
Note: SLAs = service level agreements.

Table 5. Example passenger information at different stages of their journey.

At booking	On arrival	Underway
• Travel schedule (flights, timings, connections, final destination) • Type and/or class of travel (group travel, travel with children, solo traveller, business/leisure) • Passenger (age, mobility needs, frequent flyer) • Baggage information (number of items, weight, special baggage)	• Mode of access transport (car, public transport, taxi/private hire) • Use of check-in desk versus self-service kiosk • Use of check-in desk versus self-service bag drop • Baggage information (number of items, weight, special baggage) • Type of boarding pass (paper versus electronic) • Use of fast-track security • Use of priority boarding	• Food, drink, retail, communication channel preferences • Use of wifi and/or mobile app • Passenger status and best known location (e.g. checked-in, passed security, shopping, at the gate) • Flight status and therefore passenger and baggage progress or disruptions (implications for transfer/connections, rebooking, meal vouchers)

4.2 Organisational transformation

Digital transformation is as much about transforming the business as it is about transforming the way that technologies are adopted and used. This means that, in addition to the airport´s adoption and use of emerging Industry 4.0 technologies, there are likely to be important organisational factors that affect the ability of an airport to transform. For airport operators, there is a need to both understand the factors that determine or inhibit progression to Airport 4.0, and to establish effective monitoring and self-assessment procedures with regards to organisational readiness for digital transformation.

Arthur D. Little (2018) identify four critical success factors for effective airport digital transformation. Firstly, strategic clarity, which involves setting a clear yet concise digital strategy that is closely aligned to the airports overall strategic priorities. It includes effective channeling of digital demand (ideas or requests) that may come from various stakeholders, to achieve a coherent overall approach. It involves having a clear view of who the ultimate target is for the digital strategy (e.g. passengers and/or airlines). It also involves having visible leadership support for the digital transformation agenda. The importance of strategy is supported by Kane et al. (2015: p1) that state: “strategy, not technology, drives digital transformation”.

Secondly, there is a need for effective partnering and collaboration. This includes the ability to forge collaborative relationships across multiple interfaces including inter-airport collaboration (to take advantage of trickle down proven solutions from more advanced to less advanced airports in terms of digital adoption). Partnering can accelerate the process of learning about new technologies, identify process-specific applications for the technologies, and better manage implementation risks and costs.

Thirdly, there is a need for a digital mindset and culture. This includes the ability to identify, prioritise and implement solutions that are most relevant to the particular context of the airport (i.e. depending on if it is a large or small airport, or on the main type of traffic served). There should be a digital mindset with dynamic decision-making processes. There should also be trust between key airport stakeholder groups, and a move from department-driven initiatives to a more holistic approach because digital transformation touches all aspects of the organisation (Gupta, 2018).

Fourthly, there is a need for digital skills and resources. Airports should conduct a gap analysis to compare current skills and resources to those that are needed to meet the digital requirements of the future. This is because digital transformation requires strengthening the core and building for the future at the same time (Gupta, 2018). Airports need to understand key digital technologies and plan to develop internal capabilities in parallel to partnering with external service providers. Airports need to be able to clearly articulate how digital transformation can bring value to daily roles by focusing on simple and usable solutions that build trust. Business and operational readiness for change must be accompanied by required skills and resources to make the transformation a success.

Similarly to Arthur D. Little (2018), ACI (2017a; 2017b) identify the need to engage airport leadership, identify and anticipate requirements, articulate strategy to engage and gain support from stakeholders, establish business cases that can be clearly communicated (especially regarding benefits and added value of digital transformation), join forces with other partners and stakeholders in the value chain, identify key digital talents to acquire and train while valuing and retaining existing internal resources with both business and digital competencies, develop an organisation-wide digital culture that promotes speed, risk-taking and experimentation, and a viable innovation governance that promotes, recognises and values internal ideas and initiatives for innovation.

Similar recommendations are also made by Boutin et al. (2016) who suggest that there are five rules to follow for effective airport digital transformation: see the big picture (establish clear strategic goals), build and follow a business case (support each digital initiative with a business case), overinvest in buy-in (to build support for transformation from relevant stakeholders), be open to innovation that is not invented (and partner with technology and other companies that are introducing innovation), and invest in people, not just technology (to have the skills needed to succeed).

There are some common themes from the literature that can be grouped under four categories (Fig. 2): clarity (incorporating strategy, leadership and business cases), collaboration (incorporating investment in building support, and forming and learning from collaborative relationships), culture (incorporating relevant solutions and a digital, dynamic, holistic and innovative approach), and capability (incorporating digital know-how, skills and resources, and solutions that build trust).

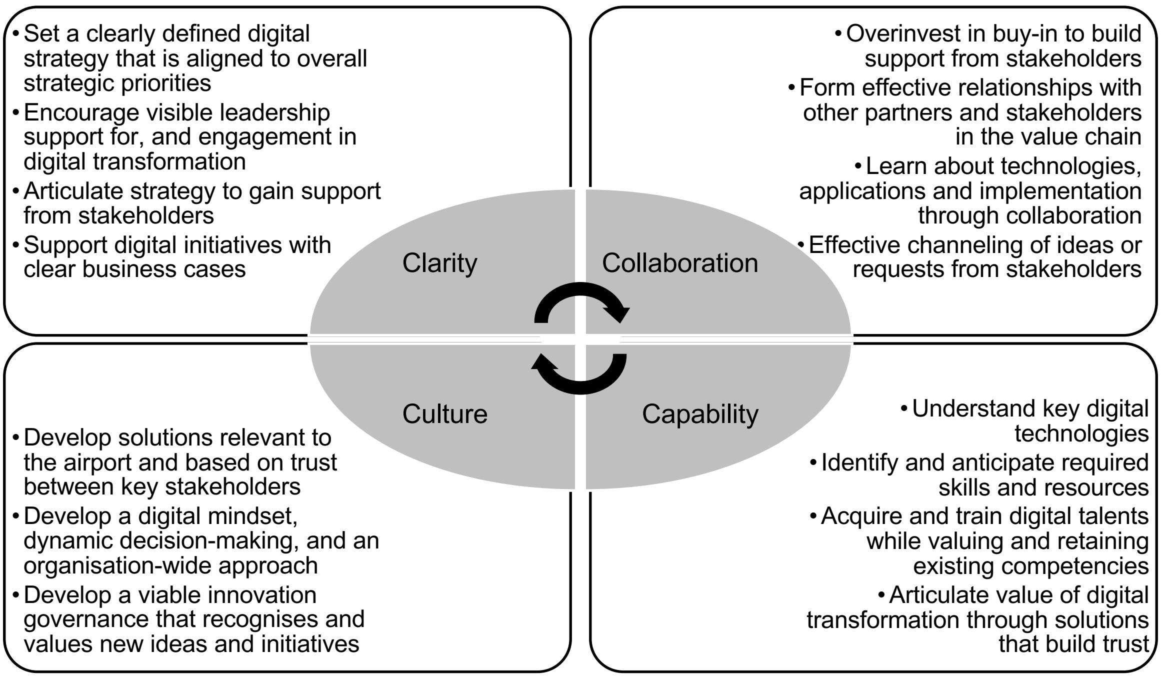

Fig. 2. Organisational readiness for digital transformation.

The rate of transformation at an airport may of course also be affected by its attitude towards the adoption of digital technologies. Diffussion of Innovations theory by Rogers (2003 - 1st edition in 1962) classifies individuals within a group according to their rate of adoption. Rogers identifies five categories of adopter: laggards (traditional), late majority (skeptical), early majority (deliberate), early adopters (respect), innovators (venturesome). Positive and negative outcomes are associated with each one. For instance, there may be a high cost of uncertainty and potential for failure amongst innovators but marketing benefits and other first mover advantages if they are successful. This compares to laggards that may enjoy a low cost of uncertainty but also a potential loss of marketing benefits from being late to adopt. The theory can be applied to airports (Table 6). Laggards are expected to be characteristic of Airport 1.0 while the majority (late and early) are Airport 2.0. Early adopters are expected to be developing Airport 3.0 characteristics while innovators are the Airport 4.0s of the future.

Table 6. Attitude towards the adoption of digital technologies.

Strategy	Description
Laggards	We are normally amongst the last few airports to use new digital technologies
Late majority	We tend to use new digital technologies when they are used by most airports
Early majority	We tend to use new digital technologies when they are used by some airports
Early adopters	We embrace new digital technologies, and are usually amongst the first few airports to use them
Innovators	We actively seek out new digital technologies and are happy to experiment with them, even when they have not been trialed much in an airport setting before

4.3 Airport digital transformation model

Based on the topics discussed in this paper, this section presents an airport digital transformation model (ADTM). As illustrated by Fig. 3, the model suggests that airport digital transformation is reliant on organisational readiness. The model further suggests consideration of appropriate enabling 4.0 technologies and instruments that should be implemented according to the various solution clusters, mandatory and optional touch points, and services related to digitally-enabled physical objects. Taken together, these serve as the mechanism for becoming a transformed Airport 4.0. The model recognises that the adoption of 4.0 technologies presents both benefits and challenges. Transformation therefore requires careful alignment of organisational transformation and 4.0 technologies in order to fully leverage on the benefits while addressing challenges associated with the transformation journey.

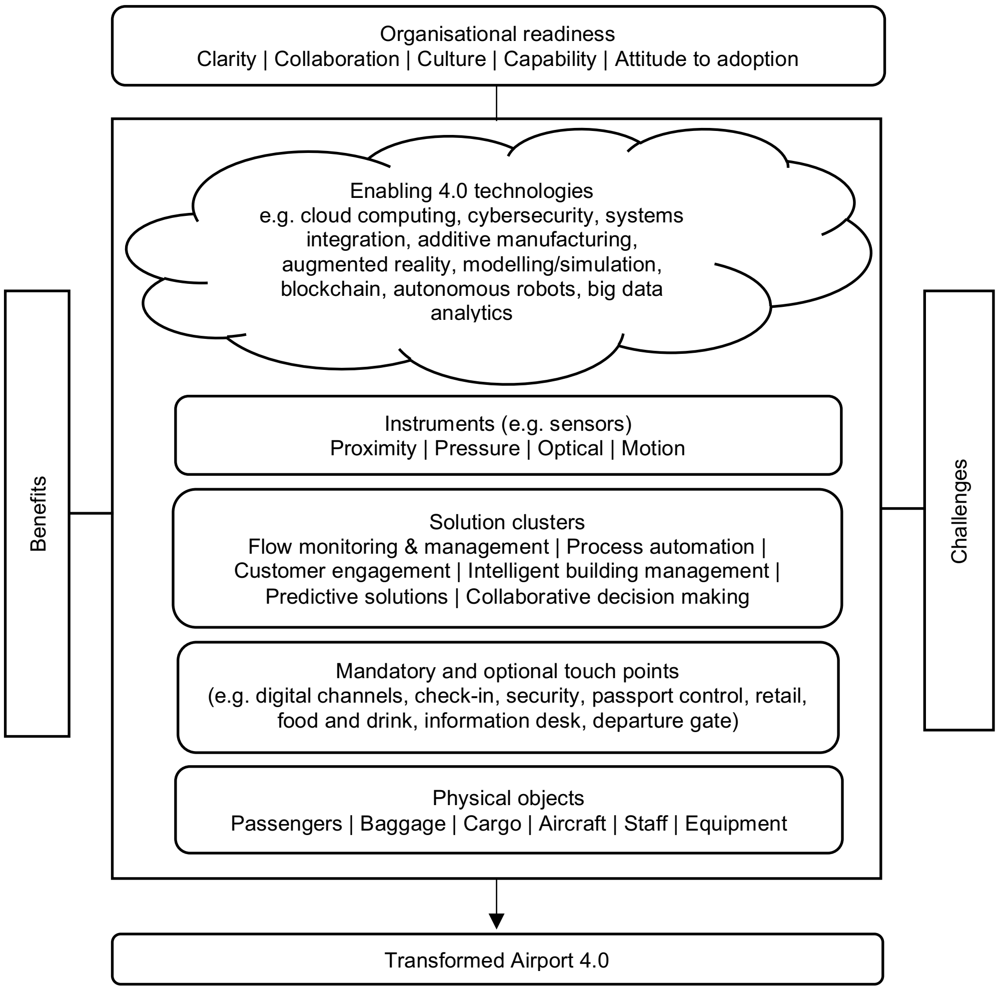

Fig. 3. Airport Digital Transformation Model (ADTM).

5. Conclusion

Based on a review of literature, this paper applies the concept of maturity models to the digital transformation of airports. The paper considers the benefits and challenges associated with investing in technology. A conceptual framework – the airport digital maturity model (ADMM) is developed. This indentifies how airport digital maturity ranges from the mere replacement of analogue processes through to the more progressive and innovative adoption of digital technologies for adding value to specific processes. Ultimately, the industry is undergoing a progressive digital transformation, a paradigmatic shift in the way digital technologies are adopted and used but also in terms of how airports address organisational challenges associated with transforming their business. Following this, an airport digital transformation model (ADTM) is presented to illustrate key concepts discussed in the paper.

In terms of technological transformation, this paper recognises the role that the concept of IoT plays on the digital transformation of airports. This involves using instruments or sensors to generate data from digitally enabled objects at a range of mandatory and optional touch points. Industry 4.0 technologies are then used to securely store, analyse and act on data for a range of solutions. As defined in the ADMM, value is created from data that is captured and shared with a range of stakeholders, and used in real-time. Sharing data therefore plays a key role in the digital transformation of airports and several challenges and opportunities associated with data exchange are considered in this paper.

This paper recognises that digital transformation is as much about transforming the business as it is about transforming the way that technologies are adopted and used. Therefore, organisational transformation is also considered. Literature tends to recognise several main themes: clarity of digital strategy, leadership and business cases; a propensity to invest in collaboration and to partner with, and learn from other actors in the value chain; an appropriate organisational culture that is digitally minded and dynamic, and takes a holistic and innovative approach; capabilities such as digital know-how, skills and resources, and solutions that build trust; and an innovative attitude to the adoption of digital technologies.

This paper is a work in progress. Related definitions, concepts and relationships between variables will be refined through interviews with airports and key stakeholders, and investigated empirically through later research.

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References

ACI (Airports Council International) (2014). *2014 ACI Airport Economics Report*, ACI, Montreal.

ACI (Airports Council International) (2017a). *Airport Digital Transformation – White Paper*, ACI, Montreal.

ACI (Airports Council International) (2017b). *Airport Digital Transformation: Best Practice*, ACI, Montreal.

ACI (Airports Council International) (2018). *World Airport Traffic Forecasts (WATF) 2018-2040*, ACI, Montreal.

ACI Europe (Airports Council International Europe) (2018). *Guidelines for Passenger Services at European Airports: The Passenger at the Heart of the Airport Business*, ACI Europe, Brussels.

Adey, P. (2004). Surveillance at the airport: surveilling mobility/mobilizing surveillance. *Environment and Planning A*, 36, 1365-1380.

Amadeus (2012). *Reinventing the Airport Ecosystem: A New Airline Industry Report*, Amadeus, Madrid.

Arthur D. Little (2018). *Airport Digital Transformation: From Operational Performance to Strategic Opportunity*, Arthur D. Little, Brussels.

Blondel, M., Zintel, M. and Suzuki, H. (2015). *Airport 4.0: Impact of Digital Transformation on Airport Economics: Viewpoint*, Arthur D. Little, Brussels.

Bogicevic, V., Bujisic, M., Bilgihan, A., Yang, W. and Cobanoglu, C. (2017). The impact of traveler-focused airport technology on traveler satisfaction. *Technological Forecasting & Social Change*, 123, 351-361.

Bouma, H., van Rest, J., van Buul-Besseling, K., de Jong, J. and Havekes, A. (2016). Integrated roadmap for the rapid finding and tracking of people at large airports. *International Journal of Critical Infrastructure Protection*, 12, 61-74.

Boutin, N., Fechtel, A., Loh, H. H. and Tan, M. (2016). *The Connected Airport: The Time is Now*, The Boston Consulting Group, Boston.

Brida, J. C., Moreno-Izquierdo, L. and Zapata-Aguirre, S. (2016). Consumer perception of service quality: The role of Information and Communication Technologies (ICTs) at airport functional areas. *Tourism Management Perspectives*, 20, 209-216.

Castillo-Manzano, J. I. and López-Valpuesta, L. (2013). Check-in services and passenger behaviour: Self service technologies in airport systems. *Computers in Human Behavior*, 29, 2431-2437.

Chaffey, D. (2010). Applying organisational capability models to assess the maturity of digital-marketing governance. *Journal of Marketing Management*, 26(3-4), 187-196.

Chiti, F., Fantacci, R. and Rizzo, A. (2018). An integrated software platform for airport queues prediction with application to resources management. *Journal of Air Transport Management*, 67, 11-18.

Crosby, P. B. (1979). *Quality is Free: The Art of Making Quality Certain*, McGraw-Hill, New York.

del Rio, J. S., Moctezuma, D., Conde, C., de Diego, I. M. and Cabello, E. (2016). Automated border control e-gates and facial recognition systems. *Computers & Security*, 62, 49-72.

Eschen, H., Kötter, T., Rodeck, R., Harnisch, M. and Schüppstuhl, T. (2018). Augmented and virtual reality for inspection and maintenance processes in the aviation industry. *Procedia Manufacturing*, 19, 156-163.

Fattah, A., Lock, H., Buller, W. and Kirby, S. (2009). *Smart Airports: Transforming Passenger Experience to Thrive in the New Economy*, Cisco Internet Business Solutions Group, Amsterdam.

Florido-Benítez, L. (2016). The impact of mobile marketing in airports. *Journal of Airline and Airport Management*, 6(1), 1-18.

Florido-Benítez, L., Alcázar Martínez, B. and Gonzalez Robles, E.M. (2016). Analysis of the impact of mobile marketing on passenger experience and satisfaction at an airport. *International Journal of Innovation, Management and Technology*, 7(1), 8-15.

Gobble, M. M. (2018). Digital strategy and digital transformation. *Research and Techonology Management*, 61, 64-70.

Gupta, S. (2018). *Driving Digital Strategy: A Guide to Reimagining Your Business*, Harvard Business Review Press, Boston.

Gures, N., Inan, H. and Arslan, S. (2018). Assessing the self-service technology usage of Y-Generation in airline services. *Journal of Air Transport Management*, 71, 215-219.

Haas, E. P. (2004). Back to the future – The use of biometrics, its impact of airport security, and how this technology should be governed. *Journal of Air Law and Commerce*, 69(2), 459-489.

Halpern, N. (2012). Use of social medial by airports. *Journal of Airline and Airport Management*, 2(2), 67-85.

Halpern, N. and Regmi, U. K. (2013). Content analysis of European airport websites. *Journal of Air Transport Management*, 26, 8-13.

Holdowsky, J., Mahto, M., Raynor, M. E. and Cotteleer, M. (2015). *Inside the Internet of Things (IoT): A Primer on the Technologies Building the IoT,* Deloitte University Press, London.

IATA (2018). *Global Passenger Survey 2018 Report*, IATA, Montreal.

Inversini, A. (2017). Managing passengers´ experience through mobile moments. *Journal of Air Transport Management*, 62, 78-81.

Jarrell, J. (2014). Happy airports make more money – satisfied passengers spend 45 per cent more on airport retail purchases (WWW document). URL: https://amadeus.com/en/insights/blog/happy-airports-make-money-satisfied-passengers-spend-45-airport-retail-purchases. Accessed 23 April 2019.

Kalakou, S., Psaraki-Kalouptsidi, V. and Moura, F. (2015). Future airport terminals: New technologies promise capacity gains. *Journal of Air Transport Management*, 42, 203-212.

Kane, G. C., Palmer, D., Phillips, A. N., Kiron, D. and Buckley, N. (2015). Strategy, not technology, drives digital transformation: Becoming a digitally mature enterprise. *MIT Sloan Management Review* (WWW document). URL: https://sloanreview.mit.edu/projects/strategy-drives-digital-transformation/. Accessed 23 April 2019.

Lee, C. K. M., Ng, Y., Lv, Y. and Taezoon, P. (2014). Empirical analysis of a self-service check-in implementation in Singapore Changi Airport. *International Journal of Engineering Business Management*, 6(6), 33-44.

Martin-Domingo, L. and Martín, J. C. (2016). Airport mobile internet an innovation. *Journal of Air Transport Management*, 55, 102-112.

Morosan, C. (2016). An empirical examination of U.S. travelers´ intentions to use biometric e-gates in airports. *Journal of Air Transport Management*, 55, 120-128.

Mullaly, M. (2014). If maturity is the answer, then exactly what was the question? *International Journal of Managing Projects in Business*, 7(2), 169-185.

Nau, J-B. and Benoit, F. (2017). *Smart Airport: How Technology is Shaping the Future of Airports*, Wavestone, Paris.

Nolan, R. L. (1973). Managing the computer resource: A stage hypothesis. *Communications of the ACM*, 16(7), 399-405.

Nolan, R. L. (1979). Managing the crises in data processing. *Harvard Business Review* (WWW document). URL: https://hbr.org/1979/03/managing-the-crises-in-data-processing. Accessed 23 April 2019.

Rogers, E. M. (2003). *Diffusion of Innovations*, 5th ed., Free Press, New York.

Röglinger, M., Pöppelbuß, J. and Becker, J. (2012). Maturity models in business process management. *Business Process Management Journal*, 18(2), 328-346.

SITA (2010). *The Airport IT Trends Survey*, FlightGlobal, Sutton.

SITA (2016). *The Future is Connected*, SITA, Geneva.

SITA (2018). *2018 Air Transport IT Insights*, SITA, Geneva.

SITA (2019). *2019 Passenger IT Insights*, SITA, Geneva.

Straker, K. and Wrigley, C. (2018). Engaging passengers across digital channels: An international study of 100 airports. *Journal of Hospitality and Tourism Management*, 34, 82-92.

Wattanacharoensil, W. and Schuckert, M. (2015). How global airports engage social media users: a study of Facebook use and its role in stakeholder communication. *Journal of Travel & Tourism Marketing*, 32(6), 1-21.

Wittmer, A. (2011). Acceptance of self-service check-in at Zurich airport. *Research in Transportation Business & Management*, 1(1), 136-143.

Zaharia, S. E. and Pietreanu, C. V. (2018). Challenges in airport digital transformation. *Transport Research Procedia*, 35, 90-99.

Zmud, J., Miller, M., Moran, M., Tooley, M., Borowiec, J., Brydia, B., Sen, R., Mariani, J., Krimmel, E. and Gunnels, A. (2018). *A Primer to Prepare for the Connected Airport and the Internet of Things*, ACRP Research Report 191, National Academy of Sciences, Washington, D. C.