Enhancing airport ecosystems with the power of data

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Introduction

Airports are complex ecosystems where a diverse set of stakeholders come together to form one of the backbones of today's universal mobile communities. Together, airport operators, airlines, ground handlers, retailers, authorities and service providers manage a vibrant, global flow of people and goods, cutting safely and securely across all borders.

To maintain this free flow, airports are leveraging digitalization to cope with their main challenges – from ever-growing passenger numbers and increasing passenger expectations to the rising importance of non-aviation revenue, the reduction of airport's environmental footprint and the need to ensure business continuity.

Airports have achieved impressive efficiency gains by implementing digital technologies: Saving ten seconds per passenger on immigration by leveraging facial recognition technology in a walk-through tunnel solution, reducing minimum connecting times by accelerating baggage handling for selected priority bags and reducing infrastructure costs by up to 10% through energy efficiency systems are just a few of the more prominent examples.

Yet many airports struggle to harness the full power of data as the key resource of the digital age. Too often, data remains locked in silos across different stakeholders, processes and systems or is only available in an unstructured form. The reasons? Investment boards frequently brush aside data-driven technologies due to unclear business cases. Moreover, conventional tendering models are often illsuited to procuring digital technologies in which costs must be borne by multiple stakeholders because they also benefit several parties. Also, many stakeholders are reluctant to share their data as they fear losing commercial control over it.

To unlock the full power of data, airports need to share their data, tear down the data silos and form an open innovation ecosystem that embraces collaboration across stakeholders and processes. Within this new ecosystem, the holistic "airport digital twin" – our vision for the airport of the future – will be cleared for take-off.

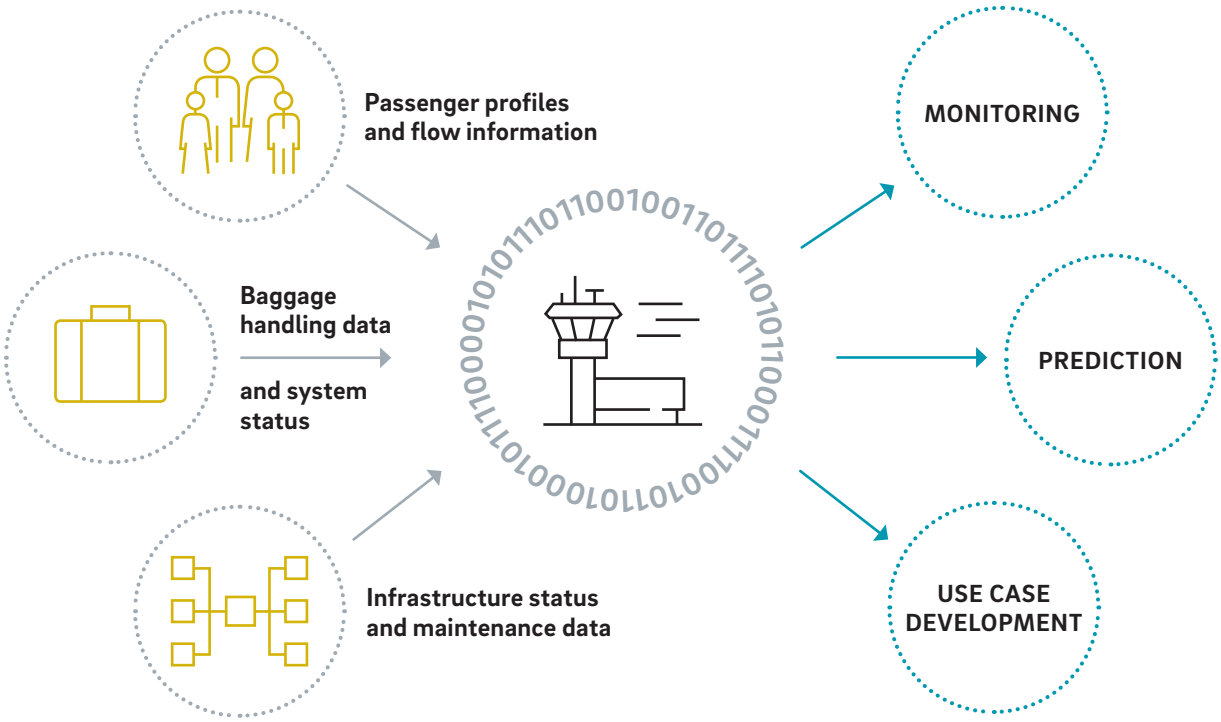
The digital twin of an airport brings all airport-related data streams – for both operations and infrastructure – from all stakeholders together in a single central data lake that is simultaneously accessible to airport stakeholders and third-party service providers. This will help to create a unified, transparent "one truth" view of airport operations. Actionable, real-time information on everything going on in the airport will be provided in dashboard views to everyone who needs to know, so that decisions can be made quickly as and when the need arises.

But that is not all: The digital twin also carries the necessary tools for advanced prediction and simulation of future developments to which airport operators can then respond proactively. In other words, the twin delivers effective decision-support tools for everything from short-term scenarios to infrastructure expansion decisions. Additionally, since data is already located in one virtual space, new use cases and applications can be developed on the fly by all interested parties. Potentially, the digital twin of an airport could even be visualized in a 3D model that would be accessible via virtual or augmented reality.

The technological basis for the open innovation ecosystem – and, hence, for the airport's digital twin itself – is an open, cloud-based IoT platform that offers secure data centralization and is able to integrate both data streams from the existing system and data from physical assets. As it allows for secure and customized multiuser access, stakeholders need not fear losing control over their data: They can easily define what is visible to whom.

The use of the right technology must be combined with a corporate culture that fosters the creation of an innovation ecosystem, a digital mindset that is ready to

A Vision of the airport digital twin



change how business has been run in the past. Proof of concept and stage-gate processes must take the place of business cases that have to be final before projects even start. This also means that airports need to adopt new procurement models that let them share both costs and benefits with other stakeholders and third-party service providers.

The digital twin of an airport is a vision that demonstrates what unlocking the full potential of data means for airports – and our vision for the airport of the future. It will help airports in coping with some of their biggest challenges. To better illustrate our vision, let's have a look at these key challenges – and the technologies airport are currently using to face them. → A

1 Data-driven technologies that airports use to improve performance and master current challenges

Airport operators must deal with a myriad of challenges to maintain their strong position. To show how powerful data-driven technologies can be in the airport ecosystem, we have identified key examples already in use across the globe. → B

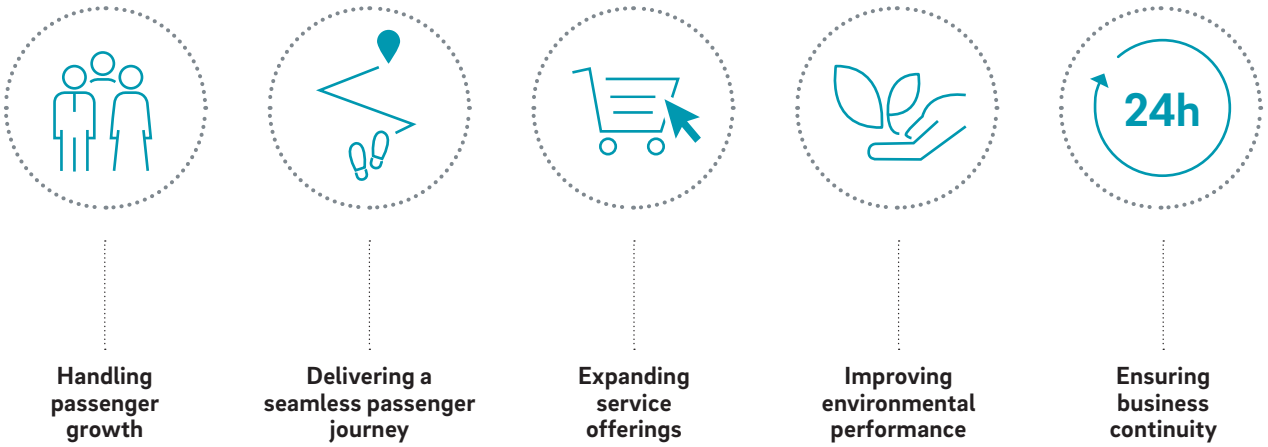
1.1 INCREASING OPERATIONAL EFFICIENCY TO ACCOMMODATE PASSENGER GROWTH

The number of global air travelers has doubled since the early 2000s and will do so again by 2036, by which time 7.8 billion air passengers will be circling the globe.[1]

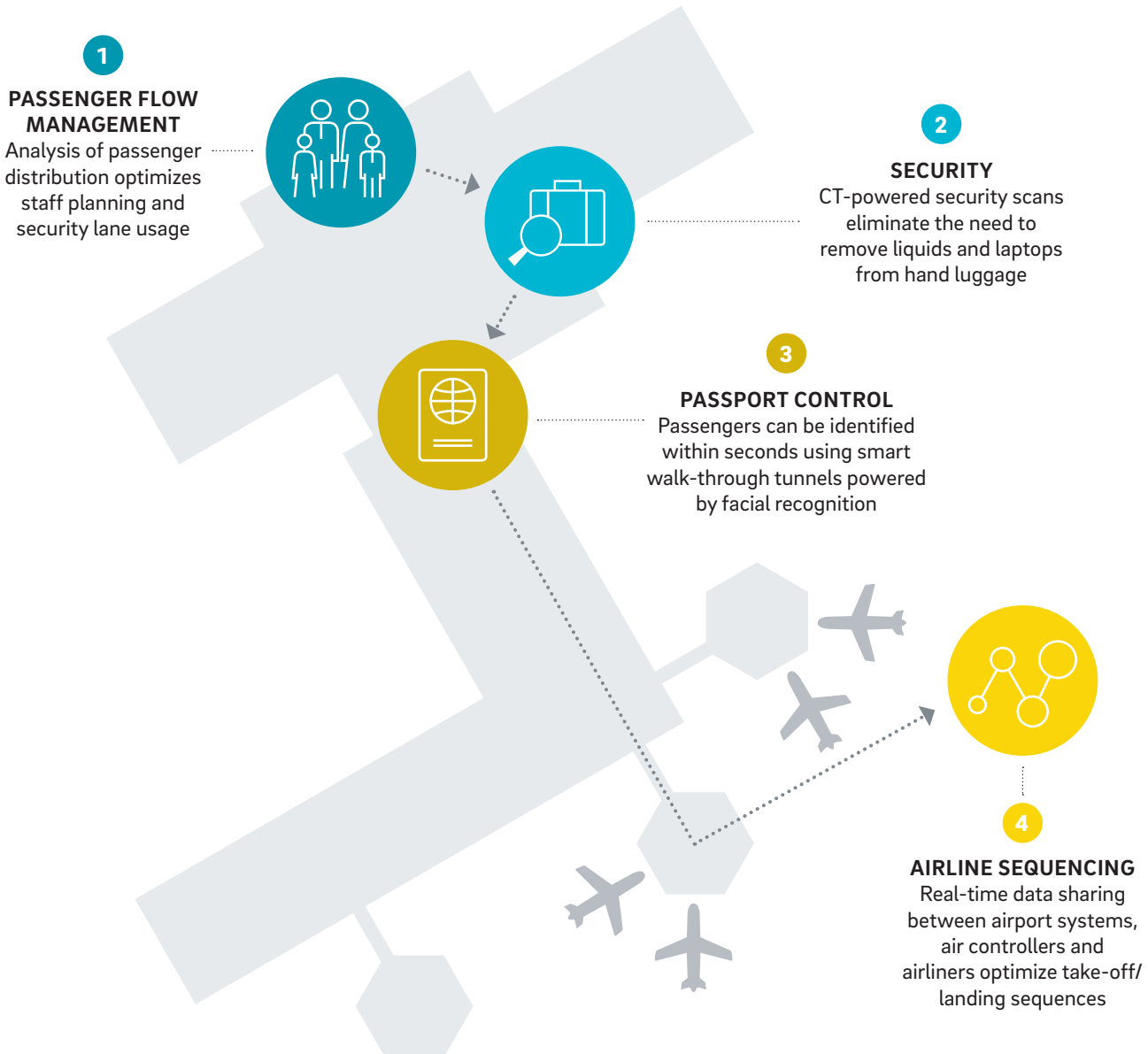
To accommodate this growth, airports have to increase their operational efficiency and maximize peak hour capacity to handle baggage, passengers and aircraft per hour. Simply adding more terminal infrastructure is often not possible due to long lead times and spatial constraints. (In some cases, it may also prove fruitless: It remains to be seen how long two-level boarding bridges will remain in use after the recent cancellation of the A380.)

Data-driven technologies can be used at bottleneck points to deliver significant impact: Is the queue at immigration too long? Then implement smart walk-through tunnels using facial recognition technology to reduce wait times and improve security. Dubai Airport managed to gain ten seconds per passenger and screen using this technology.[2] The time-consuming and tedious process of removing liquids and computers for the passenger security scan can also be a thing of the past once CT security scanners that leverage machine learning become the new standard. The resultant wait time reductions can exceed 20%.

B Current challenges in the airport ecosystem



C Technologies to optimize bottlenecks and increase peak hour capacity



Airside decision-support systems such as airliner sequencing help several stakeholders at once: By letting airport IT systems, air traffic controllers, ground handlers and airlines share data in real time, optimized take-off/landing slots can be calculated. An optimized sequence is then proposed that can reduce runway wait times by almost 50%.[3] At Munich Airport, airline sequencing is further optimized by referring to weather forecasts, thereby reducing slot wastage and improving turnaround times.[4] → C

Aside from bottlenecks, data-driven technologies can also be leveraged holistically, e.g. by optimizing baggage handling operations from end to end. Passenger flow management systems provide transparency to all stakeholders on where passengers and staff are located. That lets airports respond dynamically to hotspot situations, adjust the number of security lines and optimize staff planning. Frankfurt Airport uses this approach to predict passenger flows at more than 300 data points. The operator can thus peer into the future and plan accordingly, enabling the airport to reduce processing times while also increasing staff efficiency.

1.2 INCREASING OPERATIONAL EFFICIENCY TO ACCOMMODATE PASSENGER GROWTH

Passengers on other modes of transportation are used to being in constant, individualized contact with their service providers thanks to mobile technology. They demand the same levels of service and transparency from their aviation service providers. On top of transparency, passengers are also very keen to minimize the time they spend waiting at security, immigration and baggage carousels.

To provide real-time transparency throughout the journey, user-centric mobile applications are the centerpiece, supplying passengers with information and push notifications on delays, gate changes and wait times. At the same time, apps can leverage indoor positioning systems to provide passengers with intra-terminal wayfinding assistance. Cooperating with local mobility providers can even help with home-to-airport journey planning, delivering increased passenger satisfaction. The London Gatwick app is a good example

CASE STUDY

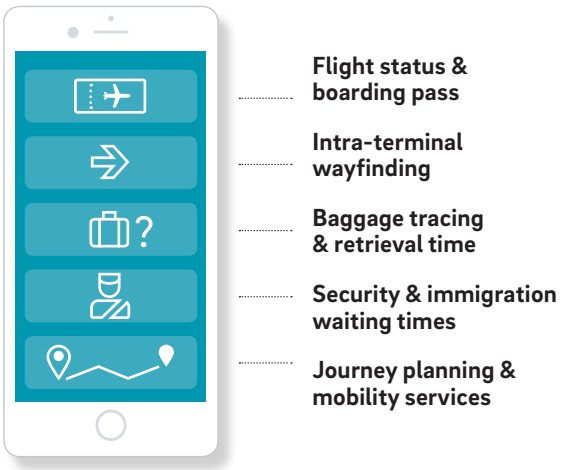
PUSHING THE SINGLE TOKEN JOURNEY AT LONDON HEATHROW

Pushing digitalization forward is not just a question of which technologies should be implemented in specific process steps, but also how that should be done. London Heathrow Airport is a great example of an airport pushing forward an idea that has long been around: the single token journey, enabling the passenger to proceed from entering the airport toward boarding pass verification, security, immigration and through the entire boarding process using only facial recognition and biometric identification, skipping boarding passes and ID verification altogether. Based on the insight that two thirds of passengers are willing to share personal data in order to speed up processes for themselves, Heathrow uses an agile approach to technology deployment in the end-to-end passenger journey. It consists of constant user verification and testing, the live testing of technology in the actual airport environment and technology demonstrations that put the passenger experience at the heart of the new journey.

of how to incorporate all these features, significantly increasing transparency and passenger satisfaction while also saving staff resources.[5] At Amsterdam Schiphol, intra-terminal wayfinding is realized by cooperating with Google Maps. The transparency provided by its mobile app is of such a high quality that physical information desks can be closed starting in 2019.

What is true for passengers is also true for their baggage. In 2017, 47% of lost bags went AWOL during transfers. Not surprisingly, then, 64% of passengers would like track their bags via an app.[6] Data connectivity between the baggage handling system and the passenger's device is necessary to enable this end-to-end baggage tracing (which is required by IATA resolution 753), once again illustrating how data sharing can enhance the array of services available at the airport.

D Mobile app features to increase the seamlessness of the passenger journey



The passenger experience can also be improved above and beyond mobile applications. By measuring and analyzing passenger distribution, Hamad International Airport in Qatar was able to guarantee queue times of less than five minutes for transfer passengers. In addition, state-of-the-art sensors allow staff to be mobilized based on real-time data about usage levels in high-use areas like restrooms. That helps airports maintain high cleanliness standards and respond more quickly to unforeseen incidents.

Data-driven technologies enable airports to directly address passengers and improve travelers' journey experience, thereby significantly improving minimum connecting times, wait times and passenger satisfaction. And happy travelers tend to part with their money more easily than stressed ones: A 1% increase in passenger satisfaction leads to a 1.5% increase in non-aviation revenue, which we will examine in the next chapter.[7] → D

1.3 EXPANDING SERVICE OFFERINGS TO CAPTURE THE IMPORTANCE OF NON-AVIATION REVENUE

Airport operators are embroiled in a fierce struggle over non-aviation revenue and passenger data ownership. In light of intensified competition and the market penetration of players from outside the airport industry, airports stand to lose between USD 2 billion and USD 4 billion in non-aviation revenue between now and 2023.[8] While overall revenue per passengers has declined over the years and the share of non-aviation revenue already dropped from 50% to 40% between 2000 and 2016, successful airport operators still claim a privileged role as the primary point of contact for passengers on their journey.

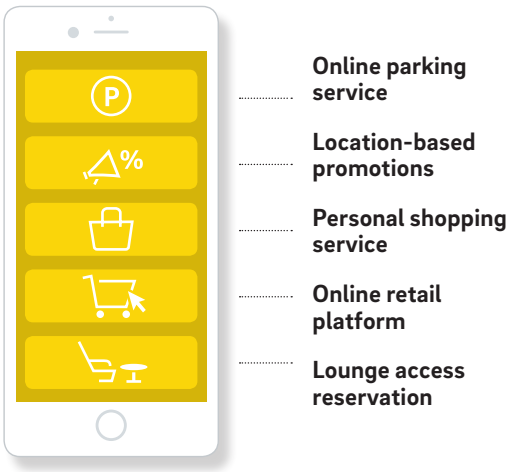
Leveraging data from dedicated mobile apps has become by far the most important component of direct

customer interfaces. Airports further widen their data sources by also gathering data from website usage, pre-bookings for parking spaces, online passenger feedback, social media and WiFi analysis. Cooperation with other stakeholders in the airport ecosystem is leveraged as an additional data source, including point-of-sale data and other data from airlines.

New services are being developed using this data: cooperation with mobility players and online parking services to offset the decline in parking revenue, location-based promotions and personal shopping services to increase retail sales, and the online selling of priority boarding and lounge access as additional revenue sources.

The ability to combine online shopping with offline retail may become one of airports' strongest assets. London Heathrow and many other airports propose a comprehensive online shopping experience across over 300 partners, including everything from duty-free products, clothing, jewelry, electronics and luggage to gifts. Goods bought and paid for online can be then picked up directly at the airport together with loyalty rewards, e.g. the Heathrow and Changi reward programs. The scalability of this model presents a logistical challenge (e.g. the security screening of goods from landside to airside) and customer expectations are very high. In response, some airports (such as Frankfurt) have therefore opted to deliver goods directly to passengers' homes instead. That way, airport stores can also function as showrooms, leaving the logistical challenges outside the airport. → E

E Mobile app features to increase non-aviation revenue



1.4 IMPROVING RESOURCE EFFICIENCY AND ENVIRONMENTAL PERFORMANCE AMID TRENDS TOWARD GREEN ENERGY AND ENVIRONMENTAL AWARENESS

The imperatives of a greener economy and pressure exerted by regulators, environmental associations and the political arena to increase environmental performance have brought the topic of ecofriendly operations to the forefront of airports' agendas. The need to raise energy efficiency and reduce their carbon footprint are key aspects, as are reducing noise and air pollution tied to airport operations: As things stand, communications, utilities, energy and waste-related costs account for almost 10% of an average airport's operating expenses.[9] And while already being a hot topic in everyday operations, more eco-friendly operations become even more paramount when airports think about expansion projects, which typically require indepth public participation.

While gradual conversion to carbon-free energy

sources marks a first step in a more ecofriendly direction, data-driven technologies can significantly accelerate this journey and help airport operators achieve their environmental targets.

Smart grid technology enables them to integrate carbon-free and conventional energy sources, and also to use batteries and energy storage systems to automate and manage responses to rapidly changing demand for electricity – a key ingredient to managing resources more efficiently.

Regarding mobile units, automated ground support equipment scheduling systems minimize the number of ground vehicles needed, as well as optimizing vehicles' operating times based on sensors, airline and airport data. That helps reduce all types of traditional and alternative fuel consumption and drives down airports' operating expenses.[9] As a first step, Lyon Airport equipped its ground vehicle fleet and the corresponding movement space with sensors that can keep track of all vehicles and send the data to a display for the operator.[11] Additionally, the vehicles can receive instructions from the sensors and can automatically reduce speed, for example, thereby contributing to lower energy consumption.

CASE STUDY

SAVING ON ENERGY COSTS AT DUBLIN AIRPORT

Another possibility is to use building management systems (BMS) based on real-time sensor data. These systems detect operational inefficiencies and provide employees with recommendations for adjustments to energy systems. They are also connected to other energy-related systems and store data on a cloud-based platform, enabling operators to access data within seconds. The BMS in service at Dublin Airport shaves almost a third off energy consumption in the terminal, even though passenger numbers have increased by 6%. It therefore contributes to a significant reduction in both energy consumption and operating expenses.

1.5 ENSURING BUSINESS CONTINUITY IN CRISIS SITUATIONS

Recent cases of drone-based attacks on airports illustrate just how vulnerable airports are to sudden interruptions. In such a turbulent environment, business continuity management ranks high on the agenda of airport operators, as reflected in redundant systems, contingency manuals, back-up processes and emergency procedures. Safeguarding cyber and physical infrastructure, maximizing system uptime and providing instant information access to the staff affected are some of operators' key concerns.

Ensuring a continuous supply of power is a key topic for building systems. The right use of data helps airport operators to guarantee system uptime in terminal infrastructure: Predictive maintenance is the most prominent case in point. London Heathrow, for instance, has implemented a baggage handling system that uses predictive analytics.[12]

To maintain continuous flight operations, a drone detection radar has been successfully tested at Manchester Airport. The system identifies lowflying objects within the runway's surroundings and shows their exact position in real time on a display in the control tower, so that airplanes can be warned and drones selectively disabled.[13] This reduces the costs

CASE STUDY

FORMING AN AIRPORT COMMUNITY AT LONDON GATWICK

In the context of business continuity, quick notifications to all relevant airport stakeholders are paramount to access status information, enable decisions and get actions assigned. Setting up notification systems can be difficult, however, starting with the question of who should bear the cost of developing such a system when the benefits are shared among all stakeholders? Using a modern, digitalization-focused approach that leverages startup collaboration and a stage-gate process, London Gatwick has built an airport community application that involves all airport ecosystem stakeholders and disseminates the latest information on the status of airport operations and focus topics in a user-centric design. The application has been well received by employees from all airport ecosystem stakeholders and is now a key element of communication. Although it does not focus on crisis communication, it demonstrates how a digital approach can help applications that are of relevance to all stakeholders be put into practice – without killing the idea in lengthy business discussions before they even make it off the drawing board.

caused by collisions, lowers the number of aircraft safety incidents and thus also contributes to reducing average delay times.

To provide advanced operational and notification services to staff, mobile apps – backed by a cloud-based system – can be leveraged to manage operations in normal and/or crisis conditions, supplying crisis information to staff and assigning tasks to individuals or user groups without delay.

To prevent delays and costs arising from lengthy IT system breakdowns, Dubai Airport has implemented a modular data center complex that hosts critical data.[14] The system receives and securely stores all data from the various IT modules. Additionally, it informs employees early on if a system deviates from normal operation. This not only reduces energy consumption by almost 30% compared to traditional systems, it also ensures a data availability level of 99.98%. That increases the uptime of IT systems and enables operations to be resumed faster after any incidents.

In the drive to ensure business continuity, data-driven technologies create more opportunities to predict and prepare counter-measures against external influences such as natural disasters, cyber-attacks and terrorism. Predictive analytics could, for example, be used in combination with weather forecasts to predict potential natural disasters. Similarly, intelligent video surveillance systems could be able to send early alerts based on automatically recognized suspicious behavior.[15] However, this requires a different approach to data than we currently see in airports, as discussed below.

2 Taking stock: Where are we at with the use of data to enhance airport ecosystems

We have seen that airports have already taken important steps toward becoming digital. And we have seen impressive examples of how airports are using data-driven technologies to enhance performance and overcome challenges. Over and above individual technologies, we also note that some airports are working on end-to-end digital innovations that involve several different stakeholders: London Heathrow and London Gatwick are good examples. The downside is that, while pioneering technologies and approaches to digitalization clearly exist, they are still the exception rather than the rule. Too often, leveraging data in airport ecosystems falls short of realizing its full potential: Technologies remain confined to helping one stakeholder and target only specific process steps. End-to-end technologies that involve several ecosystem stakeholders and seek to advance the whole community are few and far between, as may best be illustrated with a quote from one of the interviews we conducted:

"So, we lose a piece of baggage. Then we meet to find out who is to blame – the ground handler, the airline, the operator, whoever. And then everybody brings his own data to show that he is not to blame but that it must be somebody else's fault. And we spend ages on these fruitless discussions. And we know that if we just shared data, we would be better off and could just move on, but it still does not happen."

Senior baggage engineer

Why is that the case? Technology itself can hardly be the reason. Airports have all the technological tools they need to adapt to digital processes, as can be seen above; and we will explain some more about much-needed technology below.

No, the answer lies not in technology, but more in the way business is done within the airport ecosystem. We see three main drivers that hinder end-to-end digitalization across all stakeholders:

- **NO INVESTMENT WITHOUT A CLEAR BUSINESS CASE**
  In this traditionally asset-heavy industry, airports normally base their investment decisions on very concrete business cases with clear-cut costs and benefits. Investment proposals that cannot deliver black-and-white business cases are often discarded before even making it to the boardroom. Yet while use cases for digital technologies may be compelling and their impact can be described, it can be hard to quantify them accurately before giving them a chance. Gatwick's airport community app illustrates the point well. And the same argument is even more true for technologies that benefit more than one stakeholder, which leads us to our next point.

"In internal investment boards, you often compete for project funding with other departments. The project with the clearest business case is typically the winner. But this often eliminates promising digital projects where you just can't know the exact numbers before you start!"

Head of Innovation at a large Middle Eastern airport

- **TRADITIONAL TENDERING PROCUREMENT MODELS**
  Airport procurement is typically driven by traditional tendering models in which airport operators define their system needs and contract out hardware installation and fee-based services for a defined time horizon. Once a system reaches its prearranged lifespan, a new procurement cycle starts over. Innovations that happen in between tendering cycles and across systems are often of limited interest to airports, however, a fact which restrains their appetite for digital innovations to begin with. Moreover, traditional tendering procurement models are not at all suited to the implementation of new technologies whose benefits are shared by several stakeholders (within one firm or even involving other ecosystem players), and where costs should be split fairly between all the beneficiaries.

"I typically only care about procurement when a service contract for a system runs out. Then I look at what is the current technology and start the tendering process, and service it out for another 10 years. What happens in between is rarely of relevance with infrastructure assets."

Head of Infrastructure at a large European airport

- **FEAR OF LOSING CONTROL OVER DATA USE**
  Lastly, ecosystem stakeholders are concerned about what might happen to the data they have to share in order to move forward with digitalization. Essentially, they are afraid of losing control over a hard-to-grasp resource – data is the new oil, remember – and fear that, once shared, data will lose value and other players may be able to exploit it for their own commercial ends. Since the prospect of remaining in the driver's seat is limited, data sharing remains the exception rather than the norm.

"The airlines always view the passengers as theirs and do not want to share data about them – It is hard to convince them that we are not interested in passengers' buying patterns, but we want to see when they pass checkpoints or will likely arrive late."

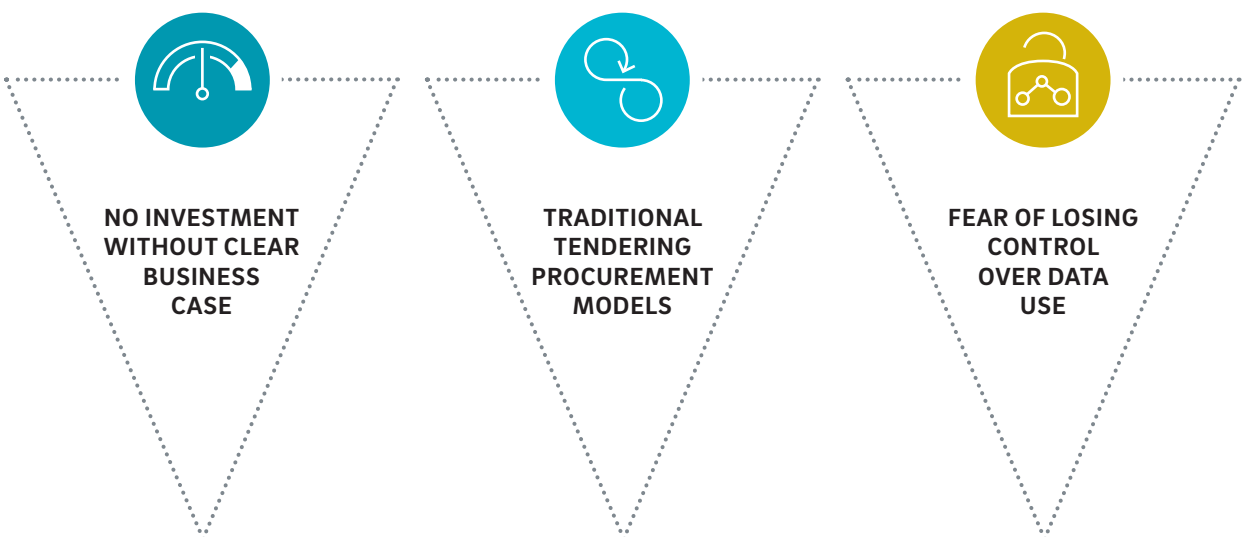
Senior operations manager

As long as these key factors persist, digitalization in airports falls short of its potential and airport operators will only slowly progress in their digital journey. Many technologies will continue to only target specific process steps on a small scale within a wider process chain, benefiting individual ecosystem stakeholders alone. Technologies will have localized impacts on a piece of the overall puzzle that is the airport ecosystem – sometimes at heavy investment cost, as in the case of smart immigration tunnels and new CT scanners.

As a result, data remains locked in silos: isolated, unstructured and inaccessible for other useful purposes. It is effectively lost to all other stakeholders in the ecosystem and, in many cases, needs to be manually collected again for other projects.

Yet the great thing about data is that it does not diminish in value if shared. On the contrary, its value increases, regardless of who can benefit from it. Since the importance of data sharing cannot be stressed enough, let us take a closer look at how data can be made available to other ecosystem players by the use of a common platform. → F

F Barriers to effectively leveraging data in the airport ecosystem

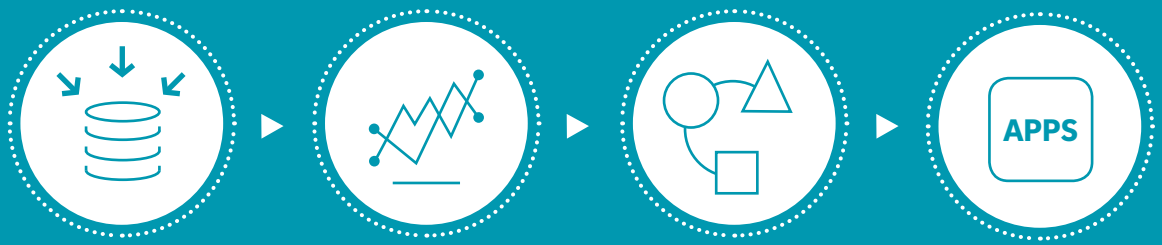


How data analytics can be used in the airport ecosystem

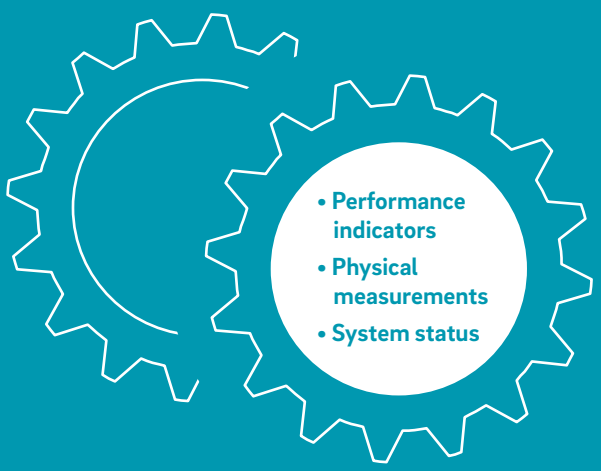
Decision makers need to know what they want to achieve and understand how the power of data can be harnessed in connected, complex environments to find solutions to specific challenges. Data – especially in large sets – gives us the opportunity to gain and act on new insights we have never before been able to unlock. In the Internet of Things, this typically means gathering different types of data over time (e.g. temperature, humidity, vibration, usage etc.) and analyzing patterns. Using statistical tools, the data can be better described and different sets of data compared using regression analysis to discover correlations between and/or the causes of specific observations. Based on the insights gathered, decision processes can be defined and automated in the form of digital applications (software).

While this may sound less than earth-shattering at first, it in fact opens up an amazing world of opportunities by connecting streams of data from different sources to reveal facts that remained hidden in the past, and to enable us to act on these insights in a coordinated manner. In the well-known use case of predictive maintenance, we use large amounts of data on vibration, temperature and other physical system parameters over time to identify surprising deviations or patterns. We are thus able to predict that a given part is likely to break, and we can exchange the part before it does. One of the best methods to organize and analyze data is to create digital twins: virtual representations of physical entities that are able to gather data about themselves and their performance and transfer these via IoT technology. To take just one example: By combining the analysis performed by established software and additional sensors, a digital twin of a baggage handling system can be created that transfers data about the physical status of the system together with performance data in a single standard. Connecting the digital twin to an overall system effectively tears down the data silo.

GETTING FROM DATA COLLECTION TO APPLICATIONS



PRINCIPLE OF A DIGITAL TWIN



3 Harnessing data's full potential across interfaces on an integrated, cloud-based IoT platform

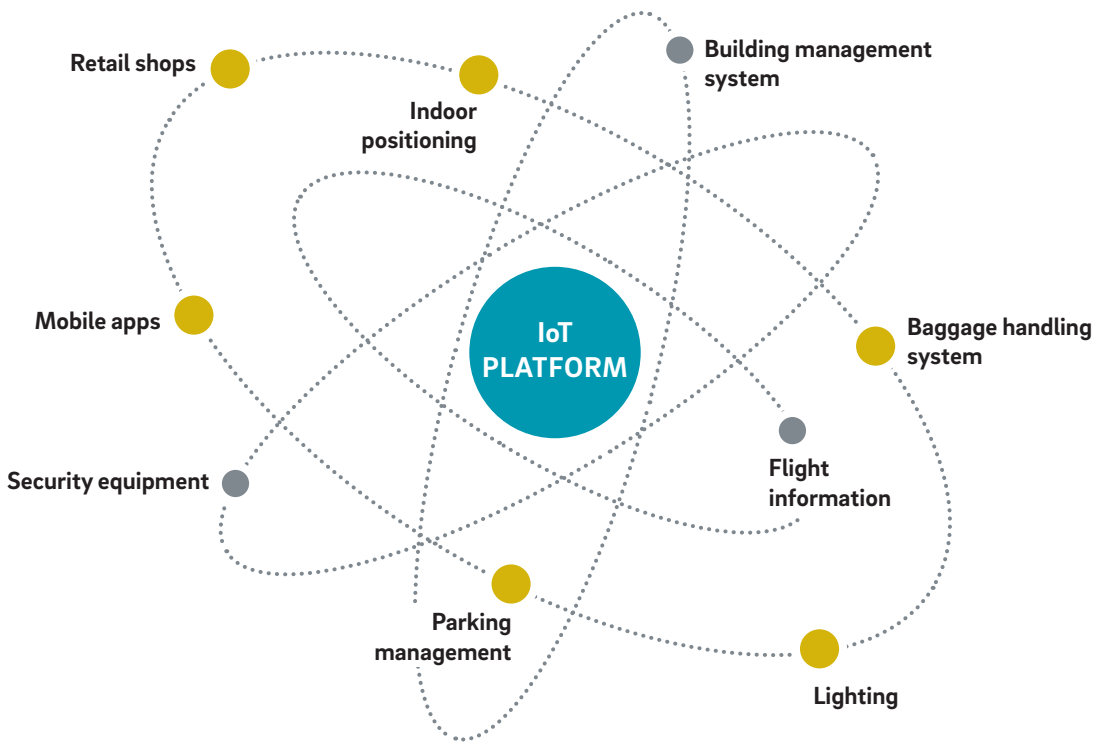
We have highlighted the importance of a technological backbone as the basis for integrating data in the airport ecosystem and pursuing the vision of the digital twin of an airport. The operational databases in place today – though at the heart of many airports' operations – are not sufficiently equipped to handle all data that would have to be integrated to create seamless airport operations. Instead, what is needed is a more open, advanced technology that puts the concept of data and its possibilities at its core and can integrate the world of airport operations with that of physical asset infrastructure in the Internet of Things. In our view, an open, cloud-based IoT operational system is the right technological backbone for this job, as these systems come with all the features needed to move forward in leveraging data:

- An open architecture with APIs that make it easy to add in applications and data streams
- A cloud-based and scalable setup
- Customizable multi-access features for airport stakeholders, partners and service providers
- Direct IoT and system data stream integration
- A proprietary tool landscape for data visualization and analytics
- Most importantly: Secure, customizable access and data management to accommodate stakeholder's concerns for the (commercial) safety of their data

The IoT operating system we are describing here is the right backbone on which to proceed to the next step in airport digitalization, based on the insight mentioned above: The great thing about data is that its value does not diminish when it is shared. On the contrary: By sharing it across partners, other players have the chance to optimize their own processes and systems and jointly increase efficiency.

G Connecting systems to set up integrated end-to-end terminal flow management

H Possible systems to be connected to an open IoT platform



Using this backbone, partners can work on the development of pioneering use cases and applications that have been under discussion for some time now.

THREE EXAMPLES:

- At specific pain points: Leverage passengers' actual position data to decide whether to keep a boarding gate open or close it.
- For end-to-end integration: Extend the passenger journey beyond the gates of the airport, enabling mobility journeys that can be planned from home to gate.
- To integrate infrastructure and operations: Automatically coordinate building system maintenance schedules with gate allocation systems.

J How to get from here to there: Step by step to developing new digital apps

STEP 1
Define business objectives and KPIs

STEP2
Define data sources to be used

STEP 3
Connect data streams to IoT platform

STEP 4
Analyze data across processes and stakeholders

STEP 5
Develop digital applications for use case

Let us go a step further regarding the potential connection of actual systems: If airports connect a passenger flow management system to data about incoming city traffic, the enterprise resource planning system, queue management systems at security and a mobile notification system for operations management, they will be able to assess the current situation at security screening, take incoming traffic into account, notify staff of what needs to be done (e.g. open a new security lane) and take all these factors into account for overall resource scheduling to optimize future staff planning. The result? An integrated end-to-end terminal flow management system. → G → H

Setting up this collaborative, secure and open IoT platform will naturally demand a heavy financial investment, not to mention staying power and top management commitment. And yes, the outcome is subject to a measure of uncertainty. Many use cases will prove to be economically non-viable, and nobody can say today which ones will turn out to be the best ones. Yet this, precisely, is what the digital spirit is all about: a willingness to remain mentally agile and allow for failure. Moreover, having witnessed the potential of digitalization and the impacts it can achieve in recent years, it is fair to say that there is an at least equally valid risk of missing out on key developments.

If we are targeting a network-based approach to build a common platform in an ecosystem, then this platform should obviously be built collaboratively, not shared only when it is up and running. The best results will be achieved by working together as partners, where investments are shared and airport ecosystem players collaborate with leading IoT firms, software developers and cloud infrastructure providers. → I → J

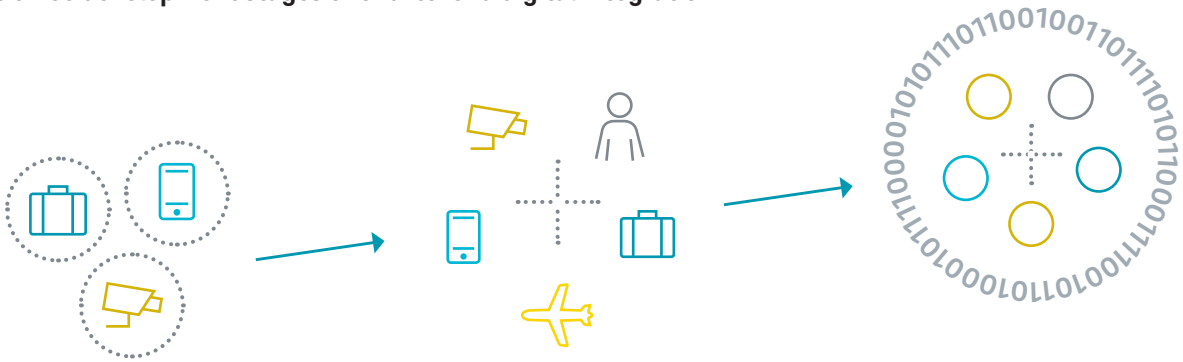
4 Moving toward the vision of the airport's digital twin

The digital twin of an airport collects data from the world of physical airport assets and infrastructure and integrates it with operational data on passengers, baggage and flights. All this is done on the technological backbone of the IoT operating system, as described above, to form an open, innovative airport ecosystem that permits the end-to-end integration of processes and stakeholders. As such, it is more than a static, virtual copy of the airport: It is constantly fed with real-time live data about systems, processes, actions, vehicles and people, and it runs in parallel to the real world. The digital twin thus enables coordinated and collaborative action across all ecosystem stakeholders and processes in three key areas: monitoring, prediction and use case development. It enables "one version of the truth" for all ongoing activities and system statuses to be monitored permanently. It allows each stakeholder at any time to receive customized dashboard information on the performance of systems and processes. Better still, it creates opportunities for joint, collaborative and speedy decision processes as all actors have the same information at their fingertips. → K

The digital twin of an airport facilitates predictive analysis of events that may disrupt operations and acts as an early-warning system. At short notice, it can provide valuable decision-support information based on predictive analysis of potential outcomes (e.g. which parking position/gate to allocate for each plane? How will that influence other turnarounds?). On top of short-term prediction, it can also help to simulate trends, scenarios and the expected gains from infrastructure updates. An airport's digital twin also empowers stakeholders to optimize system performance and realize synergies – saving everyone the trouble of duplicating data collection. If a joint approach is adopted, new service offerings can be developed by all ecosystem partners.

All users can leverage the digital twin to achieve actionable insights and identify analytical details to a hitherto unimaginable depth, potentially even in a live 3D model or in virtual reality. While this may at first

K The three development stages of end-to-end digital integration

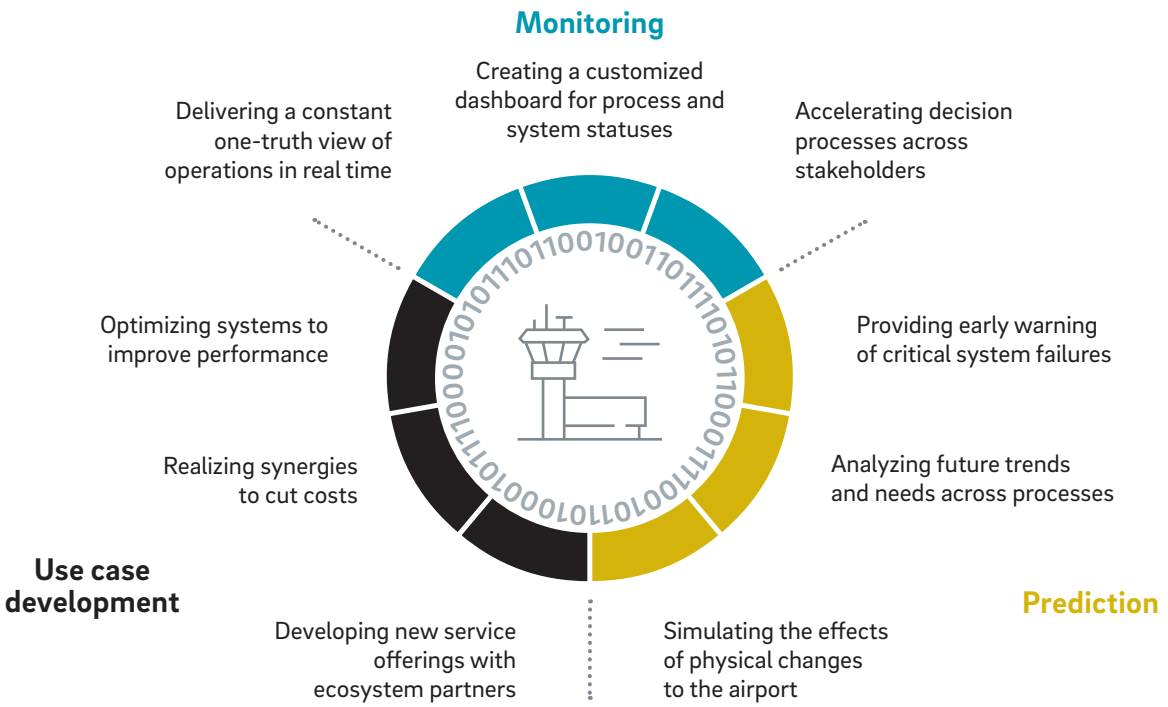


Today
Integration of digital solutions in single processes

Next development stage
End-to-end process digitalization with data-driven transparency for relevant stakeholders

Long-term vision
Full integration of all stakeholders and processes in a joint digital twin

L The potential of the airport digital twin



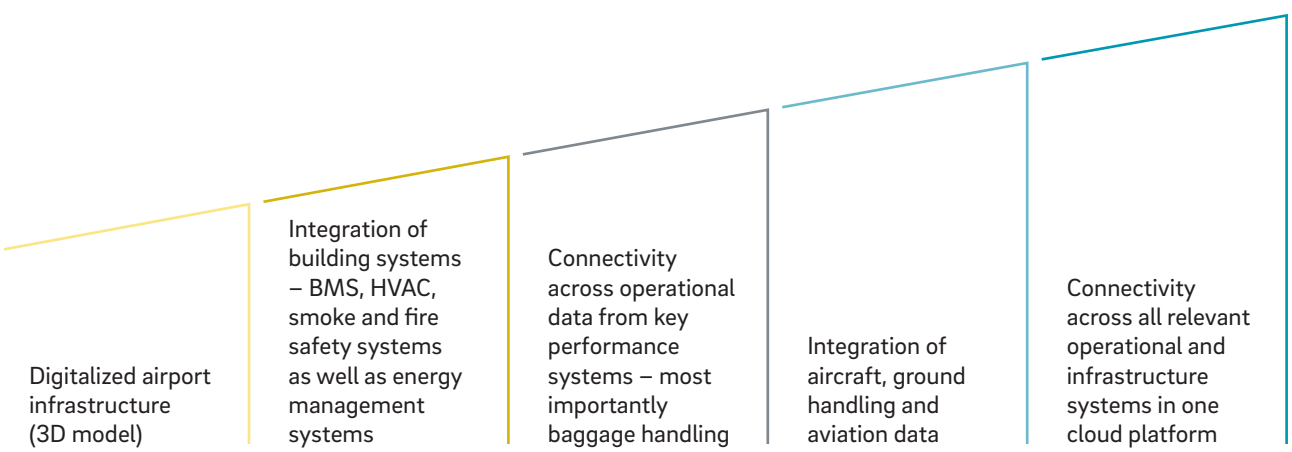
sound like a lofty promise, it is important to remember that, in factory design, digital twins are already used to pre-plan and optimize production processes and employees' work spaces before the ground is even broken for a new factory. Similarly, in construction and facility management, digital twins are a present reality that serves to constantly monitor building statuses. → L

It remains to be seen whether integrating operational data or virtualizing the physical airport infrastructure will be the most efficient way to create an airport's digital twin. That said, taking a digitalized physical infrastructure – e.g. a 3D map of the airport buildings – as our point of departure, a digital twin can be built by integrating more and more data streams in the platform: information on smoke alarms and ventilation from building automation systems, energy management data, data from the baggage handling system, input from the passenger flow management system, even aircraft and ground handling performance data. Once all data streams are harmonized and integrated, the digital twin becomes a reality. → M

For us, the digital twin is the logical conclusion of what the Internet of Things can achieve in a cloud-based environment. It is the stunning endgame, showcasing what airport operators can achieve by harnessing the power of data. → N

M Basic idea of IoT digital twin: What is going on where?

N A possible pathway to moving toward the airport digital twin



5 The way forward: Where airports need to go from here

In this white paper, we have focused on the technological side of driving digitalization forward. We have highlighted the importance of an open, cloud-based IoT operating system as the backbone for this journey. The backbone will facilitate secure, selective data integration to create a plug-and-play type background for the open innovation ecosystem. This kind of operating system is not ready to order. Instead, it must be built together with the right partners to form the open innovation ecosystem itself. Airport operators need to find an IoT operating system service provider that is ready to work with them on the technology. They must also build a network of trusted airport ecosystem partners – airlines, ground handlers, authorities and other airport users – who are willing to invest in launching the data integration process. Lastly, airport

operators should start scouring the startup community for partners willing to collaborate and develop concrete use cases going forward.

In illustrating the current status of digitalization in airports, however, we also made the point that implementing a technology alone will not be enough. Airports still have work to do to foster a digital culture that empowers employees to drive change forward, ensures that all employees harvest the benefits of digitalization and bridges the generation gap that still exists in so many airports:

"On the one hand, I have my legacy employees used to the legacy IT system. They are paramount to keeping the whole system running, but they don't want to change anymore. On the other hand, I have the young IT nerds who are eager to implement new technologies and willing to work hard on that, but who get more and more frustrated as change is slow and legacy IT needs to be maintained."

Head of IT at a large North American airport

To push forward, the simple organizational trick of installing a "Head of Digital" will not suffice. Instead, airports need a comprehensive digital change management process, dedicated digital teams to drive concrete projects forward and dedicated, successful airport apps with a convincing, user-centric design that make the lives of employees easier, not more complicated.

Hand in hand with this cultural change, the project selection and investment decision processes need to be reviewed and adapted. They must allow for digital projects to include proof-of-concept and technology demonstrator phases in a stage-gate process and postpone the business case discussion. That will give digital technologies the opportunity to "get somewhere" technologically while figuring out the business model along the way.

Lastly, conventional procurement models in airports require more modern components. Standard, EPC-like work contracts with fixed costs create no incentive whatsoever for innovation or additional investments that may possibly break even in ongoing operations. These models are not fit for the digital world. Performance-based contracts and contract models that allow for gain sharing are the right tools for digitalization – especially as they admit flexible and scalable pay-per-unit pricing, which fits perfectly with typical aviation pricing strategies.

The technological backbone, a digital mindset and careful project selection will determine airports' success in advancing on their digital journey and harnessing the true power of data. Naturally, the next step in digitalization will not absorb every last cent of free budget, nor should it do so. The normal priorities of keeping operations running remain priority number one. Yet even with just a small, dedicated approach, the journey can – and must – be started, as illustrated by one final quote:

"Of course, your main focus will be on the investments needed to keep operations going. Then you have your large projects, paramount to your airport's future, that need investments. But then you have budget left, maybe 5, maybe 10% of your investment capabilities. And that needs to go into this. Or else you will lose in the long term."

Head of Innovation at a large European airport

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Enhancing airport ecosystems with the power of data