ACI EUROPE

AIRPORTS COUNCIL INTERNATIONAL

Monitoring of Passenger Flows and Mitigation of Queues and Crowds at Airports

during the COVID-19 crisis and beyond

June 2022

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1 Foreword

This document is designed to be the ultimate handbook for airports on the many ways in which passenger flows can be monitored and congestion mitigated as the sector recovers from the COVID-19 crisis and moves into a "new normal". It pulls together both the best of practices already in place, alongside new technologies and innovative solutions which take us into the realm of the airport of the future.

This isn't completely new territory for us of course; the work you are about to read builds on the recommendations of the ACI EUROPE's Guidelines for Passenger Services at European airports (second edition), Guidelines for a healthy passenger experience at airports and Handbook for Airport Culture. It does however come into publication at a time when airports are facing significant challenges as they scale up into an abrupt surge in demand, whilst in the midst of the tightest labour market in decades.

This isn't just about short term solutions however. Yes, traffic increases, concentrated over peak periods, and staff shortages have led to serious and well-documented bottlenecks. And everything possible is being done to stabilise these challenges and restore the quality of the passenger experience as we move forward. Yet airports require solutions that will deliver value both for the recovery phase and beyond. Therefore, this document aims to describe how comprehensive airport-wide solutions can deliver value to a broad spectrum of use cases, far beyond the COVID-19 crisis and the immediate restart.

Pre-COVID, the focus was on managing queues that only occurred in specific parts of the passenger journey. In contrast, the COVID-19 health and safety requirements force Airport Managing Bodies to focus on managing passenger crowds in all public spaces of their premises. Hence there is a need for solutions that can automate the capture and analysis of critical performance data, in addition to an expansion of the mitigation solutions for crowd and queue control. This guidance document outlines how current solutions in the market can meet this need.

I trust that you will find solutions, templates and perhaps even inspiration in the pages ahead. As ever, ACI EUROPE's teams stand ready to assist you as we move proudly towards the airport models of the future – with a renewed focus on sustainability, operational efficiency and quality.

Olivier Jankovec

Director General

ACI EUROPE

Brussels, June 2022

2 Introduction

The COVID-19 crisis had a major effect on people's lives; and national, unilateral and uncoordinated public health measures created uncertainty, anxiety and fear among the travelling public leading to an unprecedented decline in air travel.

COVID- 19 rules will remain in place for longer that we might expect

Until the successful roll-out of vaccination programs makes them obsolete (or not), some health and sanitary rules will remain in place while traffic is poised to recover. This reality puts pressure on the passenger processing capacity of airports. Industry simulations and the actual experience of summer 2021, have found that physical distancing and health document checks may **reduce a terminal's capacity from 25% to 40% and significantly increase average processing times, up to 6 times longer,** than in pre-COVID[1] times. Clearly, this will create significant challenges for airports at the various touchpoints and open spaces where crowds can build up quickly, causing additional fear of travelling.

Traffic increase, operational disruptions and staffing challenges

As European countries ease travel restrictions, the recovery of passenger traffic has accelerated sharply and suddenly, concentrated over peak periods. Coping with this sudden increase and concentration of traffic is challenging for airports and their operational partners, including ground handlers and border guards. This has resulted in an increase in flight delays and cancellations, and more generally a degraded passenger experience – as key processes, including check-in, security and border control, involve longer waiting times and may lead to additional queues and crowds.

New priorities

Airport Managing Bodies face new priorities:

- Ensuring that passengers have enough **space**.

  This implies limiting densities and crowds, and expanding floor space, where people tend to gather. In space allocation, the need for optimisation (maximising revenues/m^2) needs to be balanced with the need for health reassurance (to encourage physical distancing).

- Reducing the **time** spent at the Premises.

  Passengers want to reduce the time spent "at risk", limiting interactions and spending less time in potentially crowded environments. Also, processing time has increased significantly due to additional health credential checks. For several years, Airport Managing Bodies encouraged passengers to extend the time spent within the premises to maximise potential revenues from retail, food and beverage (F&B) and other ancillary airport services. Airports must now increasingly focus on efficient and fast passenger processing, while offering attractive but safe entertainment options and retail services during dwell time.

[1] "*Impact assessment of COVID-19 measures on airport performance*", EUROCONTROL-ARC 2020

- Saving the **business**

  The current crisis has exacerbated the airport investment crunch, with less EU funding and state aid. The focus is on significantly increased resource utilisation, and maximising the revenues from these resources through high-value services in the high traffic marketplace, which airports have become.

Know your passenger

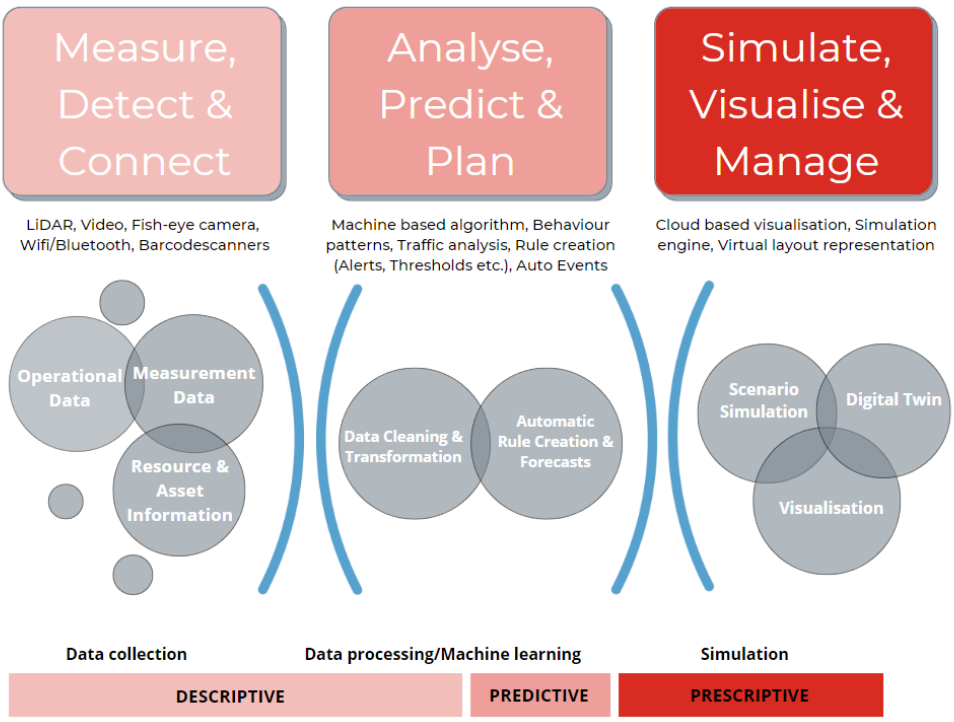
To meet these challenges, airports must first **know** how their passengers behave and then implement **mitigation** solutions to stop crowds developing in the first place.

For example:

- **Knowing the number and type of passengers when they arrive** at the Premises has a direct influence on the resource allocation at check-in, security and border control.
- **Identifying and evaluating crowds in advance** enables better planning of resources, adapting processes to prevent or mitigate crowds.
- **Sharing information with passengers to help them understand the potential impact of a crowd, such as walking distances and average walking times, processing and waiting times** from entrance to the gates, allows passengers to control their journey in the airport.

In other words, it's hard to manage if you don't measure first.

In this context, a logical step in setting up data-driven approaches is the principle of measuring, analysing, describing the problem and predicting the impacts.



Picture 1. Setting up a data-driven approach

The need for quick and affordable solutions

Clearly, space and passenger flow time monitoring and management are a core capability and competency that Airport Managing Bodies must build, which can be challenging with limited resources in this post-pandemic era. Equally, while crowd mitigation solutions promise to deliver tangible results, their return on investment may not be easy to identify at the onset. They might also take time to produce significant results and returns, time that airports might not afford in the current climate.

Therefore, Airport Managing Bodies require **affordable tools** that deliver value **quickly**.

With regard to intelligence acquisition, **manually** monitoring and managing passenger flows, queues and crowds could be done with accurate results. However, many Airport Managing Bodies may not be able to deploy the required staff resources as traffic grows and concentrates during peaks. Automating the monitoring is therefore a cost-sustainable option in the long run, as existing automated queue monitoring solutions have proven in the past.

The effort to uncover intelligence that resides in **existing data streams** such as boarding cards, can prove to be very cost-effective. Equally there are also data sensor technologies available which can make use of already existing investments in the premises, such as Wi-Fi, or close circuit television (CCTV) networks. Extracting intelligence from **existing infrastructures** can prove to be cost effective and deliver results fast.

While these solutions help to **automatically monitor and manage/control queues and crowds throughout the Premises** during the recovery phase, equally they can generate additional value for many other use cases when the pandemic crisis ends.

3 Queue and Crowd Mitigation Strategies and Solutions

While **passenger flow monitoring (PFM)** – which provides the measurement and control of flows, queues and crowds – is covered further in this document, in this chapter we will focus first on a range of **mitigation strategies and solutions,** which are often fed by these earlier measurements.

The table below provides an overview of a range of mitigation solutions covered in this document, outlining how they address specific airport strategies.

STRATEGY	SOLUTIONS
Promote off-airport processing solutions	Mobile check-in, home bag-tag printing, bag collection
Reduce on-airport processing time	Self- service, upgrade on-airport Premises (equipment) and Procecess
Direct demand, spread arrival curves	Virtual queueing, passenger real-time information
Spread crowds within Premises (terminal)	Optimise resources and People (staff) allocation, Passenger segmentation, wayfinding
Staff engagement to accompany mitigation solutions	Training in Knowledge, Attitude and Ambassadorship[2]

Table 1. Mitigation strategies and solutions

3.1 Promote off-airport processing solutions

Processes such as check-in, security and border control, often lead to queues, especially if they are manual/staffed processes. The verification of Digital COVID Certificates constitutes an additional touchpoint, mainly conducted by the airline on departure and by (health) authorities on arrival. As these certificates have yet to be fully integrated in airline booking systems, they need to be manually checked. For this reason, passengers may no longer be allowed to use kiosks and automated bag drops. Though this may be a temporary problem, it adds to congestion and queuing.

Reducing in-terminal processing minimises exposure to an infected person and enhances the passenger experience.

An additional advantage of off-airport processing is that processing is conducted by the passenger, and that related digital processes are optimised to avoid repetitive actions. This enables airports, airlines and authorities to have more flexibility to upscale and downscale operations during disruptive events, and to re-assign staff where needed.

[2] ACI EUROPE's Handbook for Airport Culture

Off-airport processing technology and use cases were already being developed and implemented long before the COVID-19 outbreak. The initial objective for off-airport processing was to reduce the overall area requirements within the Premises, increase throughput, and postpone capital investments in real estate. These benefits are still being realised, but they are now increased with the COVID-related advantages mentioned before. Therefore, it is likely that investment in off-airport facilities will accelerate in coming years.

When specific data produced at these off-airport processing steps is combined with a PFM system, the accuracy of near-term forecasting and predicting crowds can increase significantly. When those processing steps take place in sufficient time before passengers arrive at crowded areas, it enables airport operational partners to take preventive measures in good time, such as scaling up of checkpoint staffing, to avoid queues.

There are many off-airport processing steps. Some examples are listed below, such as:

- Home passenger check-in
- Mobile passenger check-in (e-boarding pass)
- Mobile airline passenger ID verification (through mobile app and biometry)
- Mobile border police passenger ID verification (through mobile app and biometry)
- Bag tag printing (or digital update of e-bag tags)
- Home / hotel bag collection
- Remote passenger check-in (railway, bus station, long term parking etc). Either with passport scan or biometry
- Remote bag check-in (railway, bus station, long term parking etc)
- Remote verification of health credentials
- Virtual queue booking
- Car park reservations and car park entries
- Railway schedule information
- Traffic information

Some processing steps are common practice already while others are still in their early stages.

Most of the off-airport data is owned by third parties and collected for system specific use cases, without the intention of being shared. The aviation industry could benefit greatly by the creation of specific data output, which could be shared for use in a PFM system. A data-sharing agreement could be established between parties to define the legal implications.

3.2 Reduce on-airport processing time

Airports face significant pressure to improve efficiencies, owing to increasing passenger traffic, concentration during peaks, space constraints, staff shortages, and new passenger needs and expectations. The COVID-19 crisis reinforced the conviction that the classical passenger processing structure needs profound changes.

Although the long-term future envisions self-service, contactless, fully-automated and biometric passenger flow, the mid-term and short-term future still requires on-airport passenger operations. Investing in new technologies, such as the introduction of end-to-end biometrically-enabled solutions or automation, could be game changing, but the challenge is here and now: how to leverage the efficiency of processes and optimise resources, with mid to low investment, while minimising delays, queues or operational risks, and creating a positive passenger experience.

3.2.1 Develop Self-Service

Self-service processes (check-in, bag-tagging, bag drop, boarding, etc) have proven to be 10-50% less time-consuming than processes performed by an agent. They increase processing capacity and decrease congestion (queues and crowds). In addition, some self-service touchpoints (usually kiosks) can be placed in previously vacant floorspace, delivering another capacity gain. Airlines and ground-handlers can also realise significant staff resource savings, which can be reinvested in many airport-led self-service projects.

As a result of little or no integration of new health-status related process steps, or the lack of a contactless interface, many self-service tools became unavailable during the pandemic. However, technology suppliers have quickly overcome these challenges. Challenging your current or future supplier to support these new process requirements, and to build contactless processing functionality and enable self-service solutions, can provide real benefit to both airports and passengers in the future.

Check-in, baggage drop and boarding are critical touchpoints that may benefit from self-service devices:

- Self-service check-in and baggage drop kiosks: installation of self-service check-in and baggage drop kiosks, using digital barcode technology and integrated printing systems, allows **passengers to use their mobile phone as a remote-control,** provide a safe and contactless experience.
- Self-service, automated gates: installation of self-service, electronic, automated gates, using digital barcode technology, at access control or boarding gates, can also provide a safe and contactless experience.
- Self-boarding: installation of self-boarding equipment at boarding gates (when e-gates are not possible).

3.2.2 Upgrade on-airport equipment and Processes (Example: Security check-point)

Analyse current equipment and Processes at critical touchpoints to determine how to improve them in a cost-effective way.

Security checkpoints are often a source of bottlenecks. Solutions should therefore strenghten security, increase operational efficiency and improve the passenger experience.

ACI Smart Security aims to deliver a step change in passenger and baggage screening in the future, whilst supporting airports to implement technologies that exist today. Extensive guidance documents[3] provide Airport Managing Bodies with the tools to design, equip and operate the ideal security checkpoint at their premises.

3.2.3 Other technologies, such as end-to-end biometric solutions, automation, and digitalisation

Authentication solutions and automated processes through self-service and contactless touchpoints, can create a more independent and seamless journey for the passenger, resulting in reduced waiting times for the passenger and overall operational and financial benefit for the airport.

[3] Smart Security Guidance documents

3.3 Direct demand, spread the arrival curves

3.3.1 Virtual Queueing

Virtual Queuing (VQ) is the ability for a passenger to book a slot at a touchpoint and wait *virtually* rather than wait in a physical line, thereby reducing stress levels. VQ has proven very effective when it comes to peak shaving and thus helps to decrease wait times.

How does it work? Passengers book their slot online or at the airport – typically slots are offered in 15-minute intervals. The VQ solution can be fully white labelled and presented to the passenger for instance as part of a digital marketplace or the airport website. A QR code is sent to the passenger as confirmation. The QR code is then validated at the touchpoint – either by an e-gate or by an agent. Results from recent VQ implementation projects show that VQ and load balancing[4] of passengers reduce peaks by 26%. Furthermore, 99% of passengers indicate they are "satisfied" or "very satisfied" with the product/service, with 63% of passengers indicating that they spent more time shopping and dining.

3.3.2 Passenger real-time information

Information to passengers is provided to personalise their journey enabling them to:

- know when to best arrive at the airport, ensuring they have sufficient time to go through the processes,
- spend the time they want in retail or restaurants,
- decide to postpone travel (provided this is possible) if there are too many people and they do not want to take risks (likely an easier decision when flying a scheduled regional flight).

What information would the passenger need/want to receive?

- Real-time or short-term forecast (every 3-5 minutes for a 30/60 minutes window) of:
    - waiting times in certain touchpoints, such as security or border control,
    - walking time between access and departure gate,
    - level of occupancy of areas that the passenger will visit, for example, *Check-in area A occupancy at 40%, Security area occupancy at 80%* – where colour codes can be used to highlight levels of congestion.
- Personalised communications, using 'opt-in' passenger data, allowing passengers to receive only those updates that are relevant to them

This information can then be made available through:

- first-party applications, such as the airport website or application,
- third-party applications (fed through APIs) such as transportation applications like Google or Citymapper. These can integrate with relevant other data such as traffic jams on the road from the city to the airport.

[4] Distribution of traffic across multiple servers to improve application availability and prevent overload.

3.4 Spread crowds within the Premises

3.4.1 Resource planning – long-term

Resource planners need to accurately plan for the forecasted demand and premises load, avoiding unnecessary capital expenditure while being able to adapt to fast-changing passenger processing trends.

A PFM solution captures essential data on the real load on the infrastructure. Analysis of this data reveals trends and cause-and-effect laws, and their parameters that can be fed into longer-term simulation tools. These tools then help the airport planner to accurately forecast the resource demand and match this with a planned resource capacity. This resource capacity can then be made available for allocation on the day of operation.

When looking back at the past few days/weeks' flows, some areas may often appear over-crowded, such as classic passenger processing bottlenecks, circulation areas, 'kiss and fly', check-in, border control, etc. While operational staff may have a good "sense" of the areas that require attention, the actual measurement of the number of passengers and/or the density (even without simulation) helps to undertake the prioritisation and adaption actions. Triggers to take action depend on the criticality of crowds, their density and frequency, and timing (on what days). All of this information is nearly impossible to assess by the naked eye, even with the best of experience.

Some immediate actions can be taken based on the analysis of the historical measurements, such as layout changes, by means of additional signage (for example, use of arrows on the walls/floor/door to identify sense of circulation), rearrangement of the furniture to force the flows into certain directions, etc.

However, feeding this historical data into simulations will reveal vital information for longer term planning.

An example where this intelligence can be applied is in the long-term planning of agent-facing and self-service check-in and bag-tagging kiosks, combined with self-service bag drop stations. The long-term simulations will inform the planner of how many units of each it should make available to handle the airports expected peak demand. From this pool of resources, the resource allocation on the day-of-operation can be optimised to meet the ever-changing demand.

The intelligence can even be utilised by airport architects designing new terminals. It is very useful in understanding exactly how passengers move through the airport journey, for scenario forecasting exercises, and identifying opportunities and possibilities.

Accurate planning of resources to meet the demand, can be facilitated by **simulations**. In simulations, a digital twin of the airport is created. In general, the higher the accuracy of the input data and the higher the granularity of the simulated processes, the higher the reliability of the outcome.

The major simulation **input sources derived from historic passenger flow data** are:

- passenger arrival pattern (when passengers present themselves at a touchpoint or dwell time location),
- passenger way matrix (how, and in what proportions, passengers go from one touchpoint to the next),
- passenger walking times (how long passengers take to walk from one touchpoint to the next),
- passenger processing times (how long a single process step takes at a specific location),
- passenger behaviour patterns (passenger categories).

Other data inputs derived from other sources are:

- Critical
    - Existing number and type of touchpoints
    - Flight schedules with passengers per flight
    - Terminal layout, with sizing of the processing areas (including queueing areas) and special flow logic
- Instrumental
    - RMS / AODB (for resource predictions)
    - Regional non-repetitive events affecting seasonal schedules
    - Retail sales receipts (for ancillary revenue analysis and prediction)

Historical flow data will not only provide vital source data, but it is equally vital in calibrating the simulation, to validate if the simulation meets reality. Continuous calibration increases simulation reliability. Some airports have even achieved simulations with higher accuracy than those measured with automated monitoring tools. Some would therefore even argue that measurement is absolutely key to improve the simulation.

3.4.2 *Simulations and what-if scenarios*

Daily operations are subject to contingencies:

- Changing flight schedules (flights and times)
- Updates on passenger loads
- Short-term notice of staff shortages (security, border control, ground handlers etc.)
- Layout based issues (e.g. spontaneous constructions, closing of areas)
- Downtime of equipment (kiosks, counters, lanes, elevators etc.)

Having the ability to identify and create scenarios for future passenger flow is key to any airport operation. Having a solution allows the operations planning team to outline multiple scenarios for the future operation. The scenarios could include:

- Different traffic schedules (reflecting growth)
- Operational changes (in part as a consequence of COVID-19), including changes in process times (check-in, security), increased adoption of digital services, encouraged physical distancing etc
- Changed allocation plans – including a change to the gate allocation, the check-in allocation or the baggage reclaim allocation
- Impact of implementation of innovative technologies like Virtual Queuing

Intra-day operational handling of resources and staff is required to react to all short notice changes and align all stakeholders in the best possible manner. Operational simulation, in this context, has proven to be capable of addressing various use cases and passenger perspectives, enabling better planning and management by the Airport Managing Body.

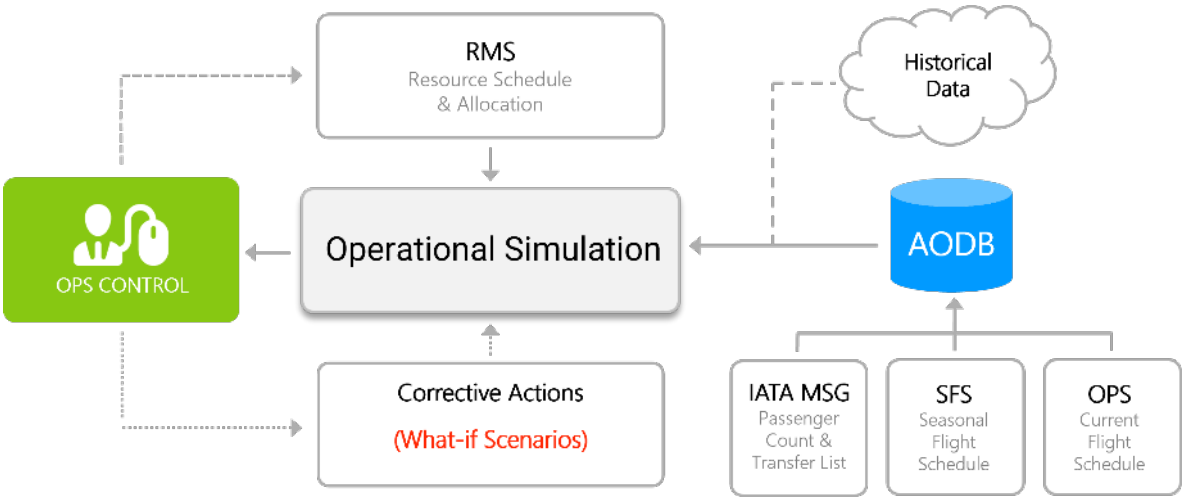
Ideally, a solution is used that can run both in planning and operational mode to minimise any system and data breaks.

To realise an ideal balancing of passenger flows with the required resources, airport staff and their stakeholders can ideally work in an agile and dynamic way, continuously updating their planning

according to the latest available data. This process should continue until, and during, the operational day with real-time feeds to ensure a best possible allocation.

In operational mode, the updates can be received immediately via the various airport systems to minimise any manual data preparation and create a high responsiveness of the operational teams.

Historical information can contribute to train the operational simulation system, and to include machine learning capabilities to fall back parametrisation. Both are not mandatory, but they help to make sure a simulation uses the best possible input data available.



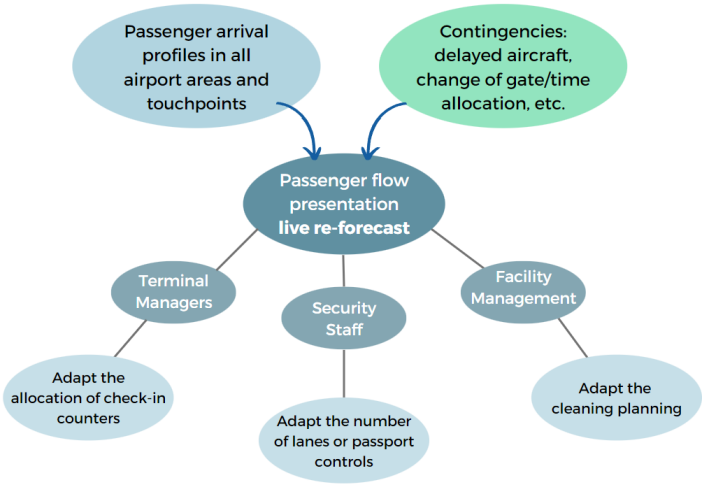
Picture 2: Simulations and what-if scenarios

3.4.3 "On the fly" resource re-allocation

Even with high performing forecasting algorithms, passengers never behave in the exact way the simulation shows. Therefore, operational teams may have to readapt during the day, to respond to passengers arriving a little earlier or later than expected. By monitoring live passenger flows and continuously comparing them with predicted flows and crowding, the operational teams are enabled to make the **on-the-fly changes** to space allocation, staff rosters (a schedule that highlights the running operations) and other resources to meet actual passenger demand.

Monitoring passenger flows and crowds across the Premises allows not only for the planning of expected flows and crowds, but also enables monitoring of the actual passenger behaviour that is currently disrupting the plan.

As an example, the stand allocation has a direct impact on the passenger flow and crowding within the terminal. Operational Capacity Managers are increasingly interested in knowing the impact of their decisions on the passenger flows and crowds. With such information, they can better collaborate with the Airport/Duty Terminal Manager and the teams working on aircraft flows, passenger flows and eventually, the teams working on baggage flows.



Picture 3. Resource re-allocation from Passenger Flow Intelligence

Airport planners must be able to immediately assess **the impact of each flight stand and time allocation on the number of passengers that will arrive at each area or touchpoint.** Capacity Managers can then identify when one of their decisions results in excessive crowding or dwell time in a specific area. They can then either change their decision, or alert the Airport/Duty Terminal Managers on the future issue they are going to face.

Similarly, a major external event may cause a large group of passengers to arrive later than expected at security or border control, causing queues and crowding issues, increasing the chance that many will miss their flight. This anomaly must be reacted to and its immediate effects down the line must be assessed, such as percentage of passengers that will miss their flight. If possible, Operations Managers increase the number of security lanes or suggest deploying additional border guards with an amount that the simulation suggests to resolve the congestion issue. They then commit these increased resources in the Allocation Planner tool for immediate execution.

While relevant for departure management, at arrivals, these same tools can prove equally valid. For example, at the arrivals baggage hall, luggage delivery at baggage belt can be synchronised with passenger arrival in the baggage area, to save belt usage and prevent large numbers of passengers having to wait, which creates frustration and health risks.

The updated flows forecasts can then also be shared with other stakeholders, such as Retail and F&B operators, so that they can make sure stores are opened and displays are full.

In essence, visualising this correlation between the flight schedule, airside and landside resources and passenger flow, so that they can be managed in a more integrated way, is one of the capabilities that the concept of Total Airport Management (TAM)[5] promises to deliver.

[5] Eurocontrol Total Airport Management

3.4.4 Quickly respond to forming crowds

A PFM solution can send alerts when a crowd density limit is or is about to be reached, enabling operators to trigger actions to avoid the crowd or to optimise sanitary conditions when the crowd cannot be spread.

Actions to spread the crowd can be voice messaging, airport hospitality or security staff being dispatched to encourage passengers to move along, etc. Actions to optimise health conditions within crowds can be proposing hand sanitiser, encouraging the use of face-masks, etc.

These actions can be performed by queue management and information personnel (if available). The goal would be to create a pool of trained staff to swiftly inform passengers, manage queues and help reduce bottlenecks, whenever or wherever needed (i.e., manage queues, help passengers at self-service checkpoints, such as reading boarding passes at e-gates, informing passengers of the requirements of specific processes). Previous planning, organisation and constant monitoring is of great importance to fine tune the number of required elements.

3.4.5 Passenger segmentation

Duty Terminal Managers need to identify the type of passengers that may generate crowds.

A first analysis looks at the type of passenger segment, notably:

- Families require longer processing times and more humanised interaction, while usually carrying a lot of cabin baggage and personal items.
- Businees travellers have lower processing times, are accustomed to traveling procedures, usually carry little cabin baggage and personal items, and avoid interaction.
- Passengers with Reduced Mobility (PRM) usually need assistance and have longer processing times due to physical challenges.
- Other passengers have average processing times, and if they are well informed, processing times tend to lower.

Analysing historical passenger flows reveals specific passenger categories that may cause critical crowding issues again. Thanks to an intelligent matching algorithm, a passenger flow monitoring solution can label individual members of a crowd with their flight and resulting origin, destination, arrival and departure times (without storing any other sensitive personal data and complying with GDPR). This data can then reveal those specific destinations that are causing repeated overcrowding, for example, destinations with passengers travelling once a year with a large amount of luggage, or airlines proposing specific deals on the amount of luggage. The common denominators causing crowding can be identified – such as the most likely airline, destination, times of the days – which will enable the Terminal Manager to target the optimal actions.

The Airport Managing Body can then proactively redirect those crowds into wider areas, where health risks are minimised.

3.4.6 Wayfinding

As outlined in ACI EUROPE's Guidelines for passenger services at European airports, Airport Managing Bodies should provide accessible, real-time and accurate information on wayfinding to passengers.

Therefore, it is important that Airport Managing Bodies provide information on wayfinding to passengers in different formats and by various means, such as:

- Dynamic signage and displays

  Real-time situation, based on queue management tools at critical touchpoints, should be displayed at central points where passengers are able to decide whether to choose alternative facilities with reasonable detours.

- Smartphone Applications / Other "Indoor Navigation Tools"

  Indoor navigation tools enable passengers to find their own way through the terminal, in the quickest, healthiest and most stress-free manner.

  Provision of this information directly to the passenger, by means of a Smartphone App or other digital indoor information tools, is far more efficient. It avoids unnecessary "terminal crossings", reduces stress and enhances passenger satisfaction.

  For elderly and inexperienced travellers, alternative wayfinding and signage indicating so called "priority lanes" can be displayed at strategic points.

  Wayfinding should be supported by staff assisting passengers in the use of automated facilities, as well as by providing mobile guides around the terminals.

  Passenger service and COVID-19 related necessities and measures must not exclude each other.

3.5 Staff engagment to accompany mitigation solutions[6]

During the pandemic, automated and touchless processes were deployed to reduce contacts with surfaces and to limit the interaction between passengers and with airport staff. Digitalisation has transformed our lives and has been embraced by the air transport industry. In the future it will be fully integrated into the passenger journey.

Accompanying this major transformation and making it successful requires the buy-in and support of all airport stakeholders and airport staff, ensuring they have sufficient knowledge of the new processes, have the right attitute and act as ambassadors of the airport. It is important that teams have the knowledge and ability to use the new automated equipment, to effectively support passengers that will be equally disorientated, when discovering automated tools for the first time. Therefore, strong, accurate and continuous training needs to be deployed for all operative staff, otherwise bottlenecks may be generated in front of automated processes with countereffects on congestion and increased times of service. For example, elderly passengers are struggling to adapt to new technologies in their own lives and are likely to need help at the airport from staff, supporting them in using automated equipment.

[6] See ACI EUROPE's Handbook for Airport Culture: The human touch in the passenger experience

Inadequate support of staff – and ineffective deployment of new technologies at the airport aimed at optimising processes, times of service and offering a seamless experience – may in fact create adverse effects, potentially causing additional stress to passengers.

Travelling can be both exciting and stressful for the passenger, and there is no doubt that the pandemic has increased stress levels. The feeling of vulnerability, risk awareness and the changing new health requirements (health documents checks, social distancing, mask wearing, hygiene behaviour) generates uncertainty and fragility.

Stress drives irrational behaviour, undermining the capacity of passengers to find their way and perform processes. It can also create disorientation, bottlenecks, queues and increases in processing times for services. Airport staff have a key role to play, in tackling the management of flows and queues, and beyond that, in reassuring passengers, helping them to find their way, supporting them in the use of automated tools. This in turn can reduce their levels of stress, restore confidence and pleasure, enabling them to fully enjoy the airport experience. Happy passengers are happy customers too.

4 Passenger Flow Monitoring - solutions and benefits

This chapter explores the different solutions for, and the benefits of, automated airport-wide PFM. It analyses what value Airport Managing Bodies can expect from them and how a suggested **airport wide-solution** addresses their use cases.

Any PFM solution starts with capturing the source data in real-time and processing it into **real-time monitoring** tools. Many benefits are also met by analysing historic data and applying discovered trends into short to long-term **historical data sets and intelligence, which** can then be turned into meaningful actions.

4.1 Overview of Passenger Flow Monitoring solution use cases

Below is an overview of the various use cases of Passenger Flow Monitoring, indicating the key actors and the type of analysis the solution can provide.

Persona	Use Cases
Airport Operations Centre (APOC)	- Triggers actions to spread crowds and support health protection within crowds based on area density level alerts. - Debriefs contingencies (strikes, weather incident, aircraft/airport technical issue) to improve response to future similar incidents. - Plans and adapts resources at the daily morning briefing and takes the actual flows of the day into account.
Facility Manager	- Triggers sanitisation actions based on real traffic in specific areas. - Adapts the sanitisation planning to the passenger presentation in each area. - Plans equipment maintenance according to forecasted flows.
Duty Terminal Manager	- Quantifies crowd issues everywhere in the airport that are traditionally reported and visually assessed by teams on the ground. - Identifies the passenger categories that generate crowds and target actions. - Adapts check-in counters allocation to airlines, in line with forecasted passenger arrival types. - Adapts call-to-gate to prevent delays and maximise revenues in retail and food areas.
Security Manager	- Quantifies traffic and dwell time in security areas to assess the quality of the passenger experience. - Makes real-time security resource reallocation in areas that welcome the most critical densities (size and frequency). - Adapts on a daily basis the number of security lines to open and staff to roster based on detailed passenger demand forecasts.

Head of Operations	- Captures the helicopter vision of passenger flows, over the entire airport. - Identifies airport areas that are less used, for consideration in overall airport space planning. - Provides passenger forecasts at Customs/ Border Control to local authorities, enabling them to provide the optimum staff roster. - Matches luggage delivery with passenger arrival profile, shortening time spent by passengers.
Passenger	- Receives real-time information about traffic and processing times, empowering them to decide when to go to the airport, and to choose the optimum processing area, to limit queue time. - Finds less crowded processing areas and well sanitized facilities at any time during the day even on the busiest of days. - Finds the fastest way to the gate, based on queue and crowd density data.

Table 2. Passenger Flow Monitoring use cases

4.2 Choosing the right solution

Choosing the right solution may be **a daunting task**. Some providers claim to offer the latest and smartest sensing technology, which solve all challenges and provide answers to all flow and crowd questions. Others have claimed that sensing signals are "dead", and cameras are irrelevant. However, the reality is nuanced, and increasingly challenging for Airport Managing Bodies to follow and make well-informed decisions.

Since these flow (a queue is a small flow) and crowd monitoring solutions began to appear on the market around 10 years ago, many Airport Managing Bodies and some airlines have invested (heavily) in technologies that enabled them to solve some immediate key challenges, such as queue and local crowd monitoring – and they have served them well.

However, the cash-crunch caused by the current crisis, combined with its new use cases and an increasing appetite for finding answers to **increasingly complex questions** (especially when looking at Total Airport Management concepts) is forcing Airport Managing Bodies to look for alternatives, or expand on what they already have in place.

Elements to consider when choosing the right solution:

- **Coverage** of the Premises: from just a couple of local hot spots (e.g. security and check-in) to 100% of the public areas, including access and the airside where aircraft and Ground Support Equipment (GSE) roam. With that scope extension also comes the desire for end-to-end flow intelligence.
- **Labelling and Categorising**: from none (e.g. only counting people's heads) to extensive. The ability to differentiate a passenger from a staff member, to associate the journey with the flight, destination, airline, visited retail or point of interest (POI) to label particular GSE and its action on the apron. And all of this must be GDPR compliant.
- **Existing infrastructure**: from new sensor-centric solutions (dedicated cameras, lidar) to technology-agnostic software that ingests data from existing sensors in the airport (Wi-Fi, CCTV, boarding cards, flight data, etc).

- **Multiplicity of use cases:** from single use case solutions (queueing only) to intelligence platforms, which through data integration can answer a wide range of increasingly complex business and operational questions (queue, flow, dwell, crowd, count, revenue, conversion, predict, decision-support).
- **Intelligence:** from airports looking for flow and crowd intelligence from their Premises, to all stakeholders looking for airport-based intelligence. From creating reports and some smaller API (Advanced Passenger Information) data feeds to integration with simulation and RMS (Resources Management System) tools. From descriptive to prescriptive.
- **Consulting-led service**: from tech install and "help yourself" self-service, to guidance-led services. The Intelligence supplier helps the airport eco-system find the complex intelligence. Flow-and-Crowd-monitoring as a service.
- **Timeline**: from long-term projects that require dedicated hardware installation and works-related time to "plug-and-play" projects that only require software configuration.
- **Cost**: from hardware-based technologies (cameras, sensors, LiDAR, etc.) that require high CAPEX to software-based technologies that only require OPEX software licence costs.
- **Right time data**: from real-time to right time data. Not all data needs to be real-time, which can often be costly to produce. Reduce costs by determining the *right* time the data is required before investing.

  Upskilling / Training Staff[7]: To achieve a successful implementation of new technologies, airport operators should as a first step upskill the workforce with digital capabilities. In addition, new talent acquired and introduced in cross-disciplinary teams enables airport managers to create a positive culture towards digitalisation, as well as build-up resilience in the new operating models. Being employee-centric and empowering individuals are key milestones in becoming tech savvy, as is giving people the means to flourish.

4.2.1 Technology categories and components

One key element in the solution choice is the data acquisition strategy. The data acquisition part of the system can be provided by different means. Sometimes the needed data can be extracted from existing systems at the airport, or provided by partners or (commercial) third parties. When this is not sufficient, an airport needs to collect the data in other ways. Depending on the intended use of the Passenger Flow Monitoring solution, sensors can be placed at specific locations where insights are needed. The following sources for the acquisition of data are identified:

A. **Existing systems.** Data acquisition through **available data** from existing systems at the airport such as boarding card scans, flight schedules and other systems such as the Airport Operational Database (AODB), Resource Management System (RMS), and Building Management System (BMS) data. Potentially video feeds from existing video surveillance system (VSS) cameras can also be used, as well as positioning signals from existing Wi-Fi antennas.

B. **Partners and third-party data**. Data that is not owned by the airport could be integrated into a Passenger Flow Monitoring system. Data from the airlines related to passenger

[7] See ACI EUROPE's Handbook for Airport Culture: The human touch in the passenger experience

bookings and check in status would make the use case significantly stronger, from which the airport, airline and passenger will benefit.

C. **Sensor technology.** There is a wide array of sensors available on the market, such as cameras with built in video analytics, Bluetooth and Bluetooth Light (BLE) sensors, dedicated Wi-Fi antennas, and specialized products that combine multiple sensors. The sensor type needed depends on the used case. A combination of different sensor types is often needed to acquire the data to generate the business information.

To sum up, there are two main **categories** of technologies on the market:

1) **Sensor Technology-centric** solutions (which often only solve local, single use-cases).
2) **Business Process-centric** solutions (which can ingest any type of sensor or existing data and can work airport-wide by default). These focus on answering a range of business and operational questions. You can call this an "*airport-wide passenger flow monitoring system*".

Business process-centric solutions appear to respond better to airports' needs. While both involve ingesting data produced by sensors (cameras, antennas), these solutions can ingest a range of sensor data as well as an extensive range of **other existing datasets,** such as boarding card scans, flight schedules and other AODB/RMS data. These existing data sets are usually provided by the local airport eco-system free of charge. However, sensing data only comes free when leveraging existing airport infrastructure.

No single technology **component** can deliver data to answer to every business and operational question. However, two data streams could be "harvested" relatively easily from an existing sensor infrastructure:**video feeds from CCTV, and signal positioning data from the Wi-Fi system**. A third one is based on **boarding card scans and prints,** as this primary data is ubiquitous in all airports. New technologies include lidar solultions. Finally, an **integration platform** is required to bring these diverse data streams together.

4.2.1.1 CCTV

Videos for **CCTV (closed-circuit television) systems** are usually fed into a server that interprets what it sees (without storing the images for GDPR compliance). The extracted data is anonymised (with no storage of passenger or staff data trackable to a specific individual), and then further cleaned and refined into meaningful intelligence.

PROs

- Like any other vision-based system, CCTVs can interpret, count and track everything they "see" within their field of view, and with a high degree of accuracy.
- The data can be fed into a wide range of use cases involving passengers, but also assets like parked cars, trolleys, apron ground support equipment, etc.
- CCTV cameras are usually everywhere in the premises; both inside the terminal as outside. The coverage potential is therefore significant.

CONs

- Since CCTV doesn't provide a continuous overlapping field of view throughout the premises, end-to-end tracking over the whole terminal is difficult. However, re-

identification software solutions are improving all the time. This may prevent use cases requiring this airport-wide tracking data in the short-term.

- Most advanced analytics using CCTV datafeeds, require HD cameras to be installed, which isn't always the case.

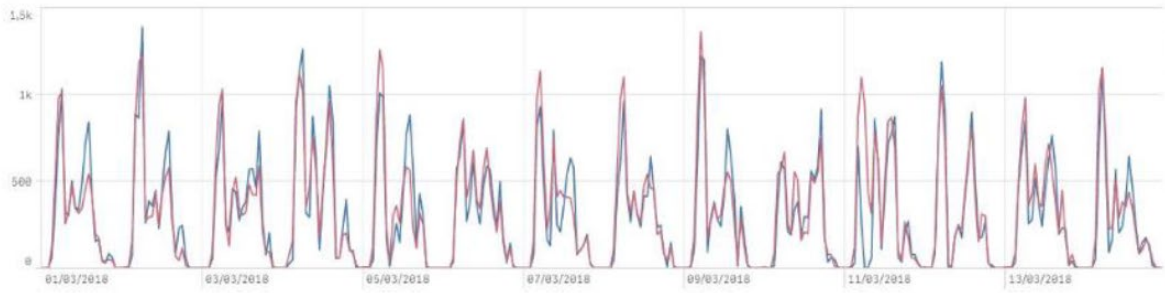
4.2.1.2 Wi-Fi

In **Wi-Fi systems**, the position and identity of the device – usually a smartphone – is captured in a server. This source data is then extracted where the identity is hashed for privacy reasons before it is further cleaned and converted into reliable data. Since a server only tracks devices which are Wi-Fi enabled, the number of passengers it "sees" needs to be extrapolated with a factor representing the average percentage of Wi-Fi signals on the total number of passengers. Calculating this figure is part of the continued calibration of these data collecting systems. Tracking assets like GSEs equipped with Wi-Fi signal emitters does not require this extrapolation.

Picture 4. Measuring crowds using Wi-Fi

PROs

- With a correlation of up to 95%, and with real numbers in a specific location at a specific time, the accuracy is more than sufficient to derive meaningful conclusions in a wide range of use cases.



Picture 5. Correlation Wi-fi (in red) and real numbers (in blue)

- Since Wi-Fi usually covers the whole inside of the terminal with overlapping coverage zones, end-to-end tracking is enabled by default.
- Extensive labelling and therefore data clustering is possible, thanks to the association logic of either passengers boarding (the Wi-Fi signal disappears) from a defined gate on a defined flight or identity matching of assets. This way very rich profile-based intelligence

can be derived on the one hand while both staff (who represent a very privacy sensitive audience) or other Wi-Fi emitting assets can easily be excluded from the data set.

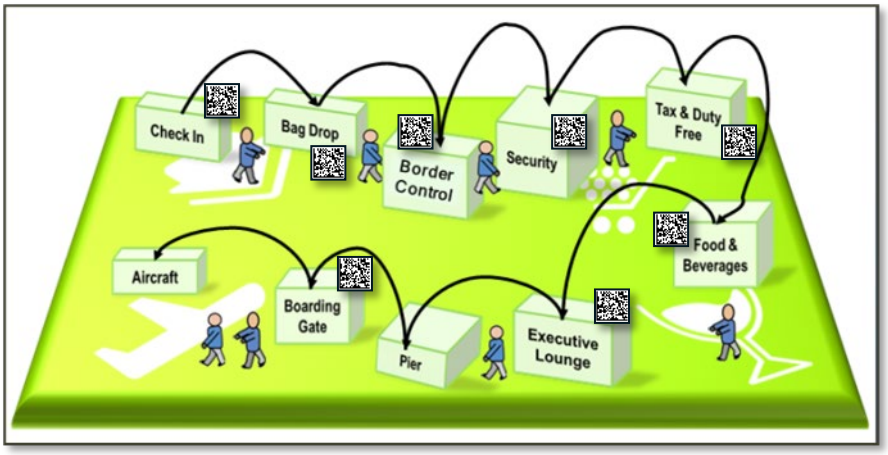
CONs

- Wi-Fi tracking outside the terminal, such as in parking lots or at the apron, often presents a challenge as usually little coverage is provided in those areas.
- The extrapolation requirements always contain a level of error that requires regular calibration for the intelligence remaining accurate. This could imply the need for a separate automated counting system or some potentially labour-intensive manual counting process. Fortunately, most airports already have some automated counting system installed, even as simple as the counter of archway metal detector at security, boarding card scans at security entrance, or an infrared counter at a door sensor.
- The capture of mobile devices is dependant on the device type and the usage of the local Wi-Fi network and the range of localisation (in the best lab case down to 1m deviance) is dependant on the network, but strong localisation alorgithms can compensate for this by recreating steps in the journey reconstruction.

4.2.1.3 Boarding Cards

In most airports, boarding card scan data is generated at security control and can therefore be viewed as an existing dataset. Some CUTE and CUSS platform providers can also collect boarding card scans at different touchpoints (from kiosk check-in over agent check-in, and self-bag drop down to the boarding gate). This rich dataset may be further enhanced by scans at the retail "Point of Sale" and lounge entry. While these scans are done at these various locations, some data aggregation system might have to be implemented to bring them all into a single data repository. Of course, in some airports it could be a problem to have access to the data of different stakeholders.

Valuable baggage tracking intelligence could be derived from capturing bag tag prints and scans from the same CUTE and CUSS platforms and these can be combined with baggage events sourced from the baggage handling systems (BHS) and baggage reconciliation systems (BRS).



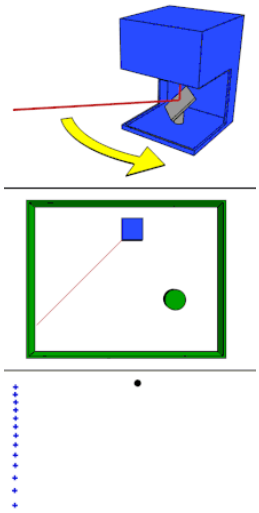
Picture 6. Boarding card data captured at different touchpoints

4.2.1.4 Lidar Sensor technology

Light Detection and Ranging (Lidar) is a relatevely new technology in the airport environment. Originally coming from the automobile industry of self-driving cars, Lidar is used to detect people or other cars in order to break or stop when needed.

Lidar is an optical sensor sending out a Laser beam which is reflected whenever it hits an object.

The optical instrument creates a 3D mesh of the surroundings by measuring distances to detected obstacles in various directions.

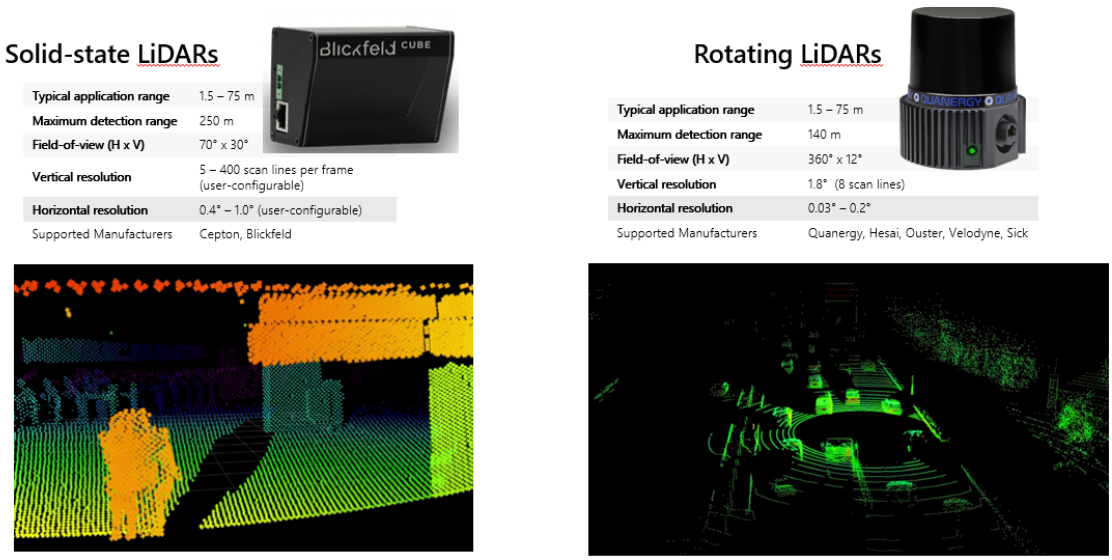


Animation 1. Lidar sensor technology

There are different Lidar scanning types available:

- Rotational scanning
- Raster scanning
- Solid state

Most importantly, a Lidar sensor itself has no knowledge of the object detected. In order to recognise an object as a person, a bag or a car, so-called **perception** software is needed to interpret objects and classify them.



Picture 6. Examples of Lidar sensors

PROs:

- Lidar is fully GDPR compliant as no personal recognition is possible due to its technology.
- It measures extremely well in areas with low ceilings as the minimum height to mount a sensor is around 3m.
- The sensors can cover large areas as the have ranges of around 100m, so they are ideal to monitor, for example, large check-in halls.
- Using the right perception software it is possible to detect dynamic queues whenever they build up.
- Lidar can also be used in a mobile set-up for temporary measurements of processes.
- Tracking of individuals is possible without GDPR concern and with full coverage.

CONs:

- Lidar sensors are still expensive, so Lidar deployment is dependant on the area of use and a positive business case.
- The quality of tracking and queue measurement is strongly dependant on the perception software used. Some Lidar manufacturers offer their own software, but results are poor and need to be improved.
- Airports are still not very familiar with this technology so there is some hesitation in its adoption.
- Some areas might require more sensors due to pillars and shadowing effects.

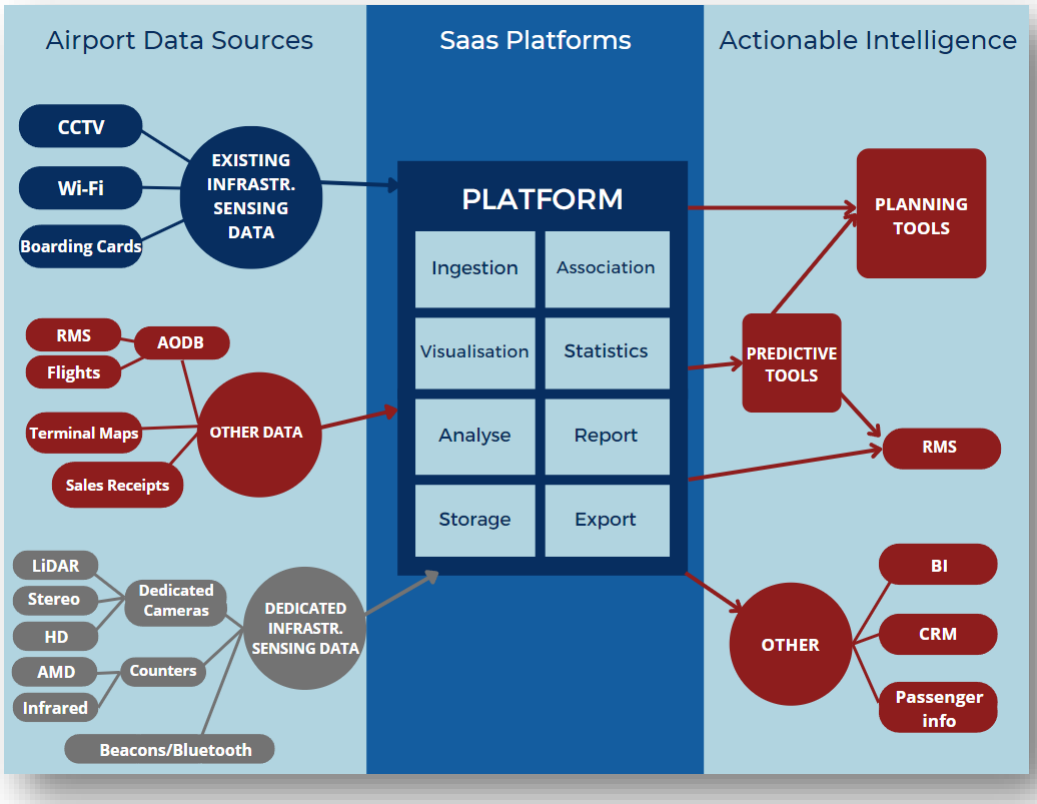
4.2.1.5 Integrated platforms

Technology-centric systems could stand on their own and respond to a limited set of business questions. An integrated platform that is truly technology agnostic on the other hand has the potential to become the basis for Total Airport Management concepts, such as the “Know Your Passengers” or “Digital Twins”.

Picture 7. Know your passengers in Total Airport Management

While the focus should be on unlocking existing infrastructure sensing data, it is essential to also integrate other sensing data from dedicated infrastructure technologies, if already implemented. Additional relevant data will enhance quality.

The following diagram shows the key components and function of such a platform:



Picture 8. Components of an integrated Flow Monitoring Platform

Some level of prediction capability already exists in technology-centric systems on the left side of the above diagram. However, accurate, reliable, and consistent predictions demand a level of complexity, so that they stand on their own while being fed by an integrated and clean data set coming from the platform. They are, however, crucial in delivering value from these platforms, as they enable improved planning and deliver operational decision support.

4.2.2 Implementation

The following aspects need to be taken into consideration when acquiring or implementing these next-generation Flow and Crowd Management solutions.

4.2.2.1 Sensing Infrastructure

Since the primary sensing data is acquired over existing infrastructure (Wi-Fi access points, CCTV camera's, 2DBC scanners etc.), the implementation of these technical components is usually limited to configuring some secure data connections.

To expand the scope, some limited extension of this existing infrastructure might be required. The benefit is that these extensions are not dedicated to gathering the intended intelligence, but extend the use case that the infrastructure was intended for in the first place. For example, extended Wi-Fi access when adding Wi-Fi access points, and extended visibility for security or safety purposes when adding some CCTV cameras.

4.2.2.2 Central infrastructure

The platforms where the data is integrated and processed are nowadays delivered from a Software as a Service (SaaS) model. This implies that there is no need for local infrastructure to host the platforms (and hence no additional cost for operating them), except for connectivity to the sensors and other data sources, such as the AODB. This model also allows for full scaling flexibility as the platforms are hosted on offsite shared infrastructure.

4.2.2.3 Integration into the local IT landscape and other stakeholders

As described in detail above, much of the value of these systems is achieved by consuming the output into other external airport system, such as towards resource management systems (RMS) for decision support or prediction tools for historic data and calibration.

Real-time APIs are the common method of importing from and exporting to these other systems. This enables not only easier data integration with central airport systems but also the most flexible way to distribute (and gain potential revenues from) to other stakeholders in the airport eco-system.

4.2.2.4 Different business models

Different business models may include:

- A service integrator providing an integrated platform and volume-based charged intelligence to the Airport Managing Body and the different stakeholders.
- A provider of specific intelligence such as "*Dynamic passenger walking time to boarding gate live display impact on F&R turnover increases*"; or "*Increase (or decrease) duty free sales conversion rate by reducing (or increasing) time spent at security check*" as a one-off effort. These studies usually imply defining a limited set of exact business questions (often

only one), implementing the temporary connections to the existing sensor infrastructure, gather the data for a few weeks or months, deliver the report, after which the technology is de-installed,

- A mix of the above.
- In-house solution (not possible in the majority of European airports).

It is key to bear in mind that while the Passenger Flow Monitoring solution is a cost for the Airport Managing Body, it can also generate revenues. As identified previously, the data provided by the system brings value to various personas within the Airport Managing Body, but also to stakeholders, that the airport may want to serve, freely or with a counterpart. It is commonly admitted that the currency counterpart can be either other valuable data or actual Euros.

4.3 Support health-related measures

4.3.1 Monitor Physical Distancing – Manage Passenger Density

Physical distancing is still encouraged to ensure health conditions within the Premises.

Measuring passenger density as an appreciation of physical distance is key, as limiting the number of people in a defined area is one of the most recommended ways to prevent transmission of infection.

The monitoring of flows in real-time provides the number of people in each area of the premises. The ratio of the number of people with the size of the area, more specifically with the usable space in each area (space passengers can access), produces a density measurement. Those measurements can then be monitored against the local thresholds, which range between 2 and 6m^2 per passenger, depending on the local physical distancing rules and can be fed into day-of-operation prediction tools.

4.3.2 Enforce demand-led sanitisation: real-time passenger flow monitoring to trigger sanitisation actions

Terminal/Facility Managers need to comply with health and sanitary requirements to provide a healthy passenger experience.

A Passenger Flow Monitoring solution enables demand-led actions, and in particular sanitization actions in toilets and in all the premises.

The solution can trigger some sanitisation action when a certain level of use of an area (such as restrooms or dedicated COVID-19 tests areas) has been reached. Rather than undertaking hourly cleaning schedules no matter how intensely an area was “contaminated”, cleaning can be done after a fixed amount of people (the threshold) have used the area. This threshold is defined following sanitary recommendations and/or quality level of service. Real-time counting of people using a specific area will then allow to create a cleaning-alert when this threshold is reached.

Demand-led sanitisation can strike the balance between optimised sanitisation and limited budgets and staffing levels.

4.3.3 Adapt layouts to avoid health issues

At the heart of the COVID-19 crisis, airports had to make choices about how a terminal layout could positively influence the behaviour of passengers to avoid queues and crowds. Looking at historical data, particularly passenger density, and the physical distancing guidelines in place, airports had the opportunity to identify necessary layout alterations.

The impact of these alterations was measured through the solution, by monitoring effectiveness of physical distancing pre- and post-alterations.

4.4 Improve daily operations efficiency

4.4.1 Monitor live traffic on premises 24/7

The role of the Airport Operation Centre (APOC) is to have an overview and control of all terminal operations. APOCs need to collect robust information and to take actions leveraging efficient tools to influence/alter situations.

The Passenger Flow Monitoring solution provides great support in data collection: quantifying in real-time what is happening everywhere in the airport in terms of traffic, dwell time and density, the solution offers a unique helicopter view that cannot be achieved without such technology.

Airports Control Centres used to rely on cameras/sensors and on the feedbacks/alerts of staff working in the terminal. However, this insight, although highly valuable, is incomplete and unquantified.

The solution is a powerful tool with the ability, at all times, to assess the situation in any area of the premises, so that APOC staff can then trigger mitigation actions and strategies and prioritize them.

4.4.2 Enforce SLAs with partners

The Airport Managing Body is obviously a major actor in the passenger flows, crowds and queues, but a large part of the passenger journey is actually out of its hands. Partners such as airlines, security companies, ground handlers, police etc perform many interactions with passengers, and can be the cause of crowds and queues.

The contractual relationship between the Airport Managing Body and its stakeholders very often encompasses monitoring the level of services provided by the partner; this is recognised by Service Level Agreements (SLAs).

At the heart of the COVID-19 crisis, SLA enforcement was suspended in many airports because the traffic was so erratic that the measurements were no longer representative.

In more normal (and new normal) times, SLAs are and will be reintroduced and still require a robust solution to measure the performance, in terms of processing and dwell times. This is provided by airport-wide Passenger Flow Monitoring.

4.4.3 Upgrade contingency plans

Terminal/Facility Managers need to document and enforce the best contingency plans in the case of critical situations.

By monitoring passenger flows all over the airport, at all times, the Passenger Flow Monitoring solution provides the best data to analyse the impact of a critical event.

Critical events can be strikes, weather incidents, major technical issues, or just, as happened many times during the COVID-19 crisis, the implementation of a new controls or regulations which creates new processes.

The point here is to measure the real-time effect of such an event and to analyse the impact of the Airport Managing Body's reaction. How did the mitigation measures impact the crowd?

Measuring the impact of the actions taken enables the Airport Managing Bodyto A/B test its answers to the crisis so as to improve its answers over time.

4.5 Adjust resources for a more sustainable and financially performant airport

4.5.1 Predict and adjust energy consumption

Energy consumption for heating, ventilation and air conditioning (HVAC) represents an important yearly budget consideration, that is meant to be monitored from both a financial and a sustainability perspective.

Energy consumption is obviously linked to the local weather, but also to the actual traffic in the airport, as passenger density affects the need for temperature alteration.

Setting up a model explaining past energy consumption based on the weather, and the passenger flow variables, enables the Airport Managing Body to predict the future energy consumption and to adjust it to the actual needs in each terminal/area of the airport, which eventually limits expenditures and negative impacts on the planet.

4.5.2 Adjust sanitary planning and budget to predicted passenger arrival patterns

Terminal/Facility Managers need to deploy the most efficient sanitization planning.

A Passenger Flow Monitoring solution provides a prediction of passenger visits to areas prone to high sanitation (such as toilets), allowing the Sanitation Team to adapt sanitization planning.

Sanitization planning is often linear; the budget is spread over a season or the year, sometimes in line with weekly passenger forecasts, but seldom with more subtlety that that.

The current crisis has, however, altered these forecasting models in a significant way (for instance, passengers may arrive earlier and there may be great variances by length of flight). This results in ineffective rostering with mismatching cleaning opportunities.

Analysing the historical measurements will reveal when and how many passengers visited areas requiring sanitisation. When fed into the simulations with updated schedules and arrival profiles, the predicted demand will enable the sanitation planner to update the longer-term rostering schedules. This, in turn, will translate into budget optimization and improvement of the passenger experience.

4.5.3 Locate assets throughout the premises

An additional, somewhat surprising use of the Passenger Flow Monitoring solution is to locate not only passengers, but also physical assets, such as wheelchairs or trolleys.

Wheelchairs, for example, need to be found easily by the staff in charge of people with reduced mobility (PRM), so that they can perform their duties efficiently, without wasting time searching for a wheelchair. Many airports report that staff time consumption for this task is incredibly high, when by just positioning a tracker on each asset, the location could be reported automatically.

4.6 Increase non-aero revenues

Monitoring passenger flows over longer periods of time allows Airport Managing Bodies to identify the **general trends** within the Premises and allows short to long-term resource planning and process changes, which could be actioned "on-the-fly". When combining with other data streams, such as from retail, they also allow the analysis ofbusiness performance.

Below are just some of the non-aeronautical business/marketing benefits of implementing a Passenger Flow Monitoring solution, which provides the ability to:

- Measure and qualify traffic entering shops and restaurant concessionaires,
- Identify high potential contributors and design high efficiency Customer Relationship Management (CRM),
- **Adapt the call-to-gate time and the gate allocation** to prevent any delay while encouraging passengers to spend time in retail and food areas,
- Enable **retail** operators to adapt **staff** break **planning,** and to ensure staff can cover foreign language requirements,
- Enable the Food & Beverage operators to forecast the optimum levels of **products** for sale,
- Include **walking patterns** for **retail** purposes, Manage detailed retail sales and conversion funnels to drive non-aeronautical revenues.

5 Conclusion

An integrated, **airport-wide Passenger Flow and Crowd Monitoring solution** supports the physical distancing, health and sanitary requirements during the COVID-19 crisis, while delivering real-time, historical, and forecasted **intelligence**. The nature of these systems also addresses the current budget and staff constraints by focusing on minimal capital costs and new business models. Intelligence will therefore provide cost-effective value beyond the COVID-1 9 crisis in the post-pandemic world.

A range of **crowd mitigation** solutions enables an airport to prevent crowds from building in the first place. Forecasts integrated with airport resource management tools help to optimise existing limited resources and staff shortages. Relevant flow and crowd information provided to passengers will enhance their experience and boost recovery.

Many of these mitigation solutions, however, require a feed of intelligence, coming from a wide range of data sources. The need for a sensor **technology-agnostic** platform to simplify this integration challenge for our complex airport eco-systems is therefore obvious.

Implementing an integrated airport-wide Passenger Flow and Crowd Management solution during recovery from the COVID crisis represents an investment both in time and resources. But choosing the right technology can ensure this remains a **cost-effective** project and becomes part of the range of key tools that airports can use to regain passenger confidence. Moreover, this intelligence will prove vital in rebuilding the business back to health and viable state, delivering business value when the industry embarks on the “new normal”.

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EVERY FLIGHT BEGINS AT THE AIRPORT.

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