Airport management: You cannot manage what you cannot measure

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Abstract
This paper will discuss how current challenges in airport management can be addressed by means of increased operational control. The paper will show that the availability and correct usage of operational data can help solve many of the headaches airport managers face today. The paper starts with an overview of the key developments that led to today's challenges, which will then be described. Next, how real-time and historical data can be used to address these challenges will be presented. Real-world examples will be used to illustrate that this is not just theory, but that tangible results are very much achievable. Finally, the paper will conclude with a summary of best practices that enable and facilitate the adoption of data-driven operations.

Keywords
capacity, sustainability, technology, data, AI, computer vision, safety

A BRIEF AVIATION HISTORY

Traditionally airports have been infrastructure companies that invest in assets which they then make available for airlines to use. Over time many airports have adopted alternative strategies in which they have both developed other activities and taken more responsibility over the experience of passengers. However, many airports are still infrastructure companies at heart. Therefore, for key problems, like capacity shortages, airports have a tendency to respond by building more infrastructure. The commercial model of most airports allows them to forward (with margin) any investments made in aviation related infrastructure to the airlines.[1] As this is at the core of the business model of the airport, it is basically what dictates how airports behave (Figure 1).

Since the 1970s, the aviation industry has grown enormously.[2] The industry developed from being a luxury service provider to a commodity service provider.

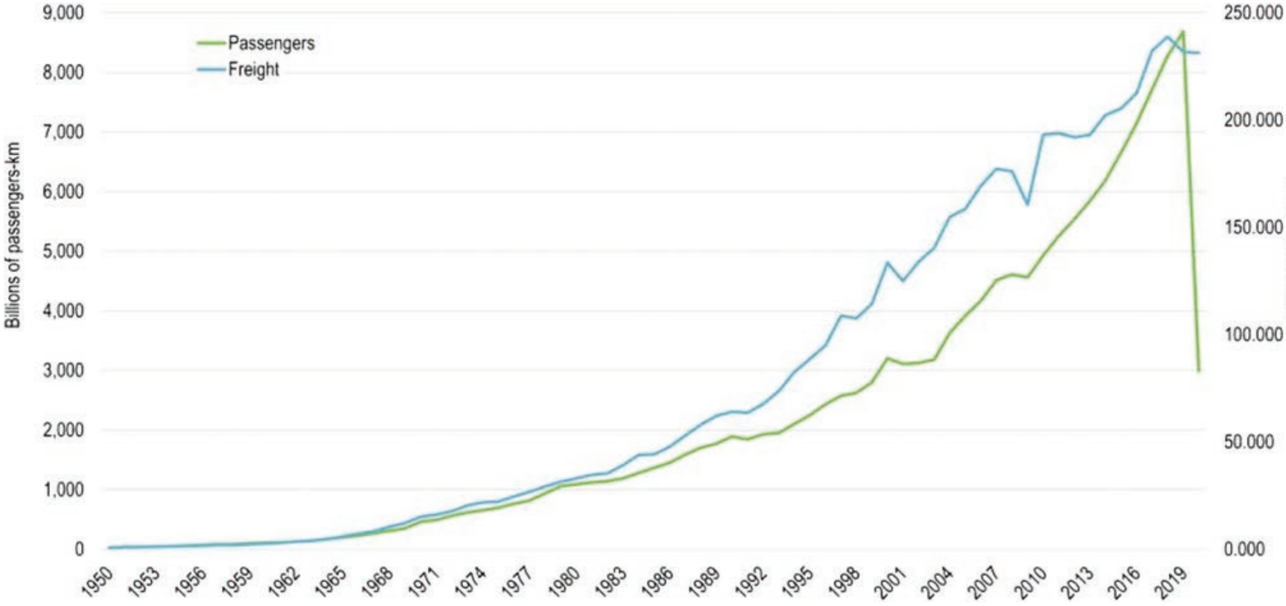

Figure 1 Growth in demand for air travel and air cargo 1950–2019

Open skies agreements have broken the traditional monopoly positions of airlines and have forced them into a price war. The industry changed from a low volume/high margin to a high volume/low margin configuration.[3] Both increased demand as well as forces to make aircraft more efficient (in order to be more price competitive) led airlines to swap smaller aircraft for larger (especially larger wingspan) aircraft.

As this trend was happening, airports were trying to keep up by building new gates, new piers and new terminals. However, by nature, building new infrastructure takes time and is very expensive which caused many of the large airports to be capacity constrained pre-COVID-19.[4] As existing gates were upgraded to accommodate larger category aircraft, gates were lost, and this actually had a negative impact on capacity (at an aircraft level). Also, many airports were hindered by physical or societal boundaries as there was no more room to expand or there was public pressure against expansion.

And then the COVID-19 pandemic happened. The way the industry dealt with the COVID-19 crisis (stop business and reduce cost as much as possible) is logical from a short-term perspective, but it created the perfect storm for today's post-COVID-19 age. Reading the daily news is enough to be aware of the extreme medium to long-term costs associated with these reductions in human resources. Especially since none of these staff reductions have been accompanied by investments that will reduce reliance on human resources once demand comes back.

So, now the world is one where people can travel again and therefore demand for air travel has largely been restored.[5] At the same time, the cost base of airlines has increased as a result of the debt they accumulated during the COVID-19 pandemic.[6] Reliance on human labour has not changed, but the availability of staff is at a point where airlines and airports can no longer cater to the demand in the market. Finally, airports have paused all investments in additional capacity, and therefore, rather than catching up with demand and closing the capacity-gap, this gap has remained or even increased.

KEY CHALLENGES TODAY

So, what are the headaches affecting airport CEOs and managers today? These will not come as a surprise, but for the sake of completeness what this paper sees as the top three priorities for the industry today will be listed and briefly discussed.

First, and maybe even miraculously, sustainability is right at the top of this list. Public (and therefore political) pressure has forced airports to move from paying lip service to reducing their carbon footprints to finally taking action. The new world reality is that, for many airports, being sustainable is directly tied to their licence to operate or at least to their licence to grow.

Second on the list is the availability of human resources. As discussed above, many people working in aviation were laid off during the COVID-19 pandemic and found jobs elsewhere (especially talented/experienced workers). While many people are quite loyal to the aviation industry, being forced to experience working conditions elsewhere also made many realise that the working conditions in aviation are not competitive (which again is a result of price wars and cost savings). The lack of human resources causes airports and airlines to cancel flights and/or artificially cap capacity in order to avoid extreme situations. It is particularly painful that after two and a half years of waiting for demand to come back, the industry is now not ready to serve this demand.

Thirdly, in aviation, safety is always a priority. Like sustainability it is often directly tied to an airport's licence to operate. Unfortunately, this priority too has suffered from the COVID-19 crisis.[7] Without any operations, the safety domain was an attractive area in which to save costs without sacrificing safety (in the short term). However, now that traffic is back, these cost savings are taking their toll. Especially given the high numbers of new and inexperienced staff, there has been a sharp increase in unsafe situations and incidents.

Lastly, there is the issue of capacity. During the COVID-19 pandemic there was no demand so capacity was obviously not an issue. However, during the pandemic, studies[8] were already showing that a capacity crunch might be expected as traffic ramped back up. In order to better understand this, it is a good idea to see required capacity as a function of operational parameters (eg turnaround time) and supply of flights and/or passengers. Traditionally, the required capacity would increase with more passengers and/or flights and would decrease as innovations and process improvements changed the operational parameters.

THE POWER OF DATA

Given these challenging circumstances, what is it that airport managers should be doing? Obviously, the traditional approach of doing more of what was already being done can be taken. More hiring, more building, etc. However, this paper focuses on doing things differently, totally in line with popular slogans like 'build back better'.

At the foundation of what this paper is presenting is nothing new. Measuring

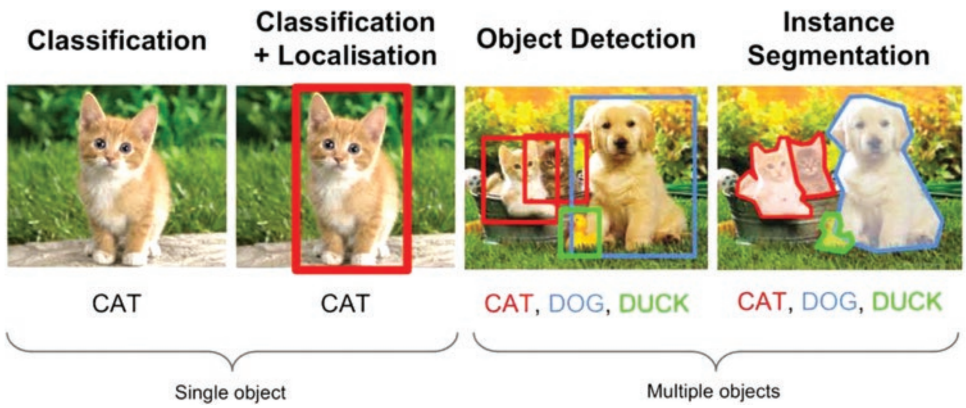

Figure 2 Computer vision technology used for object detection

output in order to optimise operational processes is as old as the industrial revolution itself. There are however a few game-changers that open up a whole new world of data-driven operations management. As a result of the introduction of computers, larger volumes of structured data could be captured and analysed. Structured data is data that can be logically organised in rows and columns. Only recently, as a result of breakthroughs in the fields of Artificial Intelligence (AI) and advanced computing, has it become possible to analyse unstructured data.[9] Unstructured data is things like audio, video and photos.

A VERY SHORT HISTORY OF COMPUTER VISION

One particularly interesting field within AI is computer vision. Computer vision technologies basically let computers see and understand the world like people do, based on vision. Whereas, for humans, it is natural to see, teaching computers to see is not an easy task. For example, for a human, it is easy to understand that a picture of a cat actually shows a cat. However, traditionally, for a computer to understand this was almost impossible. If you wrote a piece of software to recognise cats, you would have to describe exactly what a cat looks like. If the software saw the same cat from a different perspective, it would have no clue. AI software is different, in that sense, as it does not need exact descriptions. Like humans (especially children), AI software learns based on samples. Just as you would tell a child over and over again that a cat is actually a cat, you show an AI software hundreds of pictures of a cat for it to learn. The software creates its own rules with regards to defining what a cat is. If it has not seen enough cats yet, it might make mistakes, but once it has seen enough different cats, it will be able to identify cats it has never seen before (Figure 2).

AIRPORTS AS IDEAL ENVIRONMENT FOR USING COMPUTER VISION TECHNOLOGY

So, computers identifying cats is nice but how does it help airports? Airports are typically environments with lots of cameras. AI, computer vision software can be used to analyse the video feeds of these cameras as described above and thus be used to create data previously not captured. This means that often no new special hardware is required.

Airports are multi-stakeholder environments. This is true for an individual airport but even more so for airlines who work with different airports and ground handlers across the world. The collaboration between all these parties is typically arranged in service level agreements (SLAs).[10] However, the monitoring of these service levels is very difficult. Currently, the most common way to do this is via audits, manual data collection and/or self-reporting. Especially given that these stakeholders sometimes have conflicting interests, they are typically not eager to share data. This results in practices like subjective delay code discussions, which consume energy and time that could be invested into running or improving the operation. Another typical symptom of the lack of data availability and sharing is a lack of progress on continuous improvement initiatives. Without a common understanding of the status quo, it is near impossible to agree on how to invest resources for improvement. The use of objective, unbiased data from cameras is therefore a valuable asset, which leads to both efficiencies and operational improvements.

Another reason why airports in particular are good environments is because of their complexity (partly because of the multi-stakeholder setting) and because the cost of inefficiencies is relatively large. As already discussed, inefficient operations result in additional infrastructure requirements, which are expensive. Furthermore, for airlines, the cost of operating an aircraft is also very high. Depending on the aircraft type and airline, the cost of operating an aircraft is somewhere between US$100 and US$200 per minute.[11]

PRIVACY AND INFORMATION SECURITY CONSIDERATIONS

Using technology and data, and especially computer vision technologies, requires a careful evaluation with regards to privacy and information security. The former is required in order to use these kinds of technologies within the limits of legislation. The latter is to protect the IT assets of the airport or airlines against hostile activities that could potentially lead to big disruptions.

With regards to privacy, it is first of all important to note that computer vision as discussed in the context of this paper is not used to track individuals' behaviour but rather to track process performance. Furthermore, it could be argued that, if a system is analysing video streams for the detection of specific and predefined events, and that replaces the need for human agents to watch video, it would actually improve the privacy of the individuals who would be on these video images. As privacy legislation differs according to country and region, companies offering these kinds of technologies also have to have a portfolio of mechanisms to ensure compliance with these regulations. One example that can be used in case of very strict regulations is the automated blurring of people. This process basically removes personally identifiable information from the video which means that the video data can be used more freely afterwards (Figure 3).

The threat of cyberattacks on critical infrastructure like airports has increased over the past few years.[12] In response to this, airports have increased their investments[13] in this field, improved their IT security processes and increased supplier requirements. As a result, any supplier of technology systems to airports and

Figure 3 Image resolution as a tool for privacy preservation

airlines typically has to adhere to the highest IT security standards. Especially when integrating with one or several core systems. Best practices with regards to this topic are however available and independent quality assurance institutions like ISO can provide technology buyers with the confidence that suppliers' processes are designed to minimise IT security threats.

BEST PRACTICES

Before addressing how data from (for example) computer vision systems can help airports and airlines in their current day challenges, the paper will look at some best practices observed at airports that are starting to work with these kinds of technologies.

A USE-CASE AND VALUE-DRIVEN APPROACH TO DATA COLLECTION AND USAGE

Easy access to lots of data sounds good, but it must be acknowledged that data in itself does not create any value. Data, information and knowledge are only valuable for airports when they are used in an operational context. In particular, because the collection of data has a cost associated with it (software costs, cloud computing costs etc), it therefore makes sense to take a use-case and value-driven approach to data collection and data-driven operations management.

One example is to think about using data in real-time or only having a need for historical data. If your use-case is to have data about past performance to find areas of improvement, you do not need real-time data which might be more costly. However, if your intention is to get alerts about deviations from scheduled operations, you actually need real-time data. Furthermore, a clear understanding of what value is expected from investments in data collection and usage is necessary in order to be able to assess the required investments. In the real-time example above, it should be clearly understood that knowing about a deviation does not necessarily solve it. And not each deviation can be solved. However, the resolution time can be shortened in many cases. Once there is a clear understanding of the use-case, a list of requirements and required scope can be created. Even for the purpose of data analysis (where the goal is to explore data to discover patterns of interest) it is typical to start with a hypothesis that will dictate what kind of data is required.

DO NOT FORGET ABOUT THE USER

AI technologies have the potential to fully automate existing processes. For example, if a catering truck is not detected at an aircraft on time, the software could automatically notify the catering company. Or, if the catering vehicles are autonomous, the software could directly 'call' a catering truck when required. However, full automation is usually the result of a journey that includes intermediate steps like software applications informing a human agent and software proposing action (decision support) to a human agent. Only when, for extended periods of time, the software is accurately proposing the correct actions to be taken can full automation be considered. This means that even for advanced AI systems, initially, success is dependent on the user.

In operational environments like airports especially, the user is typically separated from the buyer of these kinds of solutions. This means that extra care has to be taken in order to involve users in the buying and configuration process. These users have been doing their jobs before the solution was there and, as humans are by nature reluctant in the face of change, they will require assistance to adopt a new way of working. This involves early involvement to ensure buy-in, participation in the selection and configuration process, training, onboarding, continued support and also feedback on the impact of using the new way of working.

SECTOR-WIDE BUSINESS CASES

It can be challenging to create business cases for investments in technologies with platform characteristics. That is to say that it is sometimes difficult for one party to justify an investment in technologies that enable many use cases (and thus value creation) across many stakeholders. Investments in computer vision solutions are being made by whomever owns the cameras, which is typically the airport. Luckily, by nature, airports are already investing money on behalf of other stakeholders like airlines (think about check-in desks: investment by the airport — usage by the airline/ground handler). Furthermore, airports and airlines also already have a financial mechanism to account for these kinds of investments. In that sense it is good to think of the airport as slightly changing its role from an infrastructure provider to an infrastructure plus data and technology provider.

As a result of that, however, it is important for airports to make sector-wide business cases for these kinds of investments. An investment in a computer vision solution might not create enough value for the airport directly. However, if the value generated for the other stakeholders is also taken into account this will most surely be the case. The existing financial relationships (aviation charges) can then be used as a method to distribute the value created for the airline back to the airport.

SOLVING TODAY'S CHALLENGES BY MEANS OF DATA-DRIVEN OPERATIONS

Sustainability

One area where real-time turnaround data can help airports to achieve their sustainability targets is with reducing aircraft holding/queueing times. For the first case, results Assaia has achieved together with Seattle Tacoma Airport will be referred to. At this airport, during peak hours, there are often aircraft arriving and holding for their target gate to become available. The holding occurs either as a result of early arrivals or (more commonly) departure delays. Previously, the target gate of a holding aircraft would often become available without the ground controllers realising this directly,

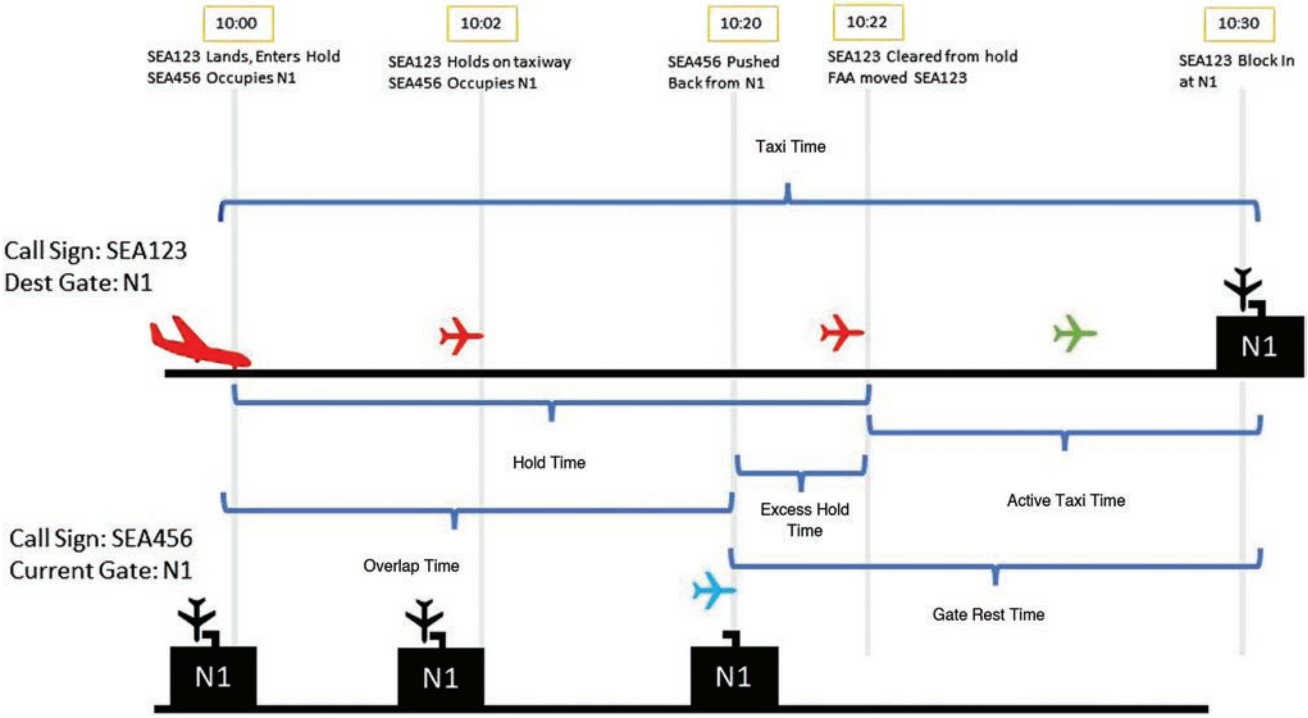

Figure 4 Aircraft arrival process including excess holding time

thus creating a situation where an aircraft is holding while its target gate is actually already available (Figure 4).

Through the use of Assaia's computer vision system the moment that the aircraft leaves the gate is registered and the ground controller is notified that the next aircraft should be cleared for taxi-in. As a result of this automated workflow, excess holding times at Seattle Airport have been reduced by almost 80 per cent. As a result, airlines' kerosene costs have decreased by roughly US$1m per year and CO_2 emissions have been reduced by 1.5m kg per year.

There is a second, even more significant case related to aircraft holding times. Before diving into this use case, it is useful to explain how real time turnaround data is used to predict aircraft off-block times. Again, AI technology is used in order to create an algorithm which continuously predicts when each aircraft is going to depart. Assaia's predicted off-block time (POBT) algorithm has been validated by an independent third-party research institute to be much more accurate than current day alternatives. The POBT can be used to clear a holding aircraft for taxi-in before the gate is even available. For example, if the average taxi-in time is nine minutes and the POBT for the target gate shows that there are nine minutes remaining before the departing aircraft clears the gate, the next aircraft can be cleared for taxi-in. The arriving aircraft will then arrive at the gate just as the other aircraft pushes back. This means that the average aircraft holding time will be reduced with the average taxi-in time (nine minutes in our example). The effect of this use case on an airport like Seattle would be fivefold of the previous case.

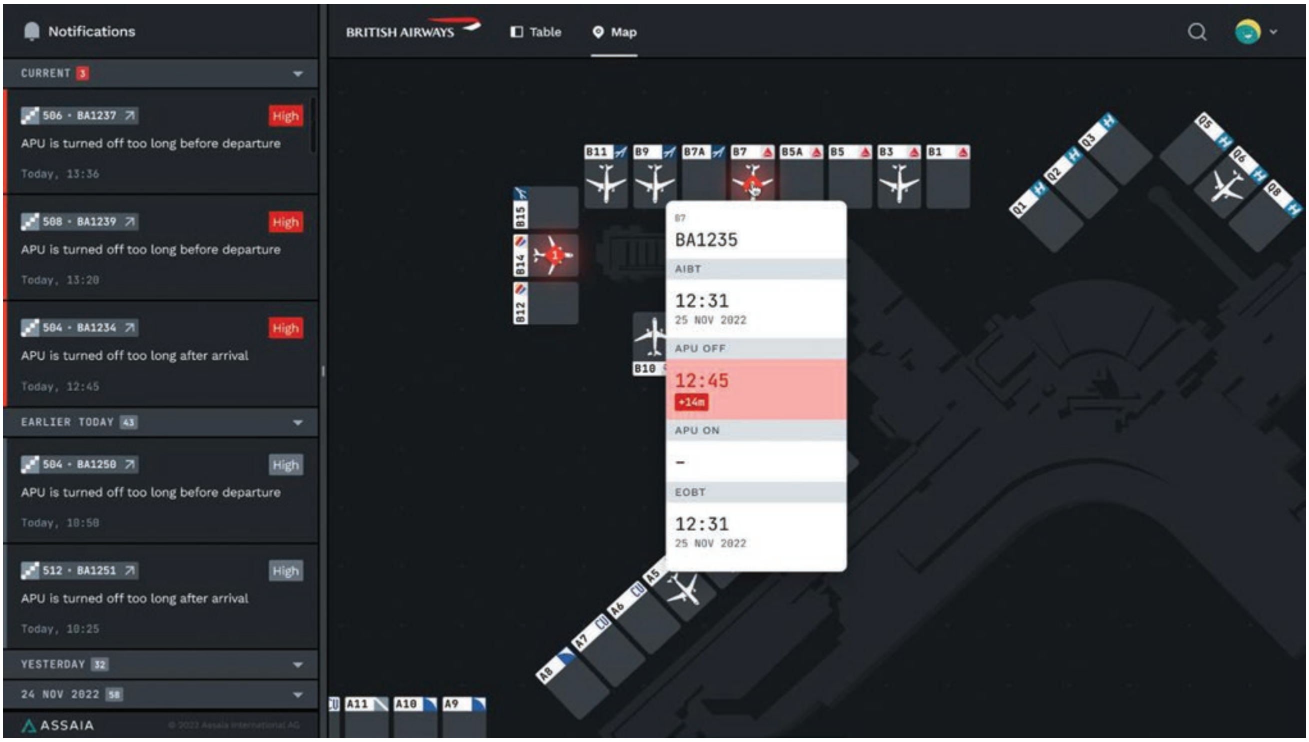

Figure 5 Assaia's ApronAI Turnaround Control User Interface

A final interesting application of real-time turnaround data for sustainability objectives is related to minimising the use of aircraft auxiliary power units (APUs). The APU is a generator, typically located in the tail of an aircraft and used to generate electricity. After arrival, the ground handler is supposed to connect the aircraft to ground power and pre-conditioned air. After this, the APU can be turned off. Before departure, the APU is turned on again before disconnecting ground power and pre-conditioned air. Since the APU is a very inefficient and therefore pollutive engine that produces a lot of noise, airports particularly want airlines to turn APUs off as quickly as possible and turn them back on as late as possible (Figure 5).

A computer vision system can detect if the ground power and pre-conditioned air have been connected. Therefore, if this has not happened the system can alert the ground handler or airline in order to get it connected as soon as possible. On the departure end, the POBT can again help ground handlers to determine the ideal moment to disconnect ground power and pre-conditioned air. With one customer, Assaia has realised an average increase in ground power connection time (thus time that the APU did not have to be on) of four minutes per flight. This saves 22kg of Co_2 emissions per flight while it also saves the airlines money. Twenty-two kg might not sound like much but for a busy airport it accumulates to significant amounts over the course of a year.

Capacity

On the capacity front two great ways have so far been found to create additional capacity for airports without building

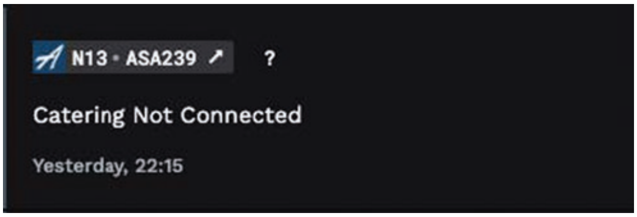

Figure 6 Catering alert

new infrastructure. First of all, it is worth noting that gate capacity directly relates to turnaround times. If the average turnaround time reduces, the required capacity automatically also reduces. Thus, reducing average turnaround times by means of reducing ground delays is an excellent way to increase capacity.

As already seen, Assaia's computer vision system is capable of issuing an alert when certain turnaround activities do not start on time. Acting directly on any deviations from the schedule instead of waiting for, for example, 15 minutes until someone reports the deviation via radio helps to resolve the issue quicker and minimise the impact on on-time performance. Alaska Airlines uses exactly the same system in their major hub, Seattle Tacoma Airport. As a result of this usage, they have reduced their ground delays by 3.9 minutes on average. At another major airport in North America, an average reduction in ground delays of 5 minutes per flight has even been observed (Figure 6)!

Another way in which additional capacity can be created is by using POBT for gate planning purposes. For optimal gate planning, the key pieces of information are to know when an aircraft will arrive and depart. If this information is known in advance with high accuracy, an optimal gate allocation can be made. However, in practice, arrival and departure times fluctuate and there are unfortunately still surprises with regards to when aircraft arrive and depart. In order to account for these surprises, airports use buffers between flights. These buffers may be as much as 25 minutes which is almost the required time to turn around a low-cost narrow-body aircraft. As mentioned before, the POBT has already proven to be more accurate than any other currently available estimation of when an aircraft is going to depart. Furthermore, the POBT also has a much lower variance which means that its predictions are more stable, and the surprises are not as big. Assaia's work with one of the biggest airports in Europe has shown that the use of POBT instead of TOBT would justify planning buffers between flights being reduced from 25 to 15 minutes. When their summer 2019 flight schedule is then replanned and the peak time looked at, it can be seen that the required gate capacity for that schedule has been reduced by four gates! This means that the airport now has four free gate-slots during its peak time. The value of these slots for the airport would be around EUR 60m per year in additional aeronautical and commercial revenues (Figure 7).

Safety

Assaia's computer vision system can detect many different unsafe behaviours and situations. Alerting airport managers to these unsafe situations helps reduce incidents. Two examples have been observed where a significant impact in terms of

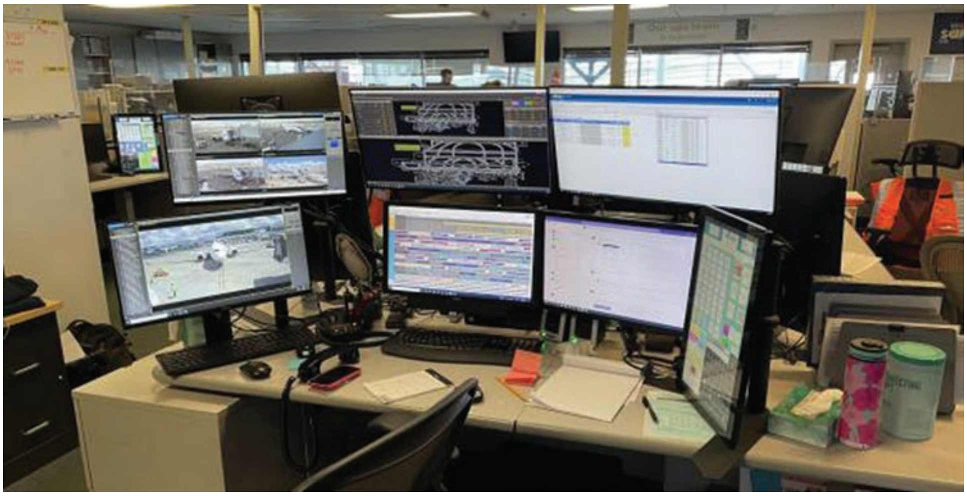

Figure 7 Assaia's ApronAI Turnaround Control in use at Alaska Airlines OPS centre

safety improvements has been measured as a result. The first case is at a small European airport where the system was (among other things) used to track if a post departure foreign object debris (FOD) walk was executed by the ground handling agents. If this FOD walk was not detected, airport operatives in the airport operational control centre (AOCC) were alerted. These alerts would trigger them to call the ground handler to enquire why the FOD walk was not executed and request that it be done. As a result of the airport's increased oversight of this safety procedure and ability to act, the percentage of flights for which this procedure was not executed reduced from 60 per cent to 35 per cent.

At a major hub airport in the US, the computer vision system is used to check if the stand is clear of larger objects and vehicles for an incoming aircraft. If a gate is not clear upon aircraft arrival, the aircraft might have to wait. Or, in a worst-case scenario, the aircraft taxis into a gate which is not clear and as a result is damaged. The system starts checking whether or not a gate is clear as soon as the next aircraft touches down. If the stand is not clear, an alert is sent to the ramp supervisor who will then coordinate actions in order to clear the gate before the aircraft reaches the gate. As a result of using the system and this workflow, cases where the gate was not clear upon aircraft arrival have been reduced by as much as 50 per cent (Figure 8).

HUMAN RESOURCE AVAILABILITY

How POBT can be used in order to plan gate resources more optimally has already been discussed. The same logic however also applies to any human resources required at an aircraft turnaround. Pushback drivers, for example, are required at an aircraft until it departs. The more surprise delays there are, the less optimal the allocation of these human resources. And, as a result, more of them are required.

On another note, turnaround activities often seem to happen in an uncoordinated fashion. A classic example of this is when catering and bag loading happens at the same time at the front of the aircraft. Baggage loading duration in

Figure 8 Stand not clear detection

Figure 9 Congestion in case of bag loading and catering loading at the front of the aircraft

these cases, compared to cases where it does not happen at the same time, has been observed to be almost twice as long. Watching a turnaround where this happens, this is hardly surprising, as the catering truck and the baggage carts are in each other's way. Using real-time data concerning aircraft turnarounds can help to synchronise the different turnaround subprocesses. As a result, in this specific example loading teams could save an average of 13 minutes on each turn where bag loading and catering at the front does not happen at the same time. These crews can then be replanned to other jobs and, overall, fewer people would be required to handle the same number of aircraft (Figure 9).

CONCLUSION

Sustainability, capacity, human resource availability and safety are at the top of airport and airlines' priority lists. Throughout this paper how these topics came into effect and how they can be mitigated has been explored.

It is clear that airports and airlines require digital solutions in order to face these challenges. Therefore, airport and airline executives need to be aware of the capabilities and challenges of modern-day technologies in order to be comfortable making investments in AI solutions.

Furthermore, the development of a more data-driven approach to operations management is critical in order to be able to accommodate the projected growth with available infrastructure and within the limits of public acceptance.

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