Best practice on automated passenger flow measurement solutions

Received: 8th December, 2014

Catherine Mayer

CATHERINE MAYER
is the primary liaison for SITA with airport industry organisations, ensuring SITA's availability and support for committees, conferences and industry missions. She is an active participant in the Airports Council International (ACI), including serving as Chairman of the ACI World Business Partners (WBP) Board and becoming the first non-airport member to be appointed as an observer to the ACI World Governing Board (2006–2011). Catherine also serves as the WBP observer on the ACI Europe Airport Board (2012–2015). Previously, Catherine was responsible for developing and leading the Airport Services solution line, including the financial results of the global business, strategy, product portfolio, implementation, customer satisfaction and improving the business to ensure that SITA continues to meet the needs of the ever-changing air transport industry.

Rolf Felkel

ROLF FELKEL
is a Vice President airside, terminal and security applications at Fraport AG. Rolf is in charge of the development and maintenance of IT applications in the field of airside, landside, security and safety-related IT solutions. In his role he represents Fraport AG on the ACI World Airport IT Standing Committee. He joined Fraport's ICT department in 2000 as a system planner for the flight information display system at Frankfurt Airport. In the following year, Rolf worked as an ICT project manager and set up a group of in-house ICT consultants, before he took over responsibility for landside IT solutions at the beginning of 2007. Before working at Fraport, Rolf studied mathematics, gaining a diploma in 1995 at the Technical University of Darmstadt, where he also completed his PhD at the end of 1999, becoming a Dr rer. nat. in the field of numerical nonlinear optimisation.

Kevin Peterson

KEVIN PETERSON
has been in the air transportation industry for over 25 years, working for Westinghouse and Northrup-Grumman before moving to SITA in 2001. He started his career in software engineering, broadening his knowledge through positions in technical sales support, marketing, sales and product management. Currently, he is the senior product manager responsible for SITA's passenger flow monitoring product suite. Kevin's formal education includes a degree in mathematics through the University of Waterloo and a diploma in electronics engineering technology through Mohawk College, both located in Canada.

Abstract

The authors introduce a best practice paper recently published by the ACI World Airport IT Standing Committee on Automated Passenger Flow Measurement Solutions. The paper shows how this supplier-independent best practice paper is structured and what benefit it can provide to those who want to implement and use such solutions in terminal buildings. Therefore, some general characteristics of the solutions are given, as well as the typical influencing factors from technology, terminal layout and passenger behaviour. The paper is available on the ACI World website at www.aci.aero.

Rolf Felkel,
Landside and Security Applications,
60547 Frankfurt am Main, Germany
Tel: +49 (0) 69-690-72025;
Fax: +49 (0) 69-690-495-72025

E-mail: r.felkel@fraport.de

Keywords

terminal management, passenger flow performance indicators, waiting time, sensor technologies

INTRODUCTION

As a passenger, moving from kerbside to airside, you want a minimum of inconvenience. You would prefer no queues, sufficient and up-to-date information, and the time to browse and shop in one of the top brand retailers before boarding. You would like it all to flow smoothly and, if there is a hold-up or congestion, you would like to know about it promptly. You would like to eliminate the stress and surprises of airport queuing and processing rather than spending time in long lines at the security checkpoint.

Unfortunately, at the majority of the world's busier airports, that has become increasingly difficult to deliver. More passengers going to more places, larger aircraft and the 21st-century essentials of security make flying more stressful and the smooth operation of an airport more difficult to achieve. Time pressure is a constant companion. Each queue — and there can be many from check-in and bag drop through to security and boarding the aircraft — can trigger a traveller's panic button.

The consequences are well known. Flight delays caused by late boarders cost airlines tens of thousands of dollars; industry figures indicate that an extra ten minutes spent at security may reduce retail spend by as much as 30 per cent.[1] JD Power found in their North American Airport Satisfaction Survey[2] that passengers reporting high levels of satisfaction with an airport tended to spend more in retail outlets — up to 45 per cent more on average.

To help them relax at airports, passengers need real-time information that puts them back in control. And not just about flight delays and gate changes, but also about queue lengths and waiting times. Fortunately, technology is providing workable solutions that deliver a wealth of extra-value opportunities for airport operators, in term of managing passenger flow inside the terminal. By obtaining 'live' information on these flows, airports can react more quickly to unfolding events by deploying extra staff and rerouting passengers to other areas of the airport, such as security checkpoints located in another part of the terminal.

This ensures that people move through the airport at an optimum rate to minimise delay and maximise comfort, which should result in higher passenger satisfaction and thus greater retail spend. It makes addressing the issue an increasingly good investment, helping not just the bottom line with better resource allocation and on-time departures, but also top-line growth.

More than 30 airports worldwide are now using some form of queue measurement system. By using data collected from these systems and touch points across the airport — both landslide and airside — airport operators can see the bigger picture based on facts revealed by the data. This then enables timely analytics — giving meaning and value to the data and facts. Airports can also track, manage and share real-time information about their assets. They optimise airport processes and decision-making for all stakeholders — in a smart predictive environment that uses IT infrastructure intelligently.

At the same time, passengers can be kept informed across the journey — often via their smartphones — with personalised up-to-the-minute information about waiting times at security and passport control, in addition to other services such as parking availability, baggage tracking, gate changes, flight status, retail offers and more.

LEARNING FROM EXPERIENCE

The number of airports with detailed operational experience of passenger flow monitoring is rapidly increasing. Recognising this, the Airports Council International (ACI) World Airport IT Standing Committee (WAITSC) has recently published a best practice paper[3] that brings together existing experience on passenger flow measurement solutions and provides a guideline for airports intending to use passenger flow measurement technologies in the future.

The scope of the paper is on technical solutions that do *not* assume explicitly cooperative (or opt-in) passenger behaviour. These non-cooperative solutions are typically integrated in the terminal infrastructure or use data from existing passenger processes, such as boarding pass scans or mobile devices and wi-fi signals. From the passengers' perspective, these solutions are transparent — they measure the flow without any awareness by the passenger, or breach of data privacy, as they monitor passenger movements anonymously.

The best practice paper takes into account:

- a performance indicator (PI) as the final output data of a technical measurement solution;
- properties of the technologies used;
- several influencing factors such as terminal environment, individual passenger behaviour and general passenger flow characteristics; and
- the characteristics of use cases in terminal operations and planning.

The PI is the top-level structuring element, with the following elements analysed:

- What is the correct interpretation of the PI type?
- Which technology (or combinations of technologies) can deliver the PI type?
- How can the terminal environment influence the results?
- How can the passengers' behaviour influence the results?
- What other issues might arise during implementation?

Different use cases for PIs have also been analysed based on a range of general characteristics. There is no specific mapping of PIs to use cases, since each PI might be used in each case. Nonetheless, as each airport and terminal is truly unique, usage scenarios have individual properties that should be considered in order to improve the benefit for terminal operations and planning.

Two underlying lessons have become apparent through the preparation of the best practice paper:

- Each location and environment is different, so only a sufficiently long testing phase in a live operations setting can help to avoid painful surprises.
- Once implemented, regular checks of the automated measurement solutions are necessary to guarantee a constant level of high-quality data.

CAREFUL CHOICE

As noted above, automated passenger flow measurement solutions can be of great value to improve efficiency and passenger service quality, but care needs to be exercised in selecting the best relevant technologies.

The best practice paper should help to resolve some typical challenges in selecting and implementing the technical solution, and so boost business value.

Generally speaking, the measurement of passenger flow PIs helps to:

- confirm and improve passenger service quality;
- estimate temporary and continuous bottlenecks in the terminal building;
- estimate future resource allocation at process points; and
- calibrate automated passenger flow forecast tools (see Figure 1 and [4]).

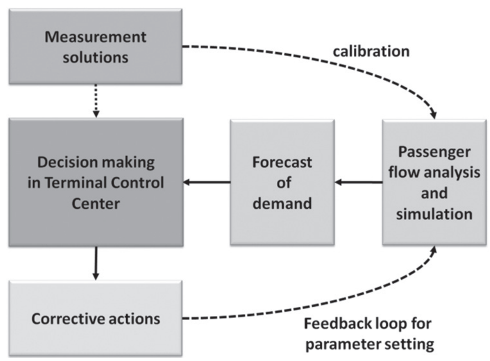

Figure 1 Role of measurement solutions for decision makers

The performance of passenger flow can also be measured manually,[5] but compared with automated solutions this has some disadvantages. For example, the quality of measurement will depend on the experience and concentration of staff, while manual measurement can only be performed as a sample and not continuously over a long period of time.

These disadvantages do not exist when using automated, IT-based solutions — because IT solutions deliver a continuously updated stream of PIs with an equal level of quality. While the automated solution usually delivers a better return on investment, the calculation of a local business case depends on the specific needs of that individual airport and the local conditions within the terminal facilities.

GENERAL DEFINITIONS

To describe the characteristics of passenger flow measurement solutions, some general remarks and definitions are needed to understand how passenger flow measurement technologies work in general.

1. Performance indicator

A PI is aggregated information in the context of passenger flow. The PI is derived from raw data (RD) that was technically measured by any kind of sensor solution. A PI delivers performance information on a certain aspect of the passenger flow, eg the waiting process of passengers, or the throughput of a process.

The calculation of a PI is often part of the measurement solution itself. PIs are usually functions of time and process locations. They may be calculated for predefined time ranges of different length (one minute, five minutes, one hour, one day, etc.) and predefined locations in the passenger terminal building (security checkpoint, border control, etc.).

A PI depends — in quality and quantity — on RD and algorithms to calculate the PI from the RD. In general, it is possible to use RD from different sensors to calculate a PI, as long as they are comparable in their meaning, quantity and quality. Examples of PIs covered by the best practice paper include:

- passenger waiting time in a queuing area, including a differentiation between retrospective waiting time and predictive waiting time;
- throughput of a process point;
- occupancy level of a defined area.

2. Key performance indicator

PIs that are extremely important to certain stakeholders may be agreed upon to become key performance indicators (KPIs). Usually, KPIs are associated with corporate objectives such as a passenger satisfaction index or a service level agreement.

3. Raw data

RD is the basic information measured by a (technical) sensor solution, which may include one or more of the following:

- data collected through BCBP (Bar Coded Boarding Pass) scans;

- timestamps of Bluetooth® and wi-fi signal strength peaks;
- people counting impulses/signals of a passenger passing an imaginary line in the terminal, using thermal, infrared and/or visual camera sensors, or counts of an automated metal detector (AMD).

RD is measured as an event, at a singular point in time, at a predefined location. RD is generally without any contextual information. Nevertheless, quality assurance should be applied to RD to some extent (eg filtering, formatting).

4. From raw data to performance indicators (and to key performance indicators)

Generally, RD is transformed into a PI by special software algorithms provided by the supplier as part of the technology solution. Therefore, less sophisticated PIs can be used as input data for the calculation of more complex ones.

5. Detection errors and their effect on the performance indicator

None of the existing solutions and products is perfect, since the sensor solution always has accuracy limitations. It follows that the knowledge, interpretation and management of detection errors and their effect on PIs is always part of the task.

For example: if a sensor detecting in-flow to a queuing area as RD has an accuracy of approximately 95 per cent and the total number of passengers to measure is 10,000 per day, the accumulated error over the whole day is up to 500 passengers. The problem with the majority of sensor solutions is the fact that they do not have an equal spreading of errors, eg following a normal distribution around the real number of passengers. Typically they detect fewer passengers than are actually present; seldom do they interpret an object (eg a suitcase) as an additional, non-existing passenger. So in this example, the measured number of passengers entering the queuing area will be approximately 9,500, not 10,000. Assuming that the out-flow of the queuing area can be measured with a higher accuracy (eg by a different type of sensor or better lighting conditions), the number of passengers in the queuing area — calculated as the difference between in- and out-flow — will be negative.

Knowledge about the typical error rate of a sensor in general and the achievable accuracy of the sensor in the real world terminal environment are very important first steps to interpreting the PI generated by the RD. But it is also important to know how the error in the RD might affect the quality of the PI as the intended output. This error propagation depends very much on the algorithm and can only be examined individually. Some algorithmic approaches will reduce the effect of the error in the RD; others will not. It is also possible that the PI as the final output of the solution will deliver an unreasonable figure, such as a negative number of passengers in a queuing area.

The lessons learned from this can only be for airports to:

- discuss typical error rates in the RD and their effect on the PIs with the solution provider;
- check the real, achievable accuracy of the sensors in the terminal environment; and
- discuss issues with the users of the PIs in order to manage expectations and achieve good user acceptance.

PERFORMANCE INDICATORS

It is important to recognise that, to some degree, and within the calculation of one PI type, one form of sensor technology can be substituted for or supplemented by others, eg video-based passenger counting sensors at the entrance of a security checkpoint queuing area can be substituted for or supplemented by BCBP scans. So a mix of well-chosen sensor technologies can support a measurement solution, so long as the quality of the RD captured with the sensors is comparable and the supplier's software supports this option.

There are five types of PI covered in the best practice paper.

Waiting times are the most difficult to measure and calculate, although they are often the most interesting for airport terminal management. There are two different classes of measured waiting times that have to be distinguished:

- The retrospective (backward-looking or historical) waiting time: the time passengers *have waited* in a queuing area before they left it.
- The predictive (forward-looking) waiting time: the expected time a passenger *will have to wait* in the queuing area when he enters the area.

To use a retrospective solution for the prediction of waiting times is generally not feasible and is successful only under very special conditions that seldom exist. So if it is planned to display waiting times to passengers in the terminal building, the only suitable PI is the predictive (forward-looking) waiting time.

There are then five ways of measuring waiting time — discussed in more detail in the best practice paper.

Process throughput involves measurement of inward and outward flow to and from the respective area per time interval or as single counting events. These are achieved through the use of sensors that can detect passengers entering or exiting the relevant area. It can involve the use of optical sensors (cameras with detection and counting firmware), laser sensors, thermal sensors, infrared sensors, BCBP scans or AMD scans. BCBP scans provide nearly 100 per cent accuracy; other counting solutions typically range from 95 per cent to 98 per cent accuracy.

Passenger arrival profile uses BCBP scanners capable of reading both paper and mobile BCBPs, which provide nearly 100 per cent accuracy, assuming the use of IATA standard type 'M' barcodes. They are typically located at the entry to security, or at boarding. The BCBP scanner can be provided through agent-manned workstations or handheld terminals and/or via automated security and boarding gates. The BCBP scans can be compared with actual flight data from the airport operational database (AODB) in order to determine how long before the scheduled time of departure a passenger shows up at the process point. This information obtained from all passengers delivers a profile of general passenger behaviour (see Figure 2).

Queue length overrun: although best measured by simply counting heads via an optical sensor(s), it is possible to detect overflow queues, and their impact on queue times, using other technologies, eg Bluetooth®/wi-fi (adjusting for the population with/without Bluetooth®/wi-fi enabled phones), typically in combination with some form(s) of in-flow and out-flow people counting.

Area occupancy is typically defined as the number of passengers in a predefined area. From this it is easily possible to calculate a density of passengers in an area by dividing the number of passengers in the predefined area by its square metres.

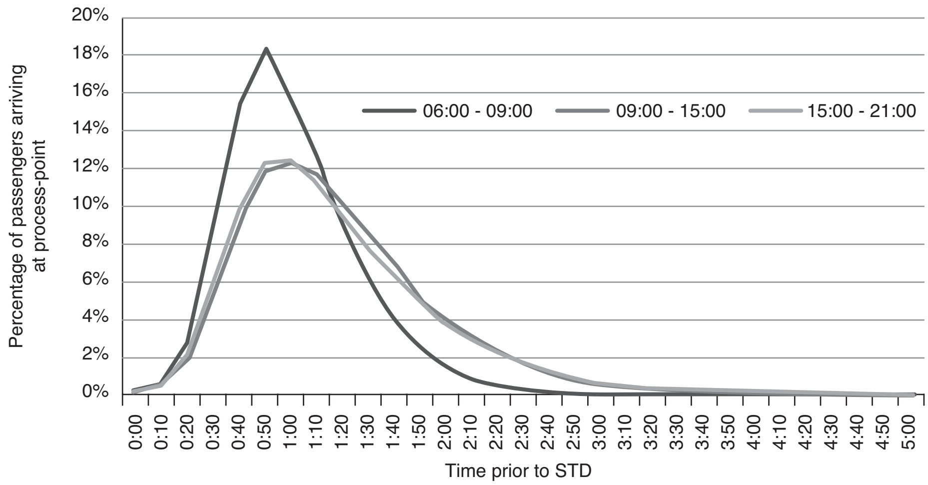

Figure 2 Patterns of passengers arriving at a process point

USE CASES

To improve passenger terminal management and planning, the best practice paper divides the output of passenger flow measurement solutions into operational, post-operational and pre-operational scenarios. Operational scenarios are relevant for the management of the current and upcoming passenger flow: post-operational typically requires historical reports on what happened during different time intervals; pre-operational is mainly for planning and resource allocation.

1. Operational use cases

More and more airports in the world are keeping their passengers informed about wait times in real time at certain process points, especially security checkpoint and immigration areas. As described at the start of this paper, the motivation for operational use cases is to provide public and online wait times and information in order to reduce passenger stress levels. The information may be supplemented with alternate, less congested, shorter wait time routes. Additionally, this feature can be combined with walking and processing times to give the passenger a more comprehensive understanding of total time to the departure gate or baggage belt. As more airports adopt these solutions, they are quickly becoming standard elements of passenger service improvement initiatives.

The provision of current wait times can technically be done by displays, integration with mobile apps, airport web pages and point-of-information systems. Therefore it is recommended that wait times be displayed in standard formats (eg <5 min, 5–10 min, 10–15 min, >15 min).

2. Post-operational use cases

The post-operational use cases analyse the historical passenger flow related PIs and KPIs that were reported yesterday, last week or last month. In order to do this effectively, the PIs should be stored in a business intelligence (BI) reporting tool so the PIs can be stored and categorised for future analysis.

The most popular mode of reporting flow data is via online dashboards. PIs and often KPIs are displayed on a dashboard giving the current situation (eg 5 minutes old), trend information and the average over the entire day. These dashboards use typical graphical features such as symbolic 'traffic lights' or red-yellow-green indicators.

3. Pre-operational use cases

The pre-operational use cases help airports to enhance planning and resource allocation. The better the forecast of demand at a process point in the future, the better resources can be allocated depending on real demand and a predefined service level. Measured PIs can be used to support this. The historicised PIs should be analysed by a BI tool in order to identify patterns and to predict scenarios and resource needs into the future.

Additionally, these measured passenger flow PIs are valuable input parameters for terminal layout and capacity planning. The mean values from historical PIs such as throughput, arrival time profiles for a specific process, or waiting times can be used to maximise terminal facilities and confirm the layout, quantity of operators (eg security lanes), etc. For the validation of a planned terminal layout, simulation tools are required using the valuable parameters and historical PIs from a passenger flow measurement solution.

INFLUENCING FACTORS

The interpretation of any passenger flow solution data depends on several influencing factors (see Figure 3): some of them are solution inherent (sensor technology and calculation software) and some are more external (terminal environment or passenger behaviour).

1. Technology: sensors and software

Obviously the most important influencing factors are encountered through the measurement solution itself. The solution architecture and the technology used (sensor as well as software) have special properties that should be known and considered by any airport looking to deploy automated passenger flow technology. For example:

- Does the general approach provide 100 per cent coverage of the relevant passengers, or is it only a sample with an uncertain ratio covered? If 100 per cent coverage is not achieved, what ratio is necessary in order to deliver adequate, quality results?
- What are the normal error rates of the sensors? Which error rate is tolerable

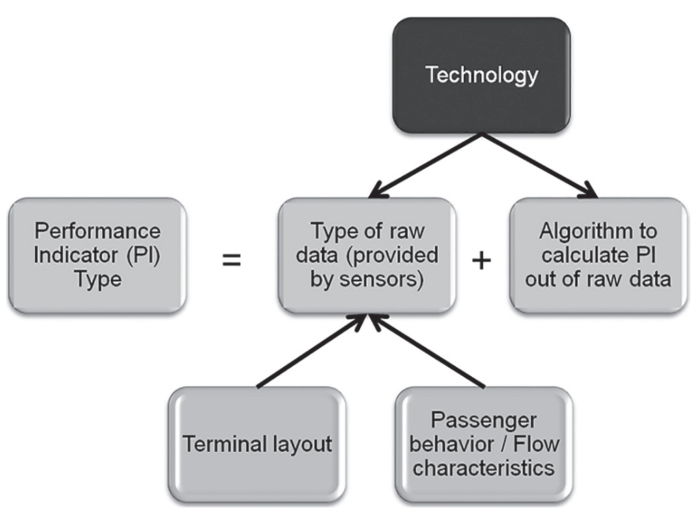

Figure 3 Performance indicators, raw data and influencing factors

in order to deliver acceptable quality results from the entire solution?
- Are there any relevant time schemes to be considered in the process of capturing the RD to the calculation of the PI?
- What is the exact meaning of the PI compared with the passenger flow (retrospective or predictive)? If it is retrospective, how long was the time from the first RD captured to the provisioning of the PI?
- Are there any data privacy aspects to be considered?
- What is the system supposed to do in 'irregular' situations, such as a total lack of passengers or too many (non-moving) passengers in a defined area at a certain time?

2. Terminal environment

The environment of the passenger terminal and the location of sensors can influence the quality of the measurement solution. Precautions that should be taken include:

- Avoid a mixture of different passenger streams in one observed area. Define queuing areas clearly — especially entrances, lines and exits — where applicable.
- Ensure that sensors are not blocked or influenced by obstacles, eg doors, walls.
- Ensure that construction activities in the terminal are planned and implemented hand-in-hand with the measurement solutions.
- Consider the lighting conditions, as suitable lighting is often necessary for visual sensors.

3. Passenger behaviour and flow characteristics

Interpreting the results of a passenger flow measurement solution must also take into account the possible behaviour of the individual or group of passengers, and the characteristics of passenger flow as a whole. Some issues to consider include:

- The timely resolution of PIs should be higher than the mean variability in passenger flow.
- Single individuals may not behave as expected, eg entering or leaving the queuing area via the wrong direction, moving within the queuing area in an unexpected way, waiting longer than necessary due to a telephone call.
- The detection of people that are not actually passengers, eg staff.
- The movement of people in groups.

A BOOST FOR EVERY AIRPORT OPERATOR

From the moment a passenger arrives at the airport it is possible to collect data about their progress and movements, suitably anonymised. As they go through check-in, bag-drop, border control, security, tax & duty free, food & beverages, executive lounge to boarding gate, their progress, speed and dwell-time can all be used to smooth progress ahead and make it easier for those who follow. Real-time and historical data analysis can help airport management provide the optimal number of processing points along with the right number of staff in the right place at the right time, and ensure that the right assets are deployed and the right information is available and presented. Each passenger becomes part of a trigger to deliver improvements to customer service that benefit everyone.

The acquisition of passenger flow data is not difficult (given the right technology and careful planning), but making the best use of that data *is* complex, requiring a forensic grasp of the processes involved and a clear understanding of what data is useful and what is peripheral.

The result is a substantial potential gain for every airport operator — financial and reputational. And the tools are now available to provide that advantage. Please visit the Airports Council International (ACI) website at www.aci.aero to download the 'Automated passenger flow measurement solutions' best practice paper.

References

(1) SITA analysis.
(2) Power, J. D. and associates (2010), 'Press Release on 2010 North America Airport Satisfaction Study', available at: http://businesscenter.jdpower.com/news/pressrelease.aspx?ID=2010015 (accessed 26th January, 2015).
(3) Peterson, K. 'Automated passenger flow measurement solutions', Best practice paper, *Airline Business*, available at: http://www.aci.aero.
(4) Felkel, R. and Klann, D. (2012) 'Comprehensive passenger flow management at Frankfurt Airport', *Journal of Airport Management*, Vol. 6, No. 2, pp. 107–124.
(5) WAITSC (2014) 'Best practice on passenger flow measurement solutions', October, ACI World Airport IT Standing Committee. ACI World Facilitation and Services Standing Committee (2012), 'RP 300A12 Manual Measurement of Passenger Service Process Times and KPI's', available at http://www.aci.aero/media/c3e17fa9-b391-4b30-ba88-07004d2b2b37/LG-_qg/About%20ACI/Priorities/Facilitation/Manual-Measurement-of-Passenger-Service-Process-Time-and-KPIs.pdf (accessed 26th January, 2015).