UITP ADVANCING PUBLIC TRANSPORT

REPORT

IMPROVING PASSENGER FLOW AND CROWD MANAGEMENT

THROUGH TECHNOLOGY AND INNOVATION

OCTOBER | 2022

/ EDITORIAL TEAM

Antonio Valente, Metro Lisbon

Balazs Berki, Streamax

Claus Dohmen, VDV Germany

Corentin Wauters, UITP

David Moszkowicz, Alstom

Georg Koenig, INIT

Gonzalo Carmena, Metro de Madrid

Henrik Koberg, Siemens

Irene Berta Moreno Sanz, Indra

Jaspal Singh, UITP

José-Cruz Peña García, Metro de Madrid

Juan Corro, EMT Madrid

Manfred Schienbein, Siemens

Maurizio Pichierri, Hitachi Rail

Normen Wiegand, Hochbahn

Rene Zeller, Maior

Roch Muraine, Alcatel-Lucent Enterprise

Sipila Tomi, Kone

Theresa Pancini-Fitzek, Siemens Mobility

Xavier Arrufat, Awaait

International Association of Public Transport (UITP)
Rue Sainte-Marie, 6 | B-1080 Brussels | Belgium

Tel: +32 2 673 61 00
info@uitp.org
www.uitp.org

TABLE OF CONTENT

INTRODUCTION

The public transport sector in all corners of the world has been dramatically affected by the global COVID-19 crisis. In order to support the process of revitalising confidence in public transport, UITP wishes to explore the methods for improving the passenger flow in public transport systems, in particular in urban networks (railway/metro/bus/tram), to maximise the number of passengers, while offering the most comfortable and safest passenger experience. We will also be looking into methods of monitoring and modelling fluctuations in mobility demand and anticipating the impacts of unexpected events and specific conditions (pandemic outbreaks, strikes, vehicle or system malfunctions, weather conditions, flooding, etc.).

An important objective is to improve the prediction of passenger demand, in order to optimise the resources and adapt the supply of transport services with the support of analytics and algorithms.

Another objective is to provide passengers with reliable information to allow them to choose when and how to travel safely while respecting social distancing, health regulations and recommendations. The integration of such predictive information into the Mobility as a Service (MaaS) ecosystem will allow users to gain greater trust in public transport and will promote sustainable transport.

In addition, it provides an opportunity to explore ways of maximising the value of the passenger dwelling time and improving potential new revenue streams, such as interactive adverts, cafe kiosks and vending areas.

SCOPE & DEFINITION

Public transport is considered the backbone of sustainable, green, and inclusive mobility, particularly in urban areas. This paper focuses on improving passenger flow and crowd management with technology and innovation for public transport networks, particularly in urban areas and well-integrated into the global mobility domain. The objective is to shift from individual to collective use of public transport mobility.

It is based on concrete use cases, demonstrating value for all stakeholders and benchmarking of existing technologies.

Stakeholders:

- PTA (Public Transport Authority) - regulating and financing transport development and planning. They require a more dynamic vision, as the situation is evolving rapidly.
- PTO (Public Transport Operator) - measuring, analysing, predicting passenger flows and equipping the network with sensors. They must publish reliable information for passengers.
- New mobility service providers – must be integrated into the public transport backbone to optimise their operations.
- MaaS service providers - must integrate demand management into their platforms in order to provide relevant guidance to the transport users.
- Passengers - need end-to-end services, including social distancing information and guidance.

Some general definitions are supplied here to ensure a common understanding:

- **Vehicle and platform occupancy:** Passengers will experience occupancy rates (impacting travel time, social distancing and comfort) during their journey, on-board vehicles, at the platform or at intermodal transport hub-level. Occupancy rates can be directly measured by sensors or video analytics.
- **Origin-destination (OD) matrix:** This is a matrix where each cell represents the number of trips from the origin (row) to the destination (column). It is used to build the transport service offer. For example, daily home-work journeys are part of this matrix. PTOs and PTAs are conducting manual surveys to build static OD matrices. However, new technologies can allow digital and dynamic matrices.
- **Flows of people:** Increasing numbers of stations, networks and vehicles are equipped with sensors for measuring flows of passengers, thus allowing demand management features. Such technologies have been fully deployed in retail and advertising sectors; public transport could also benefit from the latest solutions, based on benchmarks and use cases.

UNDERSTANDING THE PASSENGER FLOW TO INFLUENCE

Understanding passenger behaviour improves understanding of its impact and correlation with other transport activities, such as operations, security and retail. This allows going further than current service levels and capabilities offered to passengers in the terminals to encourage the use of public transport.

Identifying ambiguous information by applying big data management techniques helps improve the detection of hidden trends in diverse transport activities. In addition to existing operational evidence, these new trends will provide the public transport sector a new direction for growth via the identification of passenger behavioural patterns.

Based on historical data, business analytics algorithms allow passenger descriptive models to be defined. Combining these models with transport traffic schedules for a specific period, will enable the prediction of:

- When each type of passenger (business, economy, groups, etc.) will be arriving at the station or transport hub.
- How they will continue their journeys.

Access to such passenger demand forecasting tools seems likely to enhance decision-making processes that will improve oversight and aid management of all infrastructure resources and interlinked services.

In addition, by acquiring new insights into how passengers behave, it becomes possible to create new business models that leverage the data-driven decision making processes used in the retail sector. These could include predicting passenger preferences with customised offers and dynamic adaptation of marketing strategies based on passenger classification. Last, it is useful to be able identify each passenger and their individual movements in order to calculate OD matrices based on account management, smart ticketing, gates, and other systems.

SMOOTH AND COMFORTABLE PASSENGER MOBILITY

For health reasons, many people avoid touching surfaces due to the perceived risk that they are being exposed to infections and viruses. And yet, this poses challenges for passengers when travelling in busy vehicles. In this scenario, automating as many passenger processes as possible will be vital in helping passenger confidence and therefore recovering passenger numbers.

© Martin Adams

HIGHLIGHTING THE CHALLENGES

Here are the challenges identified by UITP's Working Group on Passenger flow and crowd management

- Maintaining social distancing in bus/train and inside stations, particularly during the pandemic
- Managing occupancy versus requested thresholds
- Adapting the transport services to match demand
- Expanding to multimodal level
- Redirecting passenger flows to alternative routes to reduce congestion
- Limiting waiting and queuing times
- Analysing passenger flow patterns and behaviour when using transport systems
- Managing, optimising and adjusting access to passenger transport services when crowds become too dense
- Addressing the challenge of data-sharing interface - SIRI, GTFS and other formats validated by National Access Point, for example in Europe
- Integrating the differing flows of data and information to positively influence the passenger flow and crowd
- Choosing the right technical solutions for measuring fluctuating demand, evaluating potential return on investment and creating benchmarks for future capital spending
- Applying centrally managed big data models and artificial intelligence (AI) for advanced prediction of fluctuations and incidents in real time, and using decision-support systems to simulate and propose operational improvements
- Deploying collaborative platforms to improve coordination of transport services and to provide reliable and predictable information to passengers
- Reducing greenhouse gas emissions

TRAIN STATION CROWDING – TRANSPORT FOR NEW SOUTH WALES, SYDNEY

Transport for NSW (TfNSW) conducted a study in 2020 looking at the levels of crowding in train stations. TfNSW is responsible for setting the standard working timetable and Sydney Trains is responsible for operating and maintaining the metropolitan heavy rail passenger service.

Sydney Trains ridership increased by 34% in the past five years (2015-2020) and is expected to continue to grow over the coming 30 years. Owing to this increased ridership, more passengers were entering and exiting stations, moving between stations to change services and waiting on platforms. These factors were adversely affecting passenger comfort and train punctuality[1].

Sydney Trains did not implement any technological solution to measure the level of crowding. Instead, it had devolved responsibility for crowd management to Customer Area Managers, who relied on frontline Sydney Trains staff to understand how crowding affects individual stations. Identified busy stations on the network have developed Crowd Management Plans (CMPs). Sydney Trains reported that crowding at stations was the cause of 31 safety incidents between 2016-2019, with 14 of these resulting in an injury.

The study recommended that Sydney Trains should systematically collect information on the use of crowd management interventions at stations, and assess the impact of these interventions. Furthermore, both TfNSW and Sydney Trains should develop a direct performance measure for station crowding and collect data to assess its impact.

© Laura Cros

1 Source: NSW Auditor-General's Report to Parliament

DEMAND MODELLING: THE OPERATOR POINT OF VIEW

As with any public transport company, metro operators understand the importance of knowing and predicting the levels of demand. A study[2] by the Operations Subcommittee of the UITP Metro Division found that metros use a wide range of systems for data collection and for forecasting. Similarly, it found that different solutions are deployed to develop mobility models and to plan service offerings.

While no definitive solutions emerged, the study revealed that all operators agree that automation (reducing human intervention) is necessary to fully understand demand. Passenger-counting solutions used among the 15 metros that participated in the study included:

- Controls at entrances
- Train weight measurers
- Sensors at train doors and at station entrances
- Counting mats

Wi-Fi is also being tested by at least one operator to collect passenger flow information. Some operators recommend combining different systems. Weight sensors were deemed satisfactory by some operators when they compared the results obtained with manual counting.

Different operators use different software to simulate passenger numbers and movement on their networks (for example Visum-PTV, CUBE, MATSim or Legion), sometimes combining them. Similarly, different tools are used for service supply planning (for example, Austrics, Open Track, IVU suites, Excel-based and other internal tools).

A wide range of data can be introduced in models. These can include socio-economic data, pricing, passengers surveys, mobile phone communications, OD matrices, transport network as well as city and urban infrastructure maps. Estimated demand is updated to organise service supply, with different metros doing so at intervals ranging from once a month to once every two years.

The study also found that demand forecasting is managed by different departments in different operators, such as the marketing, sales, planning, statistics or infrastructure departments. Simulations and demand forecasting are sometimes left to the PTA[2].

OVERCOMING THE CHALLENGES

Overcoming these challenges requires certain capabilities to be introduced to public transport organisations in a prioritised, phased approach. For example, as the planning capability is critical, matching the regulation and adaptation of the transport services to the actual demand is essential. It is pivotal to have the capability on hand to monitor the overall system, the passenger flow on one hand, and the service capacity on the other.

Finally, having the capacity to inform PTOs/PTAs staff - and the passengers - at each stage of the process must be part of the solution. Further, PTOs/PTAs should achieve the following goals:

- Have a real-time vision of passenger congestion levels in the transport system
- See the evolution of passenger flow over time and predict short- and medium-term fluctuations
- Gather a full data history of supply and demand
- Interact with individuals and crowds to optimise and assist their movement in all types of public transport systems
- Implement secure crowd-management procedures
- Attract people through value-added services, to keep them temporarily in specific locations in order to avoid overcrowding bottlenecks in public transport services
- Manage the transport supply (multimodal, service disruptions)
- Gauge service demands
- Be prepared to take action before overcrowding incidents occur / automatic contingency planning
- Leverage data from different transport modes, meteorology and traffic management

2 This survey on demand modelling was led by Metro de Madrid. The other 14 participating operators were RTM (Marseille), Metro de Lisboa (Lisbon), MetrôRio (Rio de Janeiro), Hamburger Hochbahn (Hamburg), RATP (Paris), STIB-MIVB (Brussels), SPT (Glasgow), MVG (Munich), Metro Service (Copenhagen), STM (Montreal), Wiener Linien (Vienna), TMB (Barcelona), BVG (Berlin) and Moscow Metro. The study report is available on UITP MyLibrary.

TELECOMMUNICATION INFRASTRUCTURE (FIXED AND RADIO) FOR PASSENGER COUNTING

Digitalisation and connectivity provide the foundations for improving public transport operations. Focusing on the improvement of passenger flow and crowd management systems required a wired and/or wireless real-time communication infrastructure. Most of the elements must be digitally connected, and we can assume that there a multiservice IT network infrastructure in place and deployed, based on optical fibre rings and copper.

We should explore the application and purpose of complementary telecommunication technologies.

4G/5G MOBILE TELECOMMUNICATION

Public 4G GSM technology is largely deployed outdoors in and around public transport stations. It usually provides coverage in public areas as long as they are not situated too far below ground. We also see the increasing use of underground extensions of such services using radiant cables. However, these services are managed by telecom operators, so transport operators do not have sufficient access for analysis, and it becomes onerous to apply this a technology for managing flow controls or passenger counting processes. At this stage, it could only be used to transfer traffic information from mobile devices to control centres through cloud access.

We see increasing numbers of private 4G (LTE), as well as private 5G, initiatives through which transport operators would be able to have full access to relevant data. Here, however, it would be demanding for the general public to connect to these private networks, as it requires a particular private SIM card or new applications running on their devices to connect securely, and these are not available as yet. Building such networks purely for this specific demand would be excessive but could certainly provide additional services and applications to benefit from already deployed infrastructures.

© Victoriano Izquierdo

WI-FI

Wi-Fi technologies are deployed indoors and underground for both operational purposes and for passenger connectivity. Wi-Fi technology is evolving year-on-year, through improvements allowing support for higher bandwidths as well as wider and more robust signal ranges. Wi-Fi 6 and Wi-Fi 6E are currently deployed in numerous countries around the world.

Wi-Fi technology is renewed regularly - every five years - with new specifications and enhancements. Throughput is excellent thanks to Gigabit services, and availability and the coverage radius between 100 and 200 metres is high, with all terminals supporting natively in multiple frequencies. As smartphones and other IoT devices, as well as access points and other elements of the network architectures, evolve rapidly, transport operators must constantly monitor the evolution of technologies to be able to maximise their benefit.

IOT/ LORAWAN, ZIGBEE

LoRaWAN technology is designed to cover large open spaces with a low need for data exchange. In case of transport modes, such as trams and buses, it may be interesting to gather KPIs in real time, such as temperature, humidity and number of passengers. However, this technology is not deployed inside transport terminals, as currently it remains specific to industrial IoT applications supporting facility management purposes, such as metres, waste bins or lighting.

SENSING TECHNOLOGIES FOR PASSENGER COUNTING

The group investigated the various technologies that can help improve passenger counting and flow management processes. Ticketing, vehicle weight sensors or the counting of smartphones within an area are already providing valuable information about passenger flows; new technologies will allow more precise and dynamic measurement of passenger flows.

Here is a collection of viable technologies:

WITH BLE TECHNOLOGIES (3-8M) FOR PRESENCE

Bluetooth Low Energy (BLE) is a commonly available technology in smartphones and is increasingly used within the public transport industry. Thanks to this technology, we can detect the presence of smartphones passing by BLE beacons deployed in stations and transport hubs. The receiver's range is approximately 10 metres in diameter, depending on the number of beacons deployed. However, the accuracy is not relevant, as it is only required to count the quantity of mobile phones within a set zone. Counting mobile phones will be an accurate measure of the actual number of people in a specific area. However, people may carry more than one BLE-enabled device (connected watch, wearable, mobile, tablet etc) and that might undermine the accuracy of the numbers. As smartphones move with the individual passengers, they are detected by other beacons in the mesh. The advantage of this technology is that the beacons are passive, inexpensive, have a long battery life and do not require much maintenance. The technology uses a strong backend cloud management, which tracks and registers all devices under a single umbrella. The transmission of data is supported by all the connected mobiles (crowd sourcing).

Using the same technology, but with an active network infrastructure and people tracking, is extremely relevant; it is widely deployed in hospital environments. It could possibly be adapted in a more open area with millions of visitors - where individual tracking is not appropriate – as it would works well for measuring groups of anonymised people within a monitored location. This technology requires an investment in active asset tracking infrastructure, using people's mobile phones as moving tags. In this architecture, the network actively traces the mobile virtual tags.

Having the Bluetooth function always running on a smartphone is still not yet common. However, it is growing, due to the wider use of wireless headphones, smart watches and other wireless connected devices using standard BLE. The application can be automatically launched as and when required. Bluetooth sensors can be used to track passengers' journey and help building O-D information (anonymised). This has to be crossed-analysed with other data (such as counting devices) as not all passengers may have a device and some may have several.

WITH WI-FI (1M-10M ACCURACY) FOR CONNECTED SMARTPHONES

For indoor locations such as metro stations, Wi-Fi technology, mainly Wi-Fi 5, 6 and 6E, is highly efficient. Passengers usually have their Wi-Fi enabled on their smart phones. The use of Wi-Fi Real-time locating systems improve the indoor localisation of people, and it can capture the number of people present in certain areas, the direction in which they are moving and their precise location. Using this Wi-Fi technology, the terminal can be identified even if passengers are not connected to the internet, once again assuming the 'one-mobile-device-per-person' paradigm. A use case has been published by TfL in the UK discussing the application of this one-person technology in a large, complex urban metro lines environment.

The combination of both Wi-Fi and Bluetooth technologies is adding huge value for multiple applications, such as asset tracking (tracking location and entry/exit status of assets), people tracking (including trajectory). With the assistance of this technology, it is also possible to calculate customer arrival rates and residence times. Wi-Fi can be used to track passengers' journey and help build OD information (anonymised). It has to be crossed-analysed with other data (such as counting devices) as not all passengers have a device and some may have several.


© stnazkul

WITH CCTV

To accurately identify the distribution and congestion status of passengers onboard and passing though stations, state-of-the-art CCTV surveillance systems can monitor vehicle and station interiors of by collecting videos for real-time analysis with the support of onboard AI-powered computing power. Based on meticulously designed AI and deep learning algorithms, these surveillance systems can identify the passengers and can carry out the required calibrations and counting with an accuracy of well over 95%. Crowd measurement algorithms use head features (such as head shapes and hair colour) and overall crowd features to feed into the deep learning-based blurring algorithms, which adaptively learn blurring features for a large volume of differentiated samples. All this data can be dispatched to the vehicle drivers and to the remote surveillance teams at security centres via various routes, such as control screens and audio-visual alerting devices. This enables them to take the actions needed to improve control the flow of passengers embarking and disembarking public transport vehicles.

Existing traditional CCTV systems cannot be used for passengers counting or for detecting abnormal behaviour or abandoned objects, as adding data processing capabilities to existing camera and video recording systems is not feasible due to hardware and software constraints. The positioning and the field of view of existing traditional surveillance cameras would also significantly reduce the achieved precision.

However, when deploying new surveillance systems on vehicles or inside stations, it becomes a very viable option to switch to the latest CCTV systems with edge computing features, allowing both visual surveillance and AI-powered data processing. Such technologies are now more affordable and reliable than ever. CCTV analytics are particularly efficient for passenger congestion estimation in real time and for analytical purposes. For PTOs, it is practical to be aware of the real-time congestion levels inside the vehicle by having dedicated monitoring systems integrated with their traffic management and timetable planning platforms, increasing passenger safety and convenience. A typical example of such implementation is the indication to passengers waiting at bus stops or train platforms of occupancy levels of arriving vehicles. Such information can help inform their decisions on how to plan their onward journeys in a safer and more convenient way.

WITH TICKETING DATA

Ticketing data have been used by PTOs and PTAs to model and analyse ridership for a long time. The most common situation for bus, urban and regional train is to have access to check-in data (in a station or a vehicle) without the check-out, which means that we know how many passengers are entering, but not where exit.

Crossing ticketing data with other existing data (such as weight or CCTV) can help build passenger flow models and eventually monitor passenger flow in real time, as ticketing systems are being modernised and data become available on a real-time basis.

It has been demonstrated that with check-in ticketing and vehicle occupancy data, it is possible to build back dynamic OD matrices.

WITH WEIGHT SENSORS (ONBOARD)

Weight-sensors are commonly used in metro and regional trains, as they are already equipped with such sensors for adapting the acceleration and braking to the weight of the train. Using this information, you can obtain high precision with a limited investment. In addition, you can further reduce your investment by equipping only few trains with high precision counting sensors, use offline analytics to calibrate weight information and further use in real-time. It is a cost-effective way to monitor vehicles occupancy.

CASE STUDY FROM DSB – USING WEIGHT SENSORS

DSB (Danish State Railways) operate passenger train services on the country's national network. DSB developed a web application in house that provides statistical and real-time information for passengers and deployed in quickly. The data for this service comes from weight sensors. Using this web-based service, passengers use statistical information to determine when it is best to travel, as well as being able to check the position of vehicles and their occupancy in real time.

WITH INFRARED COUNTERS AT ENTRANCE DOORS

With growing requirements for precision, infrared (IR) passenger counting sensors are used to accurately detect passengers boarding and alighting in tight crowds. It is mainly used in the bus or tramway industries, in particular to detect fraud and decide where and when to send controls.

The new generation of sensors send out pulses in rapid succession using the invisible IR range; these are reflected by objects and detected by the sensor. The distance to the object is then calculated by taking the time between transmission and reception of the pulse (Time of Flight Technology or ToF). By using ToF technology, sensors can determine the height of the passengers, which allows the differentiation between adults and children. The information of the three-dimensional image of the door space can also be used to distinguish between wheelchairs, bicycles and luggage, which all have their own distinct silhouette. It provides a high precision counting and classifying passengers. This technology is increasingly used in driverless metro networks equipped with automatic doors at all stations.

WITH INFRARED LIGHT SOURCE

Public transport systems operating 24/7 require Automatic Passenger Counting (APC) and congestion status monitoring solutions capable of completing tasks during daylight and being able to present clear images in dark environments and at night. Some intelligent camera-based automated passenger counting systems can automatically switch to infrared mode, flexibly adjusting to different light conditions throughout the daily operations. Special glass and the latest optical design methods are being used in automatic passenger counting technologies in order to eliminate issues often encountered during the focal plane shift of visible light and infrared light. This special design and function allow APCs to operate 24/7 without refocusing, meaning the monitoring system can obtain clear imaging with the assistance of infrared light sources. Different APC technologies cater for a range of scenarios around the world.

The APC device uses ToF technology, achieving over 97% passenger counting accuracy. Other systems adopt 1080p HD cameras with built-in AI-powered 3D detection technology based on deep learning procedures. These can accurately recognise passengers, determine their in and out directions and precisely count them while embarking and disembarking public transport vehicles. APC systems can bring additional benefits by connecting them with open-close door signal detection.

WITH COUNTERS AT ENTRANCE DOORS TECHNOLOGY

Counters at entrance doors are well established applications in areas such as the retail environment. Traditionally, the technology has been based on infrared photocell sensors. These sensors have clear limitations in accuracy, as sensor-beam technology cannot differentiate between different objects, direction of movement and does not have reliable counting accuracy.

WITH SEATS SENSORS

Sensors can be installed under the seats to detect and calculate the number of seated passengers and optimise the distribution in the vehicle. This technology can work alongside other application, assist in counting passenger with reduced mobility or managing the 'one seat occupied one seat free' policy.

WITH INFRARED THERMOMETERS

Using infrared thermometers, it is possible to correlate the average temperature increase of a small area with the number of people inside.

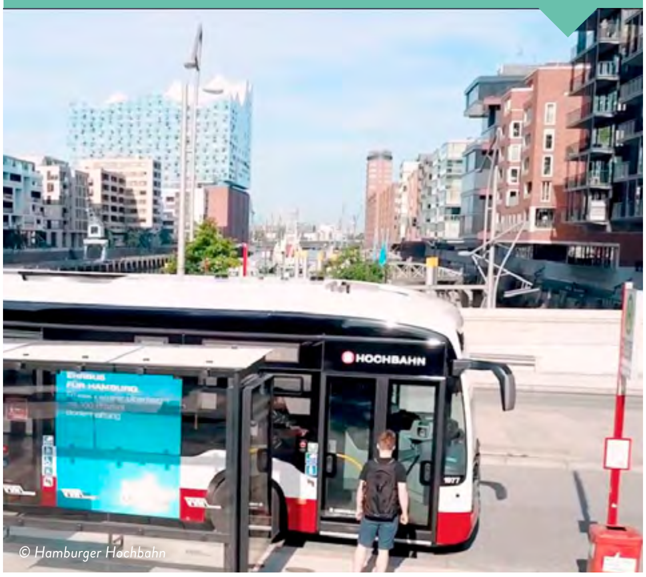
CASE STUDY FROM HAMBURGER HOCHBAHN - AUTOMATIC PASSENGER COUNTING SYSTEMS

Hamburger Hochbahn AG (HHA) operates the underground system and large parts of the bus system in Hamburg, Germany. HHA introduced crowd management using measurements from APCs on bus and metro vehicle in 2020. The system continuously helps the planning process, in areas such as calculation of passenger loads, adjustment of service/timetables and transfer of the adjusted timetables to the scheduling department.

It is possible to evaluate a substantial amount of APC measurements and compare the results (for example passenger load) with different schedules. Hastus Netplan and Rider provide crowd management for bus and metro. Both calculation of demand and adjustment of existing services can be done by a single system.

Hamburger Hochbahn can use planning tools with different views (maps, diagrams), management of data, combination of different schedules with several demand scenarios and different service levels.

The future plan includes building a single database (not only same software) with the scheduling department, interfaces with PTV Visum (demand model with OD matrices) and automation of data import (APC measurement).



© Hamburger Hochbahn

EXTERNAL SOURCES OF DATA

We could mention mobile apps, telecom data or MaaS resources as external sources of information, including travel searches engine, booking system.

- The MaaS operators could provide very useful information about mobility demand and shall be leveraged to build transport services. The main advantage of such data is the indication of future demand.
- Using mobile operator data at a large scale helps cities and regions to better understand the mobility demand, used for long-term planning.

Only a part of the demand is covered by those data, but when crossing with other precise occupancy data from each mode of transport, road traffic, using machine learning algorithms, one can generalise and provide a more precise prediction in short and medium term, monitoring and predicting mobility demand trends and fluctuations dynamically.

The challenge could be the access to such data as they are owned by all the different provider and are critical commercial data with many different formats.

© Dan Gold

FLOW ANALYTICS AND MANAGEMENT TECHNOLOGY

Customers with an APC system integrated with their ITCS (Intermodal Transport Control System) can utilise real time occupancy data of their fleet in many ways. The occupancy rate of a bus or train can be displayed for the dispatchers in the ITCS. This will allow them to react quickly if vehicles are getting close to the occupancy rate which the operator wants to accept.

In addition, this information can be fed into passenger information systems and displayed in real-time, which will allow passengers to take an educated decision on which bus or train they want to take. If used in route planning systems, occupancy data can also be used by the user to select/discard certain possible travel options due to their occupancy state. From the operator side, the data can be used to influence passenger behaviour (for example curtailing the already overcrowded travel options). For all purposes one must keep in mind that information on the actual occupancy situation is often only the first step.

REAL-TIME APC BASED WARNING FOR DISPATCHER UPON DEFINED THRESHOLD

An onboard computer will monitor, in real-time, which level of occupancy the vehicle is operating at using the calculated Number of Passengers On-Board (NBOP) value. The total capacity of the vehicle should be defined by at least two parameters – one is the number of seats available on the vehicle, the other is the number of standing passengers allowed. In addition, it is possible to oversee more detailed capacity and occupancy information such as spaces for wheelchairs, prams or bicycles.

Occupancy level thresholds (for example 0 %, 30 %, 50 %, 75 % and 100 %) are suggested as onboard computer parameters. Whenever the occupancy level changes, the onboard computer can automatically send a message to the central system to update the level change information. An extract of the information will be defined and published, or displayed to the public, according to the transport operator's policy for shaping passenger behaviour.

CASE STUDY FROM SHENZHEN EASTERN BUS GROUP - AUTOMATIC PASSENGER COUNTERS

In Shenzhen, around 6,000 P3 type APCs are installed on 3,000 electric buses operated by Shenzhen Eastern Bus Group. Passenger data will be used to improve bus dispatching, adjusting the service frequency according to real-time onboard congestion levels. The project was launched in June 2021 and installation was completed within three months (September 2021).

APCs interface with the Intelligent Transportation Platform - Shenzhen Eastern Bus Group's intelligent dispatch system - to manage its bus fleet. Furthermore, it was integrated with its IVY Bus platform, including the passenger data management and bus dispatching.

The key benefits were that all passenger data could be visualised via the IVY Bus platform based on station, trip, route and other parameters. Passenger data is used for bus dispatching and route optimisation.

There were two key challenges in the project. First, the high accuracy requirements of device performance and the data feed into the management platform. Second, high requirements on the platform side, with data management, including OD analysis, travelling distance, passenger data query, and passenger data integration.

The project is currently focusing on optimising the accuracy of OD data and the OD platform. In addition, it aims to achieve 100 percent passenger data usage on the bus dispatch and route optimisation.

© shenzhen bus group

THE STANDARD INTERFACE FOR REAL-TIME INFORMATION (SIRI-VM)

This interface allows the real time exchange of transport services and vehicles, including their occupancy, with third-party applications and mobile apps.

GENERAL TRANSIT FEED SPECIFICATION (GTFS) INTERFACE

A few months into the COVID-19 crisis, Google introduced occupancy information in GTFS format (the main format currently used by MaaS ecosystems). Public Transport Operators can provide the occupancy, in real-time, of each running vehicle, allowing the MaaS apps to provide the information to users. This kind of approach could help smooth the peaks (passengers who can change their travel timings would avoid crowding, and thus optimise public transport network capacity).

APC Data has tentatively been defined for GTFS and implemented.

Other interfaces: VDV 453/54, TRIAS (VDV 431), IoM (VDV 435), IBIS-IP (VDV 301), ITxPT

For GTFS occupancy, the number of spaces from data supply and the number of occupied spaces will be provided.

Occupancy status: Vehicle position also allows the operator to specify the degree of passenger occupancy for the vehicle. Occupancy status can be classed as follows:

- Empty
- Many seats available
- Few seats available
- Standing room only
- Crushed standing room only
- Full/Not accepting passengers

This field is still at an experimental stage, and subject to change. It may be formally adopted in the future

APPLICATIONS TO ENHANCE CROWD MANAGEMENT

MOBILE APP (MAAS + TRAVEL PARTNER/ COMPANION) ONBOARDING

Presenting the results of any calculation to passengers requires a robust user interface. This is the visible part of the iceberg, in the form of a map and an itinerary line to follow. This could be complemented with a voice assistant either inside stations or outside stations, to help guide the passenger. More and more MaaS platforms deliver such interfaces, as it is essential to transmit data using standard interfaces to platforms such as Google Maps, Citymapper, Whim, Uber, Splyt, Beeline or Smile Mobility.

TICKETING DATA/SYSTEMS

The retrieval of real-time occupancy data from a ticketing platform is feasible if the structure of the entire ticketing system is designed to allow access to such information:

- In a **closed ticketing system**, there are gated sections (stations in most cases, although sometimes also vehicles). Gates or turnstiles are opened only following presentation of a valid ticket. Thus, the number of ticket inspections and resulting 'gate open' events can be used directly for the real-time counting of passengers entering the gated area. Such 'gate open' events for passengers exiting can also be used to measure those leaving the designated area - provided that the ticket has to be re-presented to open the exit gate, or at least the exit gates count the number of passing persons.

- In an open ticketing system, entrance to stations and/or vehicles is technically not linked to a mandatory ticket inspection. Thus passengers may enter or leave an area without interacting with the ticketing system. In some cases, open systems have set rules for passengers having to check in or check out (for example, by presenting a contactless chipcard to a validator mounted near a bus entrance door). However - in contrast to closed systems - this rule cannot be enforced by technical means. Experience shows that this rule is only followed by a minority of passengers. Most of the time, season-ticket holders often decline, or simply forget, to check in or out within open systems, as they have a valid ticket independent of any check.

  As with open systems in general, we cannot assume that all passengers are counted by the ticketing transactions. Therefore, one potential approach is to use the number of ticketing transactions as a 'probe' i.e an estimation, which is used to calculate the total occupancy by application of correction factors based on historical data. On average, 10% of the customers buy single-trip tickets, thus the number of passengers boarding will be 10 times that of the number of single trip tickets sold. However, while this approach may be suitable for generating cumulative data (such as a whole day or a week), the variability to provide real-time occupancy monitoring.

  A special variant is 'Be-In/Be-Out', where the passenger is automatically registered during the stay in the vehicle by means of a special token combined with a radio surveillance technology that covers the entire vehicle interior (or the door areas). In principle, this eliminates the problem of forgotten or declined check in/check out. However, reliable counting information would require that at least a substantial number of known and stable number of passengers are using this technology, which has not been the case so far in all practical check in/out projects.

Another aspect of using ticketing data to calculate occupancy is the availability of real-time data:

- Many ticketing systems collect and store transaction data (sales, inspection, check in/check out and so forth) locally in the validator/ticket printer/vending machine. During certain cycles – daily, or even less frequently – the collected data is transferred to a backend system for further processing. While this is often sufficient for ticketing purposes such as sales statistics or payment processing and reconciliation, it means that this kind of 'delayed' ticketing data is not available for online occupancy data generation; instead, it is only for offline purposes such as statistical occupancy analysis.

CASE STUDY FROM METRO DE MADRID - DEMAND MODELLING FROM OD MATRICES

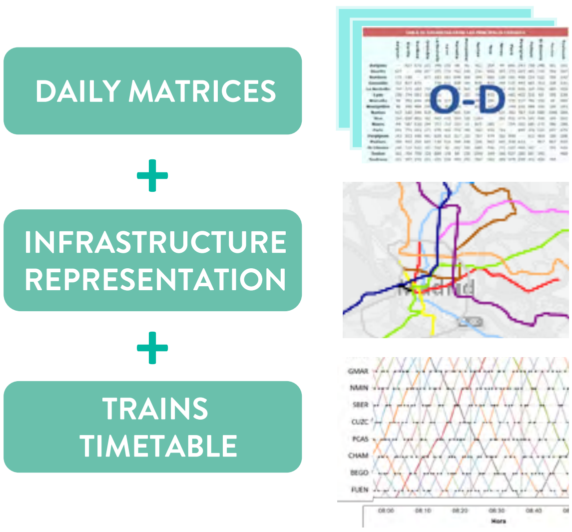
Metro de Madrid implemented a Demand Modelling system with OD matrices in 2018. This involves a three-step process from ticketing sales registers, through matrix generation algorithms to passengers estimated load onboard trains. Its main purpose is to model passenger flow. Crowd management is a side subsystem.

The system works on metro IT legacy systems and new powerful database tools. However, the agency developed an in-house solution using python and also used VISUM and Cloudera. Via the VISUM process assignment, rough entries to the network are transformed into train estimates load.

The main purpose is to identify and calculate the maximum load sections on each line in order to elaborate and optimise train schedule.

Other processes, departments and also benefit from modelling products:

- Distribution of passengers during the day at station. Useful for planning maintenance priorities and adapting advertising fees.
- Entry limitation and crowd management at the station.
- Passengers are also end users of some derived features published on the web and mobile interfaces.



© Metro de Madrid

- Other ticketing systems have permanent online connectivity between field systems (point of sales, acceptance terminals) and the fare management backend systems, immediately transferring every transaction. This applies for ID-based and account-based ticketing schemes. In this case, the ticketing data would be also available for online occupancy data generation.

BIOMETRIC ENROLMENT SYSTEMS

Biometric identification will facilitate the whole passenger process, by speeding up the digitalisation of public transport through passenger verification. On a certain level, it will reduce the physical interaction of passengers and will improve their comfort levels and experience, without obliging them to present any sort of travel documents.

Passengers' biometric features would be used during security checks, ticket validation and payments. This technology offers the following facilities:

- Automate passenger identification for any services
- Improve the accuracy of authentication and ticket validation
- Reduce passenger contacts with devices
- Increase security levels against fraud and identity theft
- Reduce operating costs
- Remove physical and payment barriers

Once passengers enrol in a biometric system via kiosks or their smartphones, they will be able to move smoothly through terminals and all other interconnected elements of the transport infrastructure.

This technology already exists and has been tested. However, the investment and the proportionate cost versus the cost per traditional ticket shows that it is not yet deployed cost-effectively. Privacy issues mean that it is only a feasible option for the public transport sector if it integrates relevant encryption methods.

NEED FOR ALGORITHMS, AI AND ANALYTICS

Big data processing and AI technologies are now available for serving Demand Management objectives:

- **Measuring and modelling passenger flows** and mobility demand in public transport networks in all dimension, including OD, density in vehicles and stations, modal share. In the short term, existing systems are already generating data modelling and monitoring in real-time, such as ticketing, CCTV, weight sensors, counting devices, MaaS apps and telecommunications systems. AI can help calibrate models with different sources of data and build a precise demand forecast. Train weight analysis, combined with ticketing data, could help build a precise model of passenger flows at the platforms. Journey planning can be used to monitor bus occupancy by calibrating with passenger counting data.
- As part of a longer-term vision, AI will help optimise the cost of deploying new sensors in transportation networks, with edge computing and data-based models.
- Developing advanced analytics for the operators and authorities to allow for **data-based decisions** in transport planning. In a rapidly changing world, understanding the mobility demand and comparing it with the existing available supply of sustainable transportation on offer is critical for providing the right services and for optimising investments. For example, root cause analysis and cross-sectional data methods will help solve frequent issues observed in the networks, such as unexpected flows of passengers and the resulting delays or service disruptions.
- Simulation techniques have been used to control the occupancy rate of trains and set a limit to 40% by regulating the number of entrance turnstiles available and through understanding passenger flow from buses.
- **Predicting** the evolution of future demand, enabling demand-based operations and multimodal integration are the main objectives of seeking to rationalise operational costs. Typically, this is done through decreasing the supply when the demand is below expected levels; and optimising passenger flow fluidity by increasing and adapting services when demand is above expected levels.
- **Machine Learning techniques** can offer precise predictions, 30 minutes in advance of the operator triggering the 'fail-to-board' indicator. This allows for the activation of specific operational actions, resulting in an 8% shorter waiting time for passengers.

- **Prescriptive algorithms** will provide real-time decision support features for PTOs to allow swift and efficient responses in the event of any incidents that may impact passengers or generate congestion, providing alternative solutions.
- Operational actions can be automatically activated based on predictive demand analytics and real-time adaptation of operational procedures.
- Application of **information to citizens/passengers:** one of the most important objectives of Demand Management is to provide the public with more reliable and detailed information, with the help of digital MaaS apps and passenger information displays. The passengers' expectations are very high: they seek powerful, interactive trip planners for understanding when and how to travel, for avoiding crow ded peak times and situations, for shortening journey times and cutting costs and for minimising their contribution to CO_2 emission reduction initiatives. AI techniques will assist in consolidating all types of information across the value chain.
- Processing information and present it to the MaaS apps users in a user-friendly way will promote public transport service use.

OCCUPANCY: COMBINATION OF REAL-TIME DATA AND HISTORICAL DATA

Passenger information systems:

Vehicles equipped with APC systems can determine the individual carload of public transport vehicles (both rail and road) and display this information to passengers waiting for the next vehicle at the next station. However, most of today's systems lack essential information to be able to accurately determine the available capacity, in that they cannot take into account that a reasonable number of passengers may get off at the next station, which may have a significant effect on the actual carload. In order to provide meaningful information to passengers, future systems must be able to accurately calculate the expected carload. In the case of metros, rather than displaying the actual status of the train capacity of the metro cars, the expected carload takes into consideration that a certain percentage of passengers will disembark at the next station, making additional space available for passengers waiting at the station as a result. Thus, the systems must collect real-time occupancy data from the vehicle and use historical data to predict the expected carload at the next station. This can be determined via the following steps:

© TMB

1) After the vehicle leaves station A, the passenger load and distribution inside the vehicle are calculated by the Onboard Unit (OBU), which immediately sends the data to the central monitoring unit.
2) In a subsequent step, the system deducts the number of passengers likely to leave the train at station B. To do so, the system uses the historical numbers of boarding passengers at station B from historical statistical data of a comparable day/daytime and deducts this percentage from the current carload.
3) As a result, the system can determine the expected spare capacity, which is sent to the platform of station B. Here, red-amber-green LED lights – similar to a traffic light system – will indicate spare capacity levels.

Driver information systems:

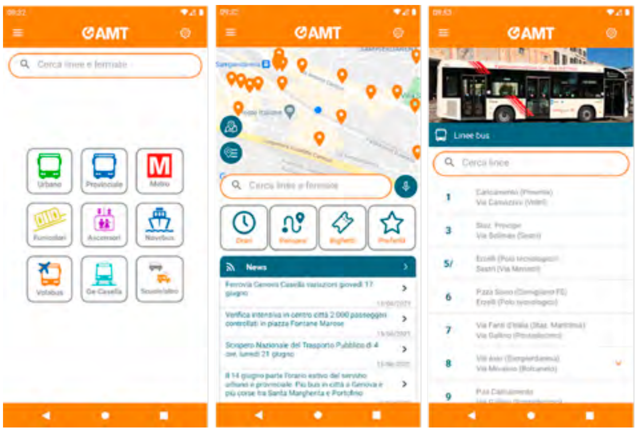
Through the continuous access to real-time passenger flow data and historical data, the system compares the number of passengers embarking and disembarking the vehicle by keeping track of the total number of passengers in real time. By comparing the real-time data with the pre-set passenger capacity level of the vehicle, different congestion level statuses can be indicated on the driver's control panel screen. The central monitoring platform interface can share the vehicle's passenger status in real time by showing colour-coded icons for the different congestion levels. A red icon displayed on the driver's screen indicates a vehicle is reaching its full capacity, therefore no further passengers should be allowed to board until some of the existing passengers disembark. It is useful for drivers and back-office managers to understand the real-time carload situation and to perform historical data queries. This will support more effective vehicle scheduling and improved timetable management processes. In addition, this type of occupancy level monitoring is also of great importance during the COVID-19 pandemic.

CASE STUDY FROM AMT GENOA – MONITORING CROWDING LEVELS

To ease mobility, AMT Genoa launched a trial of a congestion monitoring system on city buses in Genoa. The riders can see real-time information on congestion across the network and crowding levels on individual buses. Furthermore, AMT can constantly monitor the crowding level and location of vehicles and reconfigure their services accordingly to be able to meet passenger demand more accurately.

The new system was launched on 11 buses on Line 3 of the network, a route of 49 stops. The trial was conducted between June 2021 - March 2022, initially focused on the implementation of the web platform and analysis of the first data items, before being rolled out for use on passenger services.

The application works by collating data using the Si.Mon monitoring system developed by Leonardo, and providing operators with access to real-time information via a web platform. Hitachi is a technology partner for AMT Genoa.



DATA ELABORATION, AND CORRECTIONS WITH PREDICTIVE CAPABILITY

Having real-time information is critical for transport operators. Having historical data is another critical component of the equation, but the third such element is the capacity to have predictive information to hand, in order to be able to make the best possible response. Where a severe event – floods, storms, high winds – is likely to happen, it is crucial to have the ability to make accurate impact assessment. This can only be achieved through having supporting systems with predictive capabilities in place.

In most cases, what is really required is a prediction of the occupancy rate based on the actual occupancy. This is true for operations control and dispatching ("Will the capacity of the vehicle be sufficient for the rest of the trip?") as well as for the passenger ("Will there be a free seat in the vehicle that I want to board at the main station in 30 min?").

Today's APC systems record when, where, and how many passengers have embarked/disembarked which vehicle. However, one important predictive factor needs to be taken into consideration, given its significant impact on ridership behaviour - the weather in particular rain and/or snow.

Existing vehicles can easily and cost-effectively be retrofitted by simply connecting the current onboard computer to the windshield wiper to record its activity. By checking the intensity of wiper activity - high, medium, and low – it is possible to draw conclusions about the intensity of the rainfall. This means there is no need to install additional expensive rain sensors and the technology can easily be retrofitted to existing fleets, with a minimum of effort and disruption to the existing vehicle technology.

Recording the weather helps to provide a realistic ridership model, one which can be used to predict the number of passengers likely to use public transportation based on the forecasted weather. If heavy showers are expected, transport authorities may dispatch additional vehicles on the affected lines well ahead of time to meet the expected increase in demand.

Bad weather may also influence the on-time performance of a fleet. So, the « weather <-> on-time performance correlation » can further be used to enhance real time passenger information systems.

This way, transport authorities and operators can easily retrofit or expand their existing fleet into 'rolling weather stations' and improve their fleet management with improved prediction models.

Adapting Machine Learning techniques

In different vehicle congestion scenarios, people in wheelchairs are not accurately counted by the APC systems due to recognition issues. Extensive scanning through ample sources of data feeds into the deep-learning algorithm so as to improve the recognition process. In addition, the R&D specialist staff can also support the analysis and training of the algorithm through manual processes. Following the successful analysis of the scenes and scenarios of people sitting in wheelchairs, an update of the recognition algorithm can be released, and the APCs' firmware can be updated and rolled out as a new default feature.

The total volume of passenger flow during each trip is key data for bus operators, so it is essential to provide even more insightful and accurate data. By combining the passenger flow data with the current GPS information, this can further support the transit management strategy by improving the algorithm and provide complete journey data.

CASE STUDY FROM RHEIN-MAIN-VERKEHRSVERBUND - SMART ALGORITHMS

Using big data technology and self-learning models, vehicle occupancy is predicted based on trip planner requests and other data sources. Trip plans showing occupancy predictions as 'too high' will suggest alternative connections that have a lower estimated passenger count.

RMV (Rhein-Main-Verkehrsverbund) passengers planning their trip via the mobile website are able to see the predicted number of passengers along their route prior to departure. Trip plans showing occupancy predictions as 'too high' will suggest alternative connections with a lower estimated passenger count. The solution was provided in September 2020 and the corresponding software developed by HaCon together with Siemens Mobility.

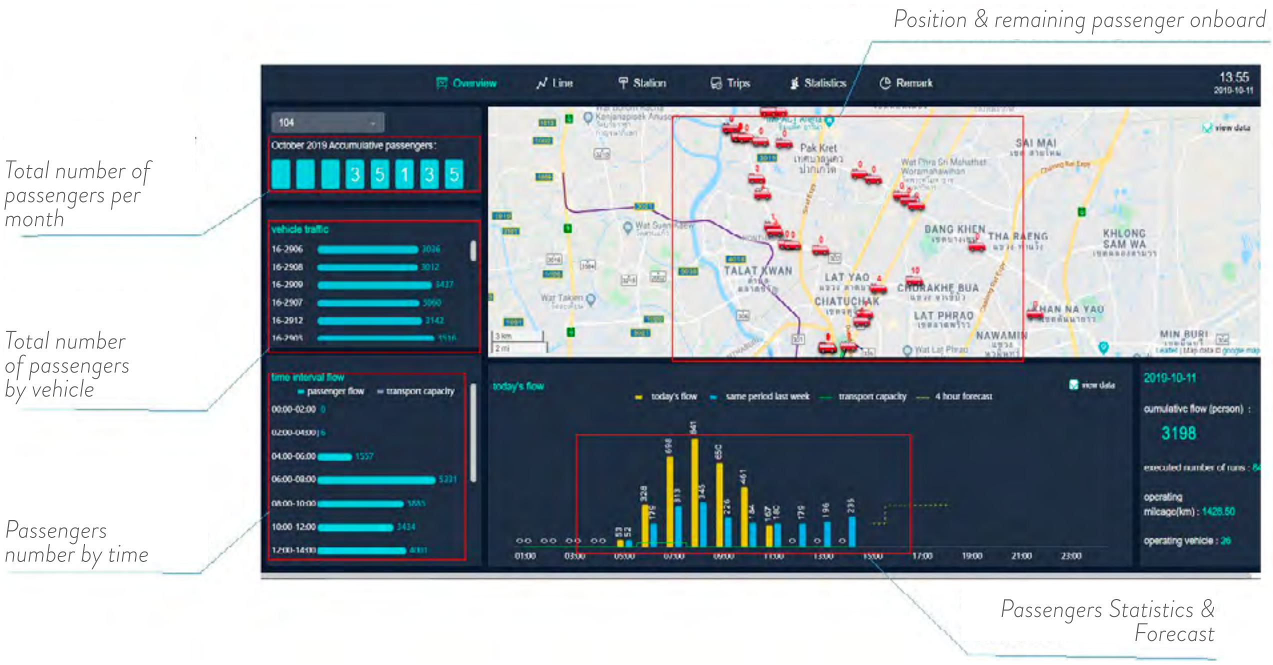
The occupancy forecast is based on the combination of connection requests from the RMV's trip planner as well as mobile ticket purchases. Data of counting systems is used to refine the model.

The lack of reservation data - typically easily available in long-distance transport - was overcome by applying big data technology on other data sources such as trip planner requests and ticketing data. In order to make these estimates more accurate, an additional calibration factor is created by using real counting data from the Frankfurt underground trains, trams, buses and the Rhein-Main S-Bahn. In addition, in its forecast the self-learning algorithm takes account of predictable external influences such as construction works and any major events.

The solution helps prevent crowds. This sets it apart from most crowd management systems, which act on existing crowds. Also, passengers are empowered to organise their journeys according to occupancy levels.

Predictive capability

The system can distinguish and count the passenger flow during both peak and off-peak times on weekdays, weekends, and holidays, thus supporting the presentation of passenger flow data covering the different time periods. The analysis of the passenger flow and capacity predictions, based on historic and real-time data, aids the operators in achieving greater efficiencies in transit management, timetables and vehicle capacity planning. The accumulation and iteration of historical data feeding into the machine learning algorithms can significantly increase the overall accuracy of AI decision-making assistance as part of the entire system.



Passenger Demand prediction and passenger behaviour based on business analytics of historical data

CASE STUDY FROM PANAMA METRO - REAL-TIME DEMAND MANAGEMENT

In 2019, the Panama City Metro Operator(MPSA), faced passenger saturation when opening a new line. Using real-time demand management and machine learning technics decreased the Fail-to-Board indicator by 50%, passengers gained an extra 8% travel time during peak hours along with a 6% increase in capacity optimisation. The solution was implemented by Alstom in 2019.

The solution assisted the MPSA in managing the COVID-19 situation as well, by helping avoid > 40% occupancy. The system applied processing and machine learning to existing data flows (ticketing and trains) without installing new sensors. The technology provider used the heterogenous data already produced by many systems, including ticketing, vehicle sensors (weight), Wi-Fi/Bluetooth/4G and CCTV.

Currently, the MPSA is implementing solutions for sharing information with the passengers (at the platform and on apps) to guide them into less-crowded timings (peak flattening). In addition, it is looking to integrate the bus system into the platform to achieve a multimodal approach.

PASSENGER INTERACTION AND COMMUNICATION SYSTEM

In order to influence passengers, it is important to reach them through different channels, adaptive signalling, voice communication (public address services), passenger information system on terminals, displays and application push 2 mobile.

Passenger communication is critical to the success of any transport operator with multiple integrated means for communication. Strong synchronisation between those methods is required in order to avoid conflicting information or passenger confusion. Measures include:

- Dedicated displays to show platform crowding early warning signals
- Dedicated onboard passenger information screen to display real-time vehicle occupancy
- Passenger information systems (PIS) through electronic displays
- PIS through audio voice messages
- Information systems, available through passenger applications, displaying time schedules and planners including scheduled incidents and reported incidents

CASE STUDY FROM JR EAST – JOURNEY PLANNER WITH IN-TRAIN CONGESTION MONITORING

JR East is one of the largest train operators in Japan, and has invested in the MaaS apps – JR East app and Ringo Pass. JR East has launched the 'Route Search with In-train Congestion Monitoring' pilot for a limited time starting in April 2022. This adds a function that allows users to see the in-train congestion on some of the routes displayed in the search results. This allows the riders to see the congestion status of the train they are about to board and when the congestion status is likely to change significantly after boarding, along with the results of the route search. A total of 23 routes in the Tokyo metropolitan area will be covered by this service.

The conventional 'real-time route search' search results screen, which reflects train delays, has been replaced by the 'predictive route search' search results screen, which reflects train delays. This service displays in-train congestion information obtained from the last 30 weekdays, Saturdays and Sundays. The data is calculated using congestion data for weekends and holidays and is updated daily.

CASE STUDY FROM SANTIAGO METRO – DIGITAL SCREEN SHOWING TRAIN CAR OCCUPANCY

Santiago Metro installed dynamic screens in Line 6 & Line 3 show train cars occupancy in real time. These screens are located on the platforms and provide relevant information such as the arrival time of the next two trains, their destination, the next combination station and a summary map showing the level of occupancy of the cars. A red light indicates full, orange shows medium density and green a low number of passengers.

This colour code indication is produced by gathering real-time data of load weight reported by each car. With this information - and assuming an average passenger weight of 76 kilos - the system is capable of estimating the number of passengers on board. The colour codes can be adjusted using the maximum train loading or other criteria, such as meeting COVID-19 social distancing measures.

Through having access to this information in advance, users can decide whether to move along the platform before the train arrives and forming lines for the most suitable car based on their priorities, be it comfort or social distancing.

Increasingly, this content is now added to the OpenData for other mobility actors to use. In order to improve this system, automation of the real-time information is critical so as to avoid human error. Cloud platforms appear as a better option for managing real-time automated information and interacting between multiple actors.

Guiding passengers is an important use case, as there is heavy demand from public transport operators and there are also considerable benefits to the passengers.

Lights on the platform or on the cars that show the crowded sections of the approaching vehicle via red, amber and green lights is an interesting solution, although they do not give warning well in advance in order to allow passengers to amend their decisions. Displaying the congestion status of the following train on the platform screen doors would be more efficient.

As information is captured from multiple systems, it is probably more efficient to gather the information through a cloud-based data management application capable of selecting the most valid pieces of information to be pushed through the appropriate communication channels, such as voice messages, text messages, passenger information displays or colour code indicators. However, this will require significant CPU power or a degree of delay to compute and process the data. An alternative could be to have the information 'on demand', pooling the data in real time to process and communicate the most accurate information.

The data format standardisation is becoming increasingly important, as is the availability of open API through the cloud, to allow smart applications to access the relevant data. Using open communication standards such as WEB RTC will be critical to encouraging the wider deployment of such contextually enriched communication.

PEOPLE FLOW SUPERVISION SYSTEM

A People Flow Supervision System is an integrated framework for supporting decision making through different processes, by using passenger flow information collected from a range of sources and from events normally beyond the boundaries of public transport systems. The final objective is to increase the level of automation of the overall system and support operators in taking the most appropriate actions under the most complex scenarios through Decision Support and Artificial Intelligence. To do this, the overall integrated system must understand 'what's happening', using all relevant integrated information and propose the 'optimal solutions' using intelligent algorithms.

The People Flow Supervision System service helps transport operators comply with actual social distancing guidelines, thus easily controlling overcrowding and improving passenger flow and ensuring efficient and safe services for all. The congestion rate monitoring functionality can provide real-time assessment of the dynamics of passengers both inside stations and onboard vehicles. Information on station/vehicle crowding is sent to users - allowing them to choose their preferred mode of transport according to network congestion - and also to operators, to ensure more effective traffic management.

Real-time occupancy data received from field technologies are acquired, aggregated and analysed to generate real-time warnings as well as predictions to help improve management of passenger flows. The monitoring and controlling of people flows both onboard public transport vehicles and inside stations -through real-time visualisation, heat maps and video analytics - allow the prediction of congestion zones and the modelling of station layouts and traffic operations for safety and comfort assessment.

Operators can dynamically tailor transport capacities to demand, automatically adapting the timetable in response to real-time fluctuations. Optimal timetables are generated and trains can be operated automatically when passenger demand exceeds normal levels, switching from 'on-time operation' to 'on-demand operation'.

© Luis Quintero

THE BENEFITS IN PUBLIC TRANSPORT

The value of reliable information about passenger occupancy in the station environment can be clustered depending on the user of the information. It therefore needs to be remembered that the feasibility of these value propositions depends heavily on the technologies used and their respective data outputs.

One important user group for passenger occupancy information is employees of the city's operation control centre (OCC). Here, the station operator is responsible for supervising stations in the network and ensuring smooth operations at all times. Having reliable information on passenger numbers and the distribution of passengers within the network of stations strongly supports the decision-making process, particularly when unforeseen incidents occur and security measures must be taken in response.

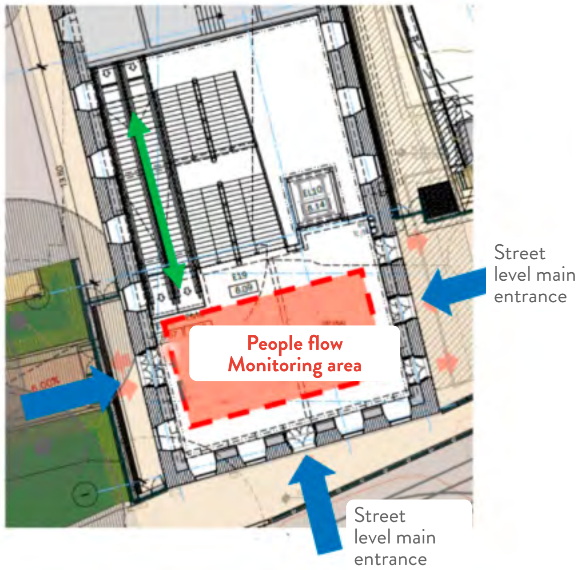
Security measures differ for every station environment, and the station operator is not always responsible for the overall security. Sometimes a third-party security agency or even the police fulfil this role, and in this event, it is their responsibility to keep monitoring passenger occupancy information.

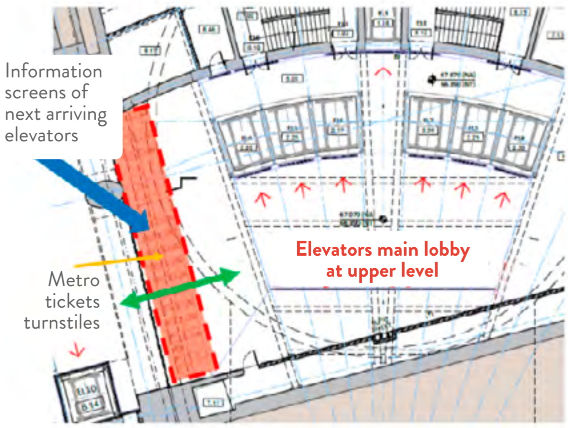
As operators receive automated real-time alerts as soon as certain thresholds are reached, they know which CCTV camera footage to inspect for the location of the detected incident, and if needed, security personnel can also be guided to the specific location. Moreover, announcements - live or as automated - can be made by the operator depending on specific alerts and locations. A further benefit of using the alerting system is the ability to optimise the use of gates, escalators, elevators or other equipment based on the actual occupancy levels.

CASE STUDY FROM LISBON METRO – SMART STATION

The Lisbon Metro (Metropolitano de Lisboa) is a rapid transit system operating four lines totalling 44.5 kilometres of routes and serving 56 stations. Lisbon Metro planned to install new system at stations, where passenger flow is transported with elevators from street level down c. 45m to the platform. The project will be implemented by KONE Corporation in Q1 2023 and will be completed by Q4 2023.

An automatic call management system will be implemented, where elevator dispatching is based on demand. Input for calls is provided by crowd detection system sensors installed at the station entrance. The system will learn the traffic patterns of the station according to the hour and day of week.





Elevator lobby is at one level down related to the street level

Demand is forecast based on previous weeks demand and traffic pattern. Vertical transportation is controlled via the demand signals. Systems will adapt and take into account exceptional events at the station in order to eliminate congestion.

Key benefits include conducting simulations to study different traffic situations prior to constructing the station, implementing automated transport capacity dispatching for peak traffic and understanding passenger indications and transport capacity management to avoid congestion.

Another role within the operation control centre is that of the line operator, who is responsible for certain lines within a city's public transport network. Informing line operators on passenger occupancy inside vehicles allows them to respond more quickly to accumulating congestion incidents and supports post-event analysis.

One vital user group for passenger occupancy information are the passengers themselves. For example, reliable real-time data on train car occupancies can be used as an effective guidance system on the platform, enabling passengers to use the carriages of incoming trains with the lowest occupancy. The most common method of transmitting this information is visualisation via Passenger Information Display Systems (PIDs). Another possibility is to visualise the information inside ticketing or other passenger apps/websites. Such accurate information will bring greater comfort during the passenger journey, generating loyalty and trust in the transport operator.

In addition, passenger occupancy information provides value to any stakeholders within the railway operator's organisation, who can optimise their processes with essential and reliable data about the station environment as a result. Historical data can be customised to any timeframe required, and automated reports can be exported focusing on specific data-metrics relations. Based on the analysis of passenger flows inside stations, business rates of commercial properties (shops, bars and restaurants) and fee structures of location-based advertisements can be adapted to better match demand and visibility.

With the use of machine learning and the base of the historical data, external data such as weather conditions, event schedules or any other station-specific factors, station and train occupancy can be predicted. This allows optimisation of train scheduling, the planning of rail replacement services, numbers of personnel and shifts or other resources, based on forecasted demand.

At the same time, it is important to note that realising these benefits will require some structural augmentation, such as greater transport capacity as well as mechanisms and processes to act on this capacity when demand prediction shows likely increases. However, as a result, public transport operations can be further enhanced by demonstrating qualitative, quantitative and serviceability improvements, and revenue streams boosted through the introduction of new services.

PRIVACY, CYBERSECURITY, CLOUD AS GLOBAL ISSUES

DYNAMIC MOSAIC TECHNOLOGY TO INCREASE PRIVACY

Personal privacy is frequently violated and leaked, resulting in unwanted nuisance messages, calls and emails. Regulatory bodies around the world are intensifying their efforts to protect the basic privacy of citizens, and the implementation and the adjustment of restrictions are continuously adopted by the latest GDPR policies averting any misuse of the personal privacy of the public in the video surveillance industry.

Driver status monitoring is becoming increasingly important in preventing dangerous driving behaviours and accidents in commercial vehicles. However, the intelligent driver-facing cameras are frequently perceived as invasive by drivers, and the related video recordings regularly raise questions of privacy protection.

In order to tackle these concerns, some market-leading system manufacturers have developed a dynamic mosaic system covering their devices, mobile applications, platform software, online platforms and SDK integrations in order to maximise the protection of facial privacy information. All facial information will be handled with a mosaic overlay filter applied, reducing the anxiety of drivers over their privacy protection. This feature can be further accompanied by double password and watermark features. These enhance the integrity and accuracy of data analysis of live and historical footage of incidents, as part of the authorisation, data access control measures applied throughout the evidence management process. These including customisable alarms and escalation procedures along with differentiated access at operator and administrator level. The overlayed dynamic mosaic masking can only be removed by administrators when so instructed by law enforcement agencies during investigations.

CYBERSECURITY

As soon as you start to connect different elements of the network, you open the door to threats. In the various elements of the system we cover, we add the connectivity of sensors, cameras, counters and IoT in general, in order to have real time information - hence the creation of cyber threats with possible intrusion, destruction or information theft.

The Zero Trust Network approach is a potentially good response to this, as disconnection is definitely not an option. Zero Trust security means that no one is trusted by default from inside or outside the network, and verification is required from everyone trying to gain access to resources on the network. Threats are both external and internal to the organisation. Most of the elements such as equipment and devices are in the open space and communication, being wireless signal, could be caught. The principle of the Zero Trust Network applies to people connecting to the network as well as IoT, CCTV camera or any device such as ticket machines. You behave within your network as you would in an airport; each person always needs to show their passport for verification; at the security check and at the boarding gate, whether you are a passenger, flying crew or airport employee.

In terms of the IT network, this means that - on top of the traditional segmentation based on virtual network - we encourage you to leverage the micro-segmentation, for example a CCTV camera cannot communicate to a vending machine. And a fire detection alarm cannot share its data with any business application to ensure fast action for emergency services in case of a fire alarm. This approach is important for all type of traffic and applications running on the entire network, whether wired or wireless. Technologies such as MACsec or encryption are commonly deployed. This policy needs to be applied all across the transport operating environment as it increasingly connects to the multiservice network. This means not only IT network but also IOT-connected devices such as CCTV and ticket machines.

LOCATION OF THE DATA, CLOUD OR 'ON PREMISES'

The location of the data, whether quantitative or qualitative - such as instant passenger counting, passenger movement, time and location of entering and leaving the transport network – should not impact the overall performance of the system, although it has some impact in term or costs and real-time processing. Either you have edge computing capability close to the data collection, or you have the capacity to collect and bring the data to the processing capability in real time. There are different types of data, those you need in real-time to instantly improve your system and those you collect and could store in a 'Data Lake' or data bank, such as for improving historical data and the prediction model. For example, the flow data could be stored locally on the OBUs or Mobile Digital Video Recorders. Operators can choose from two options for handling the accumulated data; on local storage devices or remotely in the cloud.

Locally stored passenger flow data can be accessed either by manually removing the encrypted local storage devices or copying the data to a removable SD card or USB device. It can then be viewed by authorised personnel via dedicated, securely encrypted monitoring software.

In the case of remote access, the data can be securely transferred and stored on proprietary cloud-based platforms via establishing secure channels (such as VPNs) between the on-board units and the servers, using 3G/4G/5G and/or WI-FI/VPN communication methods.

CONCLUSIONS REMARKS & FUTURE OUTLOOK

In developing this 'Improving the Passenger flow and crowd management with technology and innovation' paper, we had the opportunity to collaborate with several prominent manufacturers and transport operators, sharing different technologies, concepts and views from around the world to address the complex issues arising. We concluded that this is a vital topic, one that needs to be addressed by the wider industry. We shared a range of alternative solutions offered by leveraging existing and new technologies in progress, and we recognised the broadly associated non-technological issues: the human and organisational factors. The responsibility of dealing with such issues sits in different departments inside organisations; in marketing, operations, sales, demand management and - in some countries - even lie outside the PTOs remit, within the PTA. This aspect would certainly require closer scrutiny but it is currently excluded from the focus of this paper.

From the transport operator survey and feedback, it was also widely acknowledged that relying on a single type of technology would not ultimately solve the overall issue. Rather, a meticulously balanced combination of diverse technologies covering various aspects - such as real time counting and the application of historical and predictive models – would certainly address it more effectively. Removing human intervention as much as possible, becomes the principal target for improving the efficiency of the entire process.

The full mix of all the elements explored in this paper have not yet been fully deployed and used by any of the PTOs taking part in the recent transport operator survey. However, it is now clear that focusing on the various elements separately, such as displaying real-time vehicle occupancy to passengers before reaching the next station without the analysis of processed statistical forecast data, does not provide sufficient value. It is only when these elements are used in concert with simulation data that we could provide truly sensible solutions for passengers. All these aspects reveal enormous potential for the further development of innovative technologies. Close collaboration between industry stakeholders and PTOs can pave the way to even better solutions for our sector in the future, and we welcome the continuous innovation that will arise from combining many of these ingredients.

© Ryutaro Tsukata

This is an official Report of UITP, the International Association of Public Transport. UITP represents the interests of key players in the public transport sector. Its membership includes transport authorities, operators, both private and public, in all modes of collective passenger transport, and the industry. UITP addresses the economic, technical, organisation and management aspects of passenger transport, as well as the development of policy for mobility and public transport worldwide.

This Report was prepared by the UITP Information and Telecommunications Technology (ITT) and Information Technology and Innovation (ITI) Committees. For more information, you can contact Jaspal Singh (jaspal.singh@uitp.org) / Efe Usanmaz (efe.usanmaz@uitp.org)

UITP ADVANCING PUBLIC TRANSPORT

OCTOBER | 2022

Rue Sainte-Marie 6, B-1080 Brussels, Belgium |
Tel +32 (0)2 673 61 00 | Fax +32 (0)2 660 10 72 | info@uitp.org | www.uitp.org