KNOWLEDGE BRIEF

INVESTING IN TECHNOLOGIES FOR PASSENGER FLOW AND CROWD MANAGEMENT

MAY | 2024

INTRODUCTION

Continuing from the previous report "Improving passenger flow and crowd management: Through technology and innovation", published in October 2022, this knowledge brief presents the next phase of our research.

The interest for more insight in this key field has motivated us to explore it further. We have discovered that we need to balance various technologies, such as real-time tracking and historical and predictive models, to minimise human intervention and streamline processes. The solutions arise when these components work together with simulation data. We encourage more collaboration between industry stakeholders and public transport operators (PTOs) to refine solutions for the future, using the combined power of technology, expertise, and experience. The International Association of Public Transport (UITP) expects continuous innovation to come from this cooperation, which will, in turn, create a more efficient and passenger-oriented future.

This brief is accompanied by an annex that showcases use cases and technologies on passenger guidance, which can be accessed through the UITP My Library platform.


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BUSINESS CASE: EXPLORING THE BENEFITS OF MANAGING PASSENGER FLOW

Why should one investigate passenger flow (PF), including all existing and potential services, explore potential business models and contracts to finance the PF system, and define the right key performance indicators (KPIs), focusing on technological, information technology (IT), and telecommunications aspects?

HIGHER SERVICE QUALITY AND INCREASED EFFICIENCY

Investigating passenger flow is key to aligning capacity and operational costs with the travel demand. With growing pressure on the availability of drivers, subsidies, and fare revenue, optimal resource use is very important.

Before the 2019 coronavirus disease (COVID-19) pandemic, passenger flow was often analysed for weekend days, weekdays, and holidays across several seasons. The demand across the day consisted of several periods, such as morning peak, off-peak, evening peak, evening, and late night.

Since the pandemic, travel demand has become more variable and therefore requires better evaluation and analysis. For example, Mondays and Fridays have significantly lower travel demand, weekend travel has increased, and peaks have been smoothed out across the day. Moreover, downtown business districts attract fewer riders, whereas people travel more frequently across cities from suburb to suburb. This all results in a new distribution of resources across the network.

Riders now expect better services more aligned with their needs, i.e. shorter wait times and travel duration, greater comfort, fewer connections, constant connectivity to work, and access to media content while travelling. Accessibility and equity have now become the highest priorities in service design.

In cities across the globe, a collective realisation has emerged: a fundamental shift in mobility practices is essential. The transition away from motorised private transport toward environmentally friendly alternatives is imperative. Urban rail systems stand as a pillar in this transformation. However, accommodating the surge in mobility demand often necessitates substantial investments and considerable time. Infrastructure adaptation, such as expanding networks, increasing vehicle capacity, or adding more trips, requires financial commitment and planning. To address immediate capacity needs, optimising existing resources is crucial. Dynamic pricing strategies can incentivise travel during periods of lower demand, making it financially attractive for passengers. Furthermore, skilful passenger routing plays a vital role in enhancing service quality. Distributing passenger loads across alternative routes or within individual trains ensures efficient utilisation of available space. It is not uncommon for certain train cars to reach capacity while others have vacant seats, leading to passenger frustration and train delays. Providing targeted information to passengers about optimal distribution benefits all stakeholders. Accurate real-time PF data is essential for effective guidance. Realistic forecasts and up-to-date information are more useful than long-term averages. As cities continue to evolve, urban rail systems will remain at the forefront of sustainable mobility solutions, fostering a greener and more efficient future.

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Flattening demand peaks (influencing demand to meet capacity)

Public transport (PT) networks face a delicate balancing act: meeting peak hour demand while ensuring passenger comfort. During peak periods, the system often operates at maximum capacity, causing frustration among commuters. However, outside the rush hour period, the utilisation drops significantly, with unused capacity hovering around 80 percent.

To address this, dynamic pricing incentives should be considered during low-demand times, especially in metro networks. Positive feedback from such strategies encourages smoother distribution of passenger flow. But it is not just about monitoring demand; effective ticketing mechanisms and technologies also play a crucial role.

Public awareness campaigns can nudge commuters toward better choices. Imagine informing passengers at station entrances that seats were available just minutes before or after the train arrived — a subtle nudge to shift travel times. Furthermore, engaging in discussions with employers to adapt working hours and introduce more flexible work practices can further optimise PT capacity and enhance the overall commuting experience (the nudge approach).

Moreover, it is also possible to make direct adjustments to the service; new technologies and data are now available, allowing operators to forecast expected demand with high accuracy, even on short notice. This enables, for example, operating capacity dynamically to better match real demand and reducing unused capacity. It is important to adopt tools and processes that enable real-time responsiveness, in order to decrease operational costs and improve user perception of services.

CARBON FOOTPRINT IMPROVEMENT

Passenger flow and crowd management (PFCM) in public transport is crucial for reducing carbon emissions. The effect is two-fold: it directly improves energy efficiency while indirectly increasing the attractiveness of PT. This directly aligns with global sustainability goals and appeals to PT stakeholders for increased operational efficiency and environmental stewardship.

Initial measurement

Measuring PT's carbon footprint per passenger is crucial for effective carbon emission reduction. The key metric, "metric tonnes of carbon per passenger (T)", provides insights into environmental impact. Initially, comprehensive data on total carbon emissions

and passenger numbers should be collected. Real-time monitoring and passenger counting can enable calculation of live carbon emissions per passenger. The system wide KPI "T of carbon per passenger" can guide efficiency and emission reduction strategies.

Modal shift thanks to better services that adapt capacity to align with demand

The objective of better PT service provision with a PF focus is to attract more people while decreasing the carbon footprint and to transform it into an advantage for the population, communicating it as a reason for choosing PT over private vehicles.

Better service provision focusing on PF can mean:

- Focusing on travel and wait times: making sure PT is competitive with cars in terms of travel times and parking options.
- Ensuring that passengers have a seat when riding on PT: undertaking planning with capacity and passenger demand in mind.
- Ensuring that services are well connected: minimising the inconvenience of long transfer times.
- Making services accessible for all: clearly communicating the accessibility options in the network.

Tailoring marketing campaigns and informational materials to showcase the environmental benefits, cost-efficiency, and convenience of PT can attract a broader audience and ultimately lead to a modal shift. Moreover, incorporating digital platforms and social media for targeted communication can help the sector reach a diverse range of users and spread awareness about the advantages of PT in reducing the overall carbon footprint.

RETURN ON INVESTMENT IN COMPLEMENTARY SERVICES FOR RETAIL AND ADVERTISING

PFCM solutions, which track people's movements, provide real-time data in order to gain an understanding of user behaviour. Analytics models yield insights and metrics, enhancing complementary services like advertising placement, retail shop rental, and directions to points of interest (POIs). This is crucial in large stations, where passengers often shop during transfers and waiting periods. By analysing PFs, walking speeds, and dwell times, railway stations can optimise their layouts, improve retail performance, and strategically price rental spaces. Real-time analytics at key entrances and platforms inform decision-making, ensuring efficient management of stations and connected services—taxi hailing and e-hailing, shared vehicle redistribution, and drop-off and pick-up areas.

PASSENGER FLOW IN TIMETABLING AND SCHEDULING PRACTICES

A timetable reflects the frequency of the service and incorporates the types of vehicles deployed on the routes. An optimised timetable not only ensures acceptable and predictable arrival, departure, and waiting times, but also travel comforts like connectivity between services and guaranteed seating.

Multimodal integration

One of the most important factors for PF and attracting passengers is to ensure that riders have the shortest possible travel times, with a minimum number of connections. In the case of many origin-destination combinations, passengers cannot reach their destination with a direct service.

PT planners need to design the services in such a way that they integrate multiple modes such as local buses and on-demand services, commuter buses/rail, and metro services.

Planning and scheduling tools can analyse travel demand and projected ridership and optimise timetables for the best possible service provision to riders, as well as operations.

Route optimisation for buses and transit oriented development

Route optimisation for buses and transit oriented development (ToD) are crucial to ensuring that PT services are available within walking distance while wait and travel times are competitive with those of car travel.

This means bus service planning needs to find a balance between covering as many people as possible, meaning more frequent stops and less direct routes, and travelling as fast as possible, meaning straight routes on corridors with fewer stops.

Figure 1. Planning and scheduling tools can optimise services across multiple modes (Courtesy of GIRO/HASTUS)

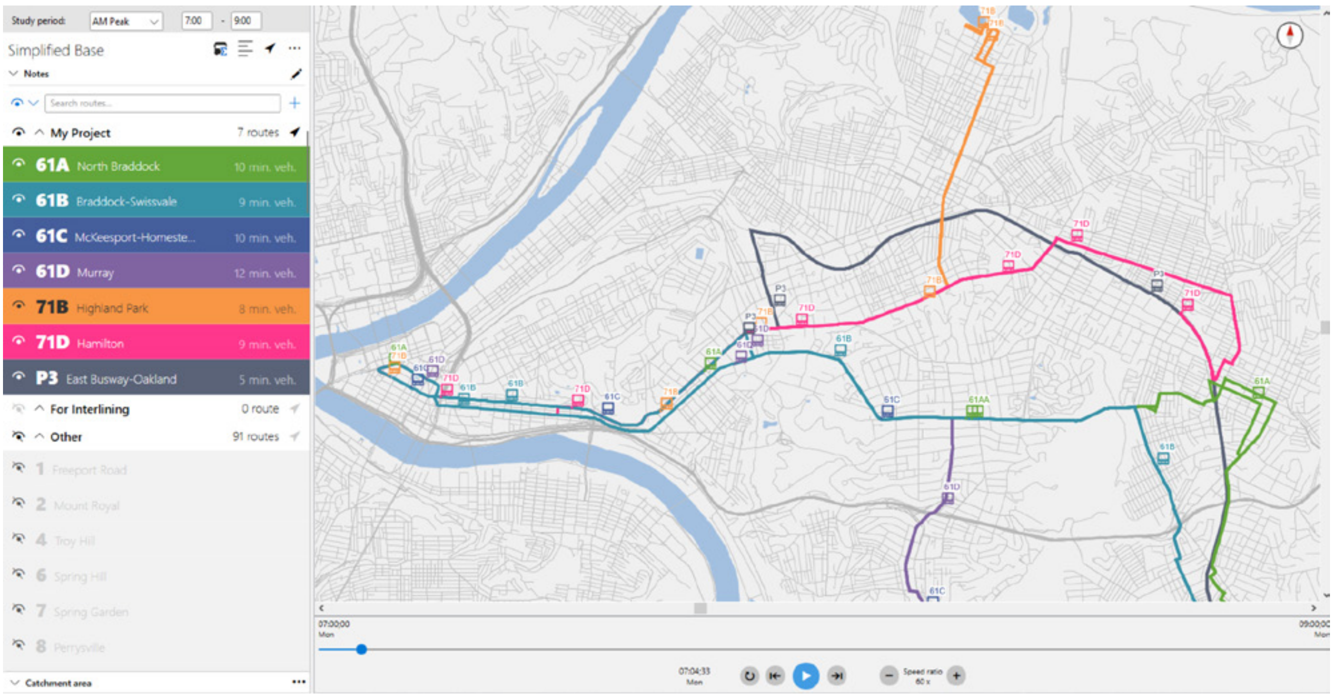
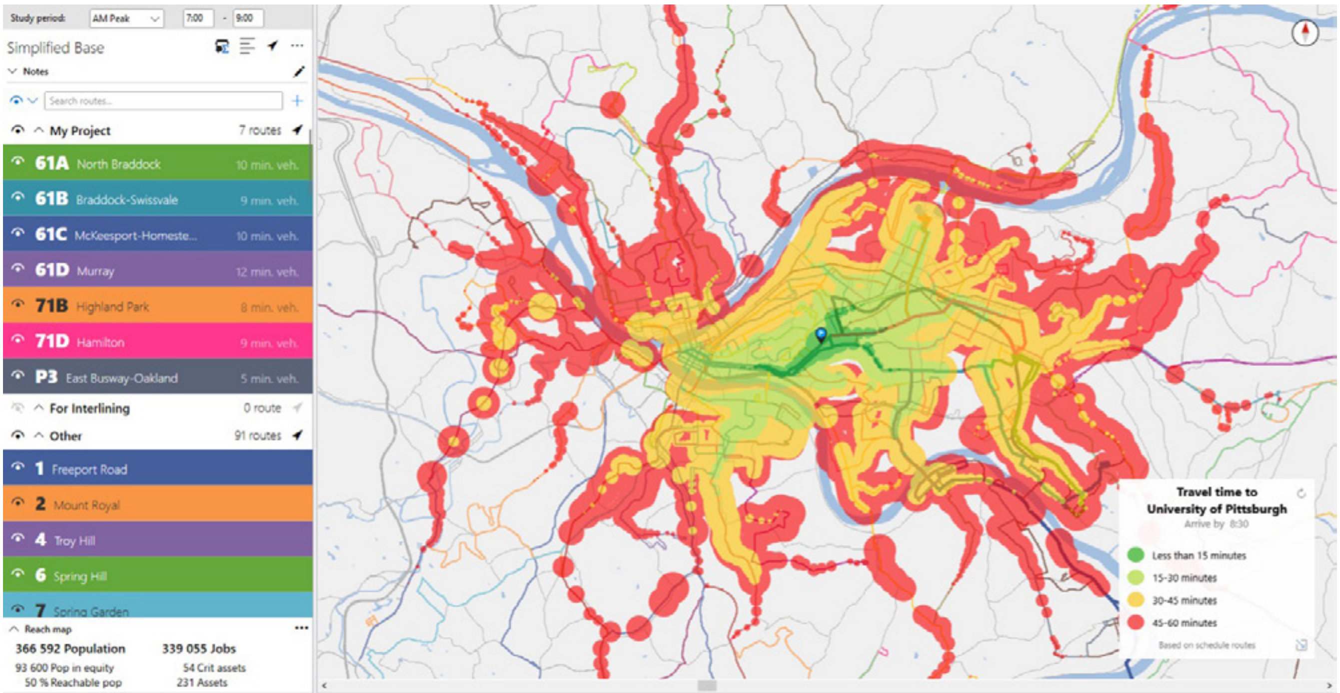


Figure 2. Planning and scheduling tools provide insights on coverage and travel times (Courtesy of GIRO/HASTUS)



Bus planning and scheduling applications can help planners make these complex decisions and show decision makers how the impacts align with the policies in place.

The most effective strategy to attract passengers and ensure attractive travel times is to support ToD, which entails building higher-density residential areas combined with well-connected work and recreational areas. The goal of ToD is to concentrate jobs, housing, and services around PT stations. Guidance on ToD can be found at various sources such as The World Bank (*link*), FTA (*link*), and ToD Institute (*link*).

OPTIMISED RESPONSES TO INCIDENTS AND EMERGENCIES

The competence of a PT operator is measured by passengers and authorities not only based on good operational scheduling, but also on incident management (both planned and unplanned). Here, we analyse the need for counting and redirecting passengers in both cases.

Service disruptions due to planned events

PT networks play a vital role in urban mobility, but disruptions—whether planned (maintenance, roadworks, etc.) or unforeseen (strikes, accidents, etc.)—can significantly impact service quality. These disruptions ultimately impact passenger experience and overall system attractiveness, especially when alternative options are scarce.

During peak traffic hours, disruptions can cause frustration and inconvenience. Precise data on the number of affected passengers are essential. Armed with this knowledge, transport authorities can devise strategies for attractive alternatives to bypass blocked sections. But it is not just about rerouting; optimising the events themselves is equally critical.

Construction work, for instance, must not disrupt an entire line throughout the day. Temporary solutions can be implemented during specific hours, minimising passenger inconvenience. Alternative services must prioritise speed, comfort, and capacity. Fast and seamless transfer connections can enhance the attractiveness of these alternatives.

Monitoring alternative routes is crucial. Collateral effects on other transport services and modes should be assessed. If no alternative routes exist, planning alternative transport (usually buses) becomes essential, varying based on the time of day. Extra attention must be paid to temporary terminal stations during disruptions, as they can accommodate a significantly higher number of passengers. Precise PF data and simulations can inform the development of secure accommodation solutions, addressing bottlenecks like stairs. Guidance personnel and the use of multiple alternative routes can enhance planning accuracy.

In summary, the more precise the data, the better the alternatives can be planned, ensuring smoother journeys for passengers and maintaining the resilience of PT systems.

Service disruptions due to unexpected incidents

When an incident occurs, disrupting services, it is important to know, as precisely as possible, how many passengers are currently already in the system and how many will enter it while the system is affected, to provide solutions to reroute and transfer passengers to alternative services.

In rare cases, spontaneous events can cause a train to stop between stations, resulting in trains having to be evacuated. In such a case, looking at the cameras, questioning drivers, and accessing data on average occupation or forecast data can be helpful, but these measures alone may not be sufficient. Real-time passenger data is essential for security services, fire brigades, and other rescue teams, as it enables them to effectively adapt their rescue and evacuation measures.

Generally, to manage incidents effectively in real-time, it is important to estimate their relevance with respect to the number of affected passengers and arrange for the most efficient mitigation measures, considering the additional effects these measures will have on all the travellers affected by the changes.

OPTIMISED OPERATIONS

Staff and rolling stock optimisation

Operators delivering services according to a strict timetable should not need counting systems in principle, but in reality, PT operations and maintenance (O&M) contracts are increasingly integrating ridership increase. Operators can and need to adapt and optimise their capacity to align with the dynamic demand.

Additional service deployment at peak times or for special events, based on existing PF data, is needed to deploy additional vehicles efficiently without creating unused overcapacities. For timetables based on service interval rather than departure time, services can be optimised by using the PF data to optimally meet demand, thus ensuring both passenger comfort and operational stability. If real-time PF data is available, it is possible to react to unforeseen peaks in demand. While reserve personnel must be available for driver-led trains, the reaction options in unattended train operation (UTO)/grade of automation 4 (GoA4) services are optimised based on the data, when trains are effectively stabled.

Staff deployment to address crowdedness

Many operators deploy staff to speed up passenger onboarding, especially during rush hour. The personnel are deployed based on experience to different locations at the same time even if they are only needed for a small part of their shift. Precise PF data can enable the operator to shift the personnel within their network to process the extra flow of passengers only when and where this is needed. In this way, it is also possible to adapt to the passenger fluctuations across the different days of the week. Real-time PF data will significantly reduce the reaction time and thus reduce crowdedness. Predictive data could also make it possible to position personnel before peaks or events occur.

PROVISION OF INFORMATION TO PASSENGERS

The attractiveness of PT strongly relies on the provision of reliable information to users before and during their journey. The information currently being provided to daily commuters is globally confusing and often not well-integrated, particularly in terms of real-time information when disruptions occur. The lack of reliable and transparent information threatens passengers' trust in and willingness to use PT regularly.

PF data and management can ensure information is provided to passengers to help them effectively plan their trips and avoid congestion and stations and vehicles with high occupancy, the latter being an issue often emphasised by people who decided to not use PT. Real-time data on occupancy, and especially forecasts of this, give even discerning people the opportunity to carry out their trips according to their individual preferences. This increases travel comfort and is therefore a decisive factor in enhancing the attractiveness of PT. More details on this can be found in the annex.

INTEGRATION OF CROWDEDNESS DATA INTO MULTIMODAL MOBILITY ECOSYSTEM

The integration of crowdedness information into the multimodal ecosystem works in two ways:

- Providing statistical, real-time, and predicted occupancy rates from each mobility system to the other operators and Mobility as a Service (MaaS) applications will help each public transport operator adjust their capacity to align with external demand, as well as enable citizens and passengers to access to crowdedness information and adapt their trips to their preferences in terms of comfort, leading to a flattening of the demand peaks.
- MaaS apps are gathering detailed information about passenger demand, particularly forecasts (trip planning is used in advance of the trips) and hidden demand (trips searched but not carried out with PT or shared mobility modes). In their agreements with MaaS providers, city governments are starting to include the need for sharing data, which represent a confidential and competitive value for the providers.

BUSINESS CASE: EXPLORING THE INVESTMENTS, INTEGRATION, AND OPERATIONS IN PASSENGER FLOW AND CROWD MANAGEMENT

DATA SOURCES

When considering what kind of solution to implement for PF management, it is important to choose an integrated platform that is infrastructure- and technology- agnostic, to ensure it can incorporate any type of sensor or existing data and interact with pre-existing service management tools to generate value.

A well-designed PFCM solution entails investments in time and resources for PTOs and public transport authorities (PTAs) that will deliver business value. These investments often include:

1) Crowd monitoring and queue management:

a. Installing cameras and sensors in stations and vehicles to monitor passenger movements.

b. Enhancing existing surveillance cameras for security/crowd monitoring.

c. Utilising digital signage and announcements to organise queues and maintain order during peak travel times.

d. Implementing algorithms and software solutions to predict PF trends and identify bottlenecks and congestion points, in order to allocate resources accordingly and optimise operations.

2) Smart ticketing systems:

a. Deploying contactless ticketing and payment systems (mobile apps, smart cards, be-in/be-out, etc.) to reduce queues and streamline passenger access.

b. Implementing technologies for touchless entry into vehicles.

c. Implementing modern fare gates and turnstile systems that can monitor and control PF while providing data for analysis.

d. Adjusting ticket prices based on demand to reduce peak-hour congestion.

3) Real-time passenger information:

a. Providing real-time updates through mobile apps, websites, and digital displays on crowdedness, routes, delays, and platform changes to help passengers plan their journeys and reduce congestion by suggesting transport alternatives.

b. Developing or enhancing apps and online platforms for passengers to plan their journeys, purchase tickets, and receive alerts, reducing the need for physical interaction.

Significant investments are required to improve infrastructure and connectivity. In this domain, the following aspects need to be considered:

1) Internet-of-things, digitisation, and connectivity:

Deploying integrated digitised infrastructure to enable the real-time communication of data collection devices across transport hubs and vehicles is essential. Using Internet of things (IoT) technology to connect these data-gathering devices to a central control system may require investment in network equipment and bandwidth. This will ensure that data is constantly updated and can be accessed remotely, while simultaneously reducing operational expenditure (OPEX).

2) Technology installation and maintenance:

When choosing between on-premise and cloud-based solutions, specific needs should be considered, such as scalability, data security, budget constraints, and IT expertise.

a. Cloud-based solutions: These solutions often provide cost savings in terms of initial capital expenditure (CAPEX), because there is no need to purchase and set up onsite hardware and infrastructure. Cloud service providers also handle infrastructure maintenance and updates. Moreover, cloud-based solutions can be easily scaled up or down as needed, making them cost-effective. Furthermore, storing and managing data in the cloud enables real-time access from different locations, making it easier to share information with relevant stakeholders.

b. On-premise solutions: These solutions may offer more control but require higher upfront investment in hardware, data centres, and infrastructure and ongoing operating and maintenance expenses.

3) Open data initiatives:

Transport operators may adopt open data policies, making certain non-sensitive data available to the public and third-party developers. This data can be used to create innovative crowd management apps and services.

4) Collaboration with local authorities:

Sharing data with local government authorities and emergency services should be done to ensure public safety and coordinate responses in the case of emergencies or crowd-related incidents.

5) Wi-Fi and mobile data networks:

Wi-Fi connectivity and improved mobile data coverage can be offered to passengers, which will enable them to get real-time updates and use mobile apps while in transit.

6) Data privacy and security:

The privacy and security of passenger data should be maintained through robust encryption and compliance with data protection regulations.

7) Feedback loops:

Passengers should be encouraged to voluntarily provide feedback and data through apps and surveys to gain insights into their experiences and preferences and areas that need improvement.

8) Social media and crowdsourcing:

Passengers can be encouraged to share their real-time experiences on social media, or this information can be captured through crowd-sourced data, to help identify congestion points and potential issues.

These investments aim to create a seamless and safe travel experience while optimising resources and reducing the impact of overcrowding. Moreover, they often leverage data and technology to adapt to changing conditions, such as special events or unexpected disruptions, to improve PFCM. It is advised to conduct a cost-benefit analysis and consider the long-term benefits, including improved safety and efficiency, when evaluating the investments in such systems.

SYSTEM INTEGRATION

Modern urban transport systems encompass intricate ecosystems, spanning planning to real-time monitoring, with all of them converging toward a cohesive framework. Integration, driven by data standardisation and open data sharing, yields advantages for operators, authorities, and passengers alike. Achieving this requires a multifaceted approach that covers technology, organisation, and strategy.

Capital injections are vital for establishing the necessary technological backbone for system integration. Standardising PFCM data benefits both users and transport providers. Well-crafted application programming interfaces (APIs) and system interfaces facilitate seamless integration and real-time data exchange, acting as bridges across systems. Alternatively, middleware can serve as centralised hubs. Scalable designs, adaptable to evolving tech and different needs, can accommodate additional features, data sources, and emerging standards.

Allocating resources to expertise acquisition, protocol formulation, and data transformation is essential. Software development, including passenger-centric applications and user-friendly interfaces, requires financial commitment. These investments, coupled with sensor and infrastructure costs, yield substantial returns, boosting efficiency, automation, passenger satisfaction, and sustainability. At the same time, they can foster informed decision-making, reduce PT's carbon footprint, and potentially enhance revenue streams.

DATA PROCESSING

Data models and algorithms

To create accurate prediction models, data must be constantly updated by skilled people. Then, the data coming from different sources, as explained previously, must be stored and processed according to the operator's requirement. Based on the data model, it can be enriched, and more complex algorithms, artificial intelligence (AI), and machine learning, used. It should be noted that the different data sources will constantly provide new data that need to be properly stored and secured. It is important that the system gets constant feedback from the field to compare the actual numbers with what is in the data model.

Generating predictive data

To get accurate occupancy rates, it is important to prioritise certain types of data at different points in the process. A passenger trip usually consists of three stages:

1) The passenger plans a trip in the near future.

At this stage, historical data will be the main type of data used for prediction; the system must find comparable trips from the statistical database.

2) The passenger waits at the station for the vehicle to arrive.

At this stage, the prediction model will use real-time data from the actual services deployed, including delays, vehicle size, weather, incidents, and/or accidents, and will be able to deduct the probable number of alighting passengers for an arriving vehicle at a particular station.

3) The passenger is in the vehicle and takes the actual trip.

At this stage, the system can forecast the expected vehicle load for the following stations based on statistical data, real-time data, and other external data (e.g. the number of passengers waiting at the next station or weather conditions).

3.3 Minimum investments

To implement a system with a basic prediction model, the minimum requirement is a statistical database containing historical data, from which the expected occupancy percentages can be generated and provided to passengers. For a vehicle fleet, this means that at least 25% of the vehicles should be equipped with an automatic passenger counting system. From the compiled data, the backend system can extrapolate the occupancy rates for the entire network.

Enhancing this statistical information with real-time data requires interfacing between the Intermodal Transport Control System (ITCS) system and the other data sources. A substantial cost factor is the communication interfaces between the different data sources. To reduce complexity and cost, the prediction software should import and export data via standard interfaces.

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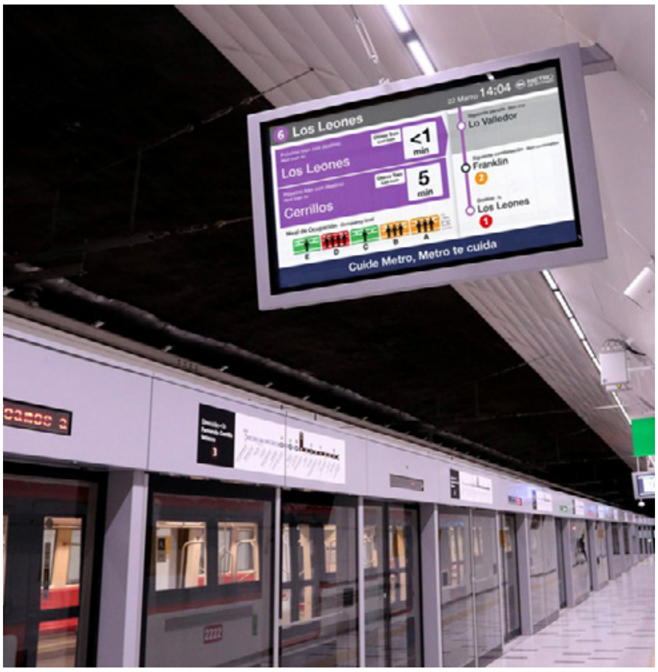


USE CASE: METRÔRIO

MetrôRio, a private company that operates Rio de Janeiro's metro system, prioritises data for operational and strategic decisions. Their investments span cutting-edge technologies like passenger counting, real-time information, and software development.

The ticketing system serves as their primary data source. This historical database informs customer behaviour analysis and ridership forecasts. It captures events impacting the metro, weather variations, and day-specific patterns (on working days, weekends, & holidays). These factors shape demand projections, train schedules, staff distribution, and commercial space valuation.

While historical data aids in efficient operational planning, MetrôRio is seeking new technologies for greater accuracy. Passenger counters in trains and stations, along with real-time information, will enable smoother journeys for passengers. Currently, they are exploring market solutions to construct an even more efficient data model and ultimately enhance operations and customer satisfaction. Through their continued focus on operational excellence, MetrôRio aims to provide reliable and efficient transport services to the city of Rio de Janeiro.

CHANGES NEEDED IN BUSINESS MODELS & FINANCING

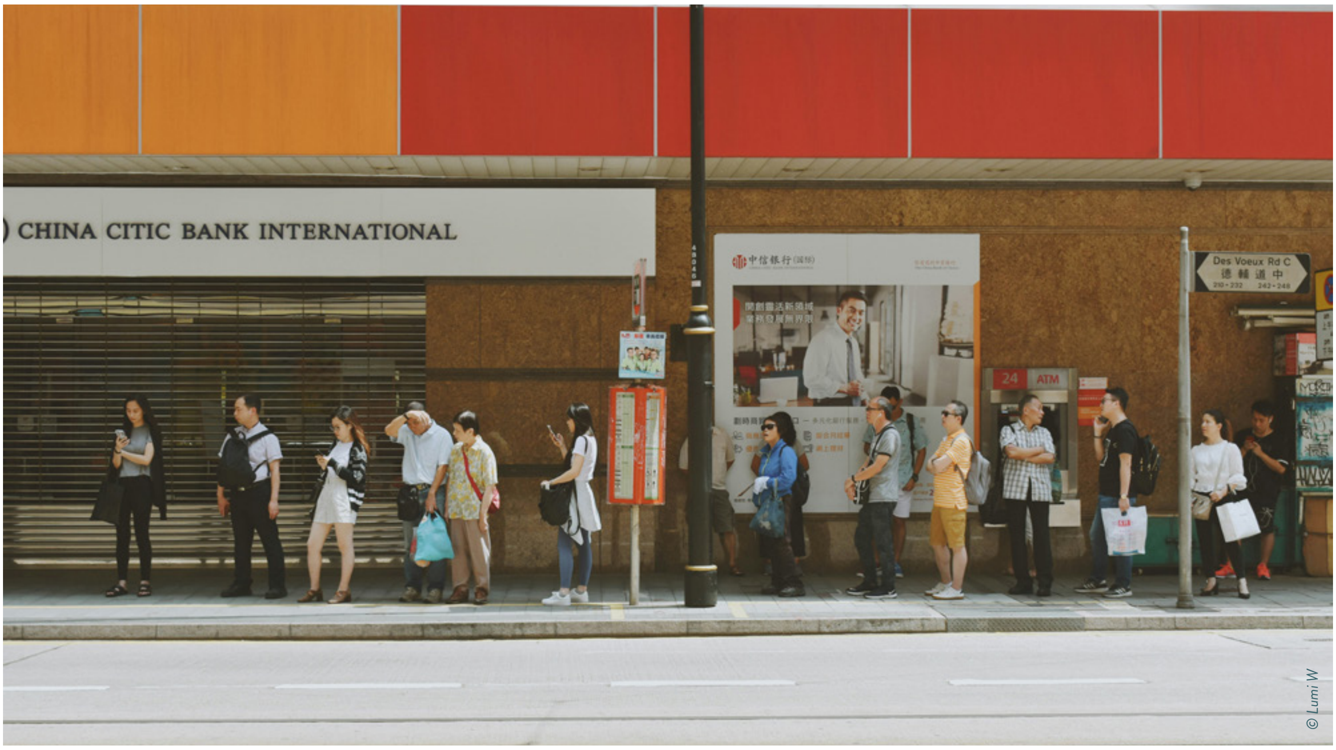
This paper addresses the critical need for measuring, modelling, and forecasting passenger flows in public transport. Key to these advancements is the shift from traditional hardware-based business models to software and services using cloud computing.

This shift brings several challenges:

- CAPEX vs. OPEX: Investments in services and software become more prominent than hardware, and there are continuous operational costs similar to when hiring system operation experts. Tender regulations need to be adapted to reflect this shift.
- Software as a Service (SaaS): Requires long-term contracts between operators, authorities, and service providers that include dynamic clauses that cover evolving technologies.
- Innovation: Rapid data technology evolution requires proactive experimentation, possibly through simulation platforms. Collaborative innovation frameworks, potentially led by organisations like UITP, are essential.

In public transport tenders, several key aspects should be considered:

- Selecting appropriate sensors, telecom, data flow, and integration systems, like counting sensors in vehicles and stations, based on current models.
- Establishing the right (potentially cloud-based) infrastructure for comprehensive, flexible data management, using iterative approaches due to evolving PF models.
- Promoting data sharing among stakeholders, from those who collect data to those who consume it.
- Increasing the emphasis on collecting ridership data. By deriving metrics related to ridership and service from this data, the focus of service contracts can be shifted towards meeting demand, rather than merely generating a predetermined capacity.
- Collaborating with organisations like UITP to structure innovation frameworks, leveraging simulation tools to test feasibility and operational value before making an investment.



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ARTIFICIAL INTELLIGENCE

AI technology is significantly improving public transport by offering novel solutions for PF management. Traditional AI effectively addresses counting, crowding, safety, security, preventive maintenance, and optimisation challenges by analysing and leveraging real-time data from transit network equipment and devices. These applications will continue to evolve, covering more aspects of transport operations and planning.

The breakthrough in generative AI, highlighted by the emergence of sophisticated large language models (LLMs) such as ChatGPT in late 2022, is set to transform passenger interaction. When properly integrated, these systems enable applications ranging from sensible text chats to customised verbal interfaces. And ChatGPT has only begun a race for smaller, personalised LLMs that will eventually fit into personal devices, in both closed and open-source approaches.

These advancements are leading the PT sector into a new era of interaction between transit data and passengers, going beyond instant information updates. LLM integration into personal devices will enable a system that understands and responds to passengers in a personalised manner, even adjusting to their preferred language, voice, and tone. This evolution will result in a PT system that is more responsive, efficient, and user-centred.

CONCLUSION

Throughout this paper's development, collaboration with PT stakeholders enriched our understanding. We hope you are convinced of the value in exploring and further developing PFCM systems, not as an overlay to existing systems, but, rather, as an integrated part of it. Our research has emphasised the pivotal role of data-driven decision-making and technological innovation in managing PF and crowd control. By embracing a diverse range of data sources from both mature and advanced technologies like cloud computing and AI, we can foster safer, more efficient, and more passenger-centric transport systems. These insights underscore the importance of prioritising technology investments to drive meaningful change, in line with the current level of digital transformation maturity.

Looking ahead, concerted efforts in innovation and collaboration will shape a new era of public transport experiences seamlessly integrated with and responsive to passengers' needs. This collaborative approach will ensure that urban mobility aligns with societal needs, environmental concerns, and technological advancements, thereby enhancing overall quality of life.

ANNEX

Passenger guidance: how to inform and guide passengers based on crowding level aligned with demand management (this document can be accessed via the UITP My Library app).

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This is an official Knowledge Brief 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 Knowledge Brief was prepared by
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