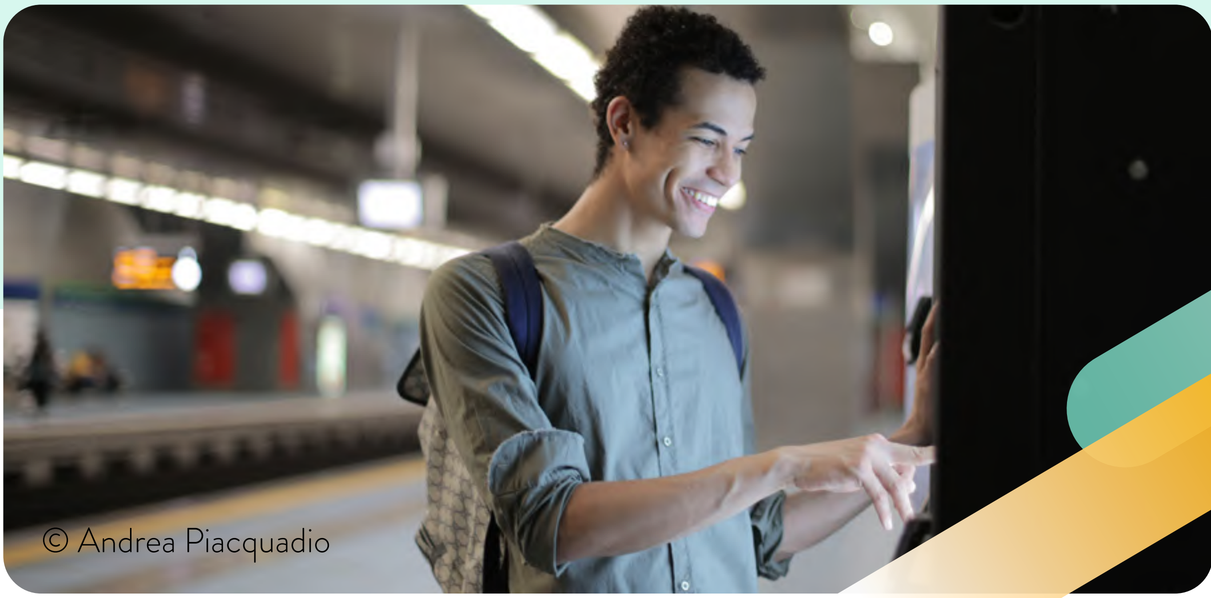
Insights

Ticketing & Payments in Public Transport

Beyond demystification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Technological advancement has helped systems evolve dramatically. However, things have gotten complicated for public transport operators (PTOs) and authorities (PTAs). The objective of this report is to demystify new innovations.

This 2026 update builds on the 2020 report. We continue to acknowledge with gratitude those who contributed to the original edition, while also thanking the additional experts whose insights have strengthened this version.

2020 Contributors:
Roberto Andreoli, ATM
Audrey Delavarenne, Wizway
Jarl Eliassen, Ruter
Stenio Franco, Idea Partners
Ralph Gambetta, Calypso Networks Association
Philippe Vappereau, Calypso Networks Association
Paul Gwynn, INIT
Klaus Janke, INIT
Helge Lorenz, TCAC
Nicole Louvat,
Wizway Lindsey Mancini, UITP
Johan Van Ieperen, PTV
Argo Verk, Ridango
Nils Zeino, VDV
René Zeller, HiTouch

2026 Contributors:
Filippo Logi, Siemens Mobility
Faheem Mirza, Hitachi Rail
Efe Usanmaz, UITP
Ralph Gambetta, Calypso Networks Association
Jean-Luc Van Ginder Deuren, STIB
Philippe Vappereau, Calypso Networks Association
Reto Schmid, FAIRTIQ
Andrea Soehnchen, UITP
Enrique Diego Bernardo, EMT Madrid
Peter Jensby Lange, MOVIA
Ellin Ivarsson, World Bank
Joanna Moody, World Bank
Dionisio González, UITP

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

Ticketing and Payments in Public Transport. Beyond demystification

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Introduction

Ticketing and payment systems are key elements of a public transport system. Ticketing exists due to the need to establish a contract between passengers and transport operators; ticketing is the gateway to mobility and the freedom for all to move about[1].

Technological advancement has helped ticketing systems evolve dramatically over recent decades. However, things have gotten complicated for public transport operators and authorities. Twenty years ago, it was just a matter of choosing the tariff scheme, the technology, the design of the system depending on passenger flows and the supplier (or the ticketing integrator that would deliver a turn-key system). Nowadays, the challenge starts with trying to understand about closed-loop versus open-loop, card-centric vs system-centric, pre-paid vs post-paid, account-based ticketing, open payment, national payment schemes, location-based ticketing, subscriber identity module (SIM)-centric mobile ticketing, Secure Element, host card emulation (HCE), interoperability, multiservice, beacons, near field communication (NFC), quick response (QR) codes, and so on.

The objective of this publication is to demystify these concepts by:

- → Clarifying the current landscape of ticketing and payment in public transport
- → Detailing the different technologies and solutions on the market
- → Describing the different systems and business models
- → Looking ahead to relevant emerging trends in the mobility sector and their impact on ticketing and payment for public transport operators and agencies.
- → The use cases will be provided separately as an annex to this report, as it is intended to be a 'live document' continuously fed with new use cases from UITP members. It will alsonclude use cases provided by the World Bank, thanks to the collaboration on the topic.

A brief history of public transport ticketing

From the 1950s to the late 1980s, single medium systems such as tokens, paper tickets or magnetic stripe tickets were generally used. During the 1990s, ticketing started a transformation process made possible by the emergence of new information and communication technologies (ICT) such as location services, real-time passenger information services as well as contactless smart cards. This technological revolution in ticketing significantly improved user experience and created a new era of marketing opportunities for public transport authorities (PTAs) and public transport operators (PTOs): contactless smart cards have supported a stronger relationship with customers, knowing them and better understanding their needs.

Well-known smart card schemes include Oyster (London), Octopus (Hong Kong SAR, China), Navigo (Paris), Suica (Japan), and Bilhete Único (São Paulo, Brazil). In these schemes, the travel information and the rights to travel are stored physically within a chip embedded in the card itself: memory size, microprocessor security and contactless performance are key to the success of this technology.

→ Leveraging common items carried by passengers or account-based ticketing are two prominent innovations.

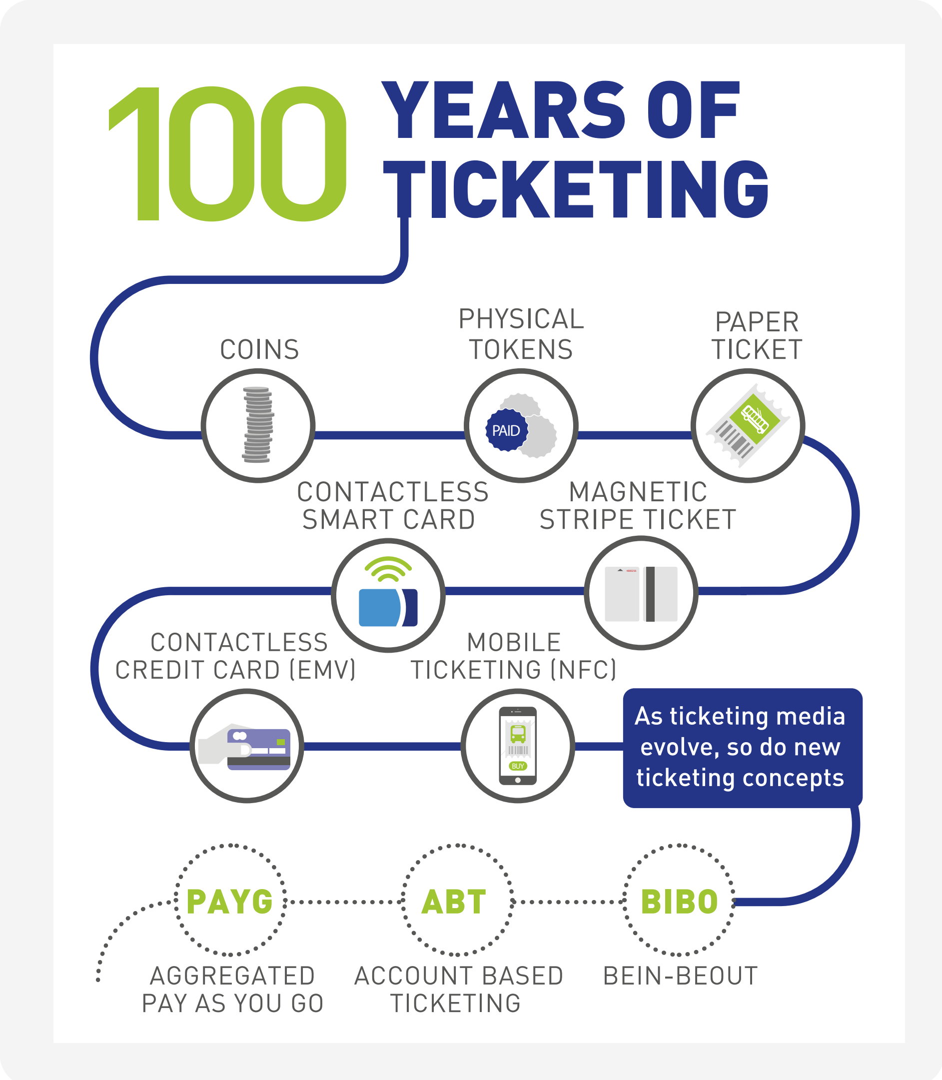
Thanks to rapidly changing telecommunication technologies, the next innovations centers around two main concepts:

→ Leveraging existing 'items' already in the traveller's pockets, ubiquitous enough not to be issued by the transport operator. The two main devices today are:
  - The contactless credit/debit cards: this is often referred to as 'Open Loop', as opposed to 'Closed Loop' systems, where a proprietary media must be acquired.
  - The smartphone which can be used in either a closed loop system (in which it emulates a transport card dematerialised) or for app-based mobile ticketing (pre-paid or post-paid).

→ The launch of 'account-based' ticketing (ABT) systems gives a greater degree of flexibility in terms of traveller convenience and operational performance. In a ABT system, transport rights are stored on a central system, not on a customer card. Software processing no longer takes place on front office equipment (e.g., validators, vending machines, ticketing inspection devices, or mobile phones) but on the central system instead. The customer 'device' becomes simply a means of identification where no data is stored.

There are also hybrid models, in which transport titles are stored on the central system, but validation data are registered in the card. Thus, the best of both media-based ticketing (MBT) and ABT are combined.

Interestingly, the whole spectrum of media and systems can be found simultaneously in the market. Technological innovation in ticketing does not necessarily lead to the most basic systems being made obsolete. Tokens, paper tickets and magnetic stripe tickets continue to be deployed and it will be many years before they are phased out. The same is true for contactless equipment or cards, as PTA investments are not yet written off. One innovation does not replace the previous one, and in fact, the smooth harmonisation, transition and integration of existing and new systems and technologies is often a key challenge for operators, which need to offer innovative solutions on the one hand, while at the same time maintaining their existing investments. Nevertheless, channel shift strategies provide potential to save cost, increase operational excellence and improve overall customer experience..



Source: UITP & Messe Karlsruhe for IT TRANS →

The current landscape

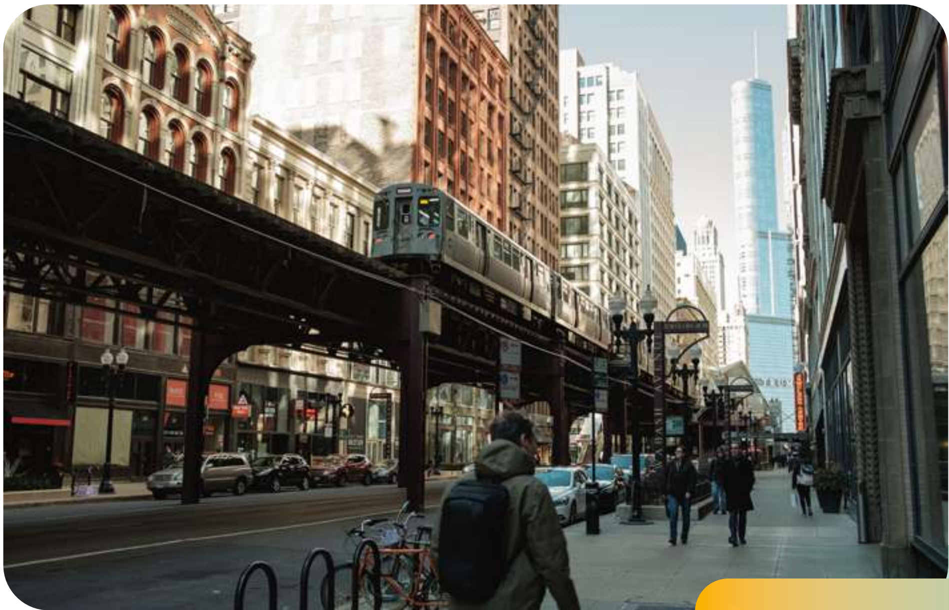
Key challenges

The chasm between city and suburban or rural life continues to widen as the technological revolution focuses on maximising outcomes for dense communities. To ensure no citizens are left behind, solutions must scale in either direction. Ensuring equitable experiences across age, demographic, and personal choice is difficult but a necessary ingredient as PTAs move toward new standards for interoperability and data sharing. Considerations relating to data privacy, confidentiality, and Personally Identifiable Information (PII) are subject to established regulatory and security frameworks such as the Payment Card Industry Data Security Standard (PCI DSS) and the European Union's General Data Protection Regulation (GDPR). However, their interpretation and implementation may vary across jurisdictions and business models, particularly in complex, multi-actor mobility ecosystems.

Currently, decisions are made within siloed organisations across government but increasingly touch multiple facets of the value chain of government services. At the same time, shared modes of transport with pay-after-use mechanisms increasingly integrate with traditional public transport services, creating additional opportunities but also increasing the complexity of ticketing and payment. This opens up opportunity for new approaches to coordination but willingness to forgo any part of individual control of that ecosystem is a difficult proposition.

Current demands

Growing urbanisation, rising consumer expectations, and changing demographics together with declining government funding streams



Chicago, USA © Johannes Krupinski →

have created a perfect storm in the traditional provision of service for public transport. Private innovation led by venture capital funding has brought new focus to the value of mobility. Public transport service provision was traditionally, and in some places still is, a function of government, sometimes offered through contract service to private providers, but is receiving new attention as technology creates potential business models attractive to new players. While adding complexity to the system, private mobility service providers offer new alternatives that can expand the user base of public transport. However, it is important that market opportunities are shaped by government decisions in favour of the public good. This will help ensure that impacts on costs, environment, congestion, health, and quality of life are considered as part of a holistic, people-centred urban mobility solution. .

Ticketing is no longer a simple part of the public transport experience: it is what enables freedom of movement across modes and borders.

Within this array of challenges lies hope in a future that improves the lives of all citizens. Ticketing is no longer a simple part of the public transport experience, it is what enables freedom of movement across modes and borders. With models such as Mobility as a Service (MaaS) and combined mobility, account-based systems can connect movement in a region with new opportunities for reward programmes, loyalty toward preferred modes, and access to recreation, entertainment, commerce, and employment. Shifting 'service-consumed' business models among providers does not currently align to types of available funding options. However, with every challenge there is equal opportunity, the specifics of which are further explored in this Report.

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Smart ticketing

Media-based ticketing

A media-based ticketing (MBT) scheme is a fare collection system in which the funds, proof of entitlement to travel and any primary records of travel are held directly on the medium used by the traveller, for instance a smart card or a mobile device. All front-end equipment in a MBT system must be able to update travel records and/or perform fare calculation directly to the medium each time it is used.

- → During the validation process, the validator/terminal checks that the medium is genuine, and that appropriate rights/value are present.
- → In gated systems which use a media-centric scheme, the validator also updates the data on the card and such card-terminal transactions are secure and instantaneous.
- → MBT schemes can work offline, and failure of telecommunication has no impact on validation or even on loading. .

In many ways, MBT solutions, and in particular smart card-based schemes, have become the de-facto standard for public transport payment over the past three decades because they have a number of advantages over older paper-based systems. Smart cards are more flexible, secure, easy-to-use and have reduced operating costs, compared to paper tickets.

Since the advent of smartphones, mobile ticketing solutions (i.e., solutions where users purchase digital tickets through a mobile app) have spread significantly as an additional component to MBT schemes. Smartphones can be used in two modes:

- → Top-up function: allowing customers to reload a physical card.
- → Card emulation: in which transport tickets are digitalised in the phone.

Main characteristics of MBT

MBT can facilitate interoperability, but it is often complex to implement the data is exchanged via the card, which provides the necessary information to apply the interoperability rules. Validators/terminals need a certain level of intelligence to perform complex functions

- → Upfront infrastructure investments
- → High operational costs, due to the need to maintain proprietary infrastructure (although new solutions are emerging to avoid this)
- → In many cases customers are forced to use dedicated hardware for top-up or ticket purchase, making the whole process slow and

inconvenient. There are also significant costs for issuance and management of proprietary travel cards.

- Smartphones avoid the operators' cost for issuing and managing smart cards because the cost of the medium (the smartphone) is borne by the traveller.
- Resilient to network failures
- Integration with third-party transport systems is often more complex and costly
- Losing a travel card means a loss of funds or travel rights on it, unless it is managed by the system through the personal account
- May provide strong data-minimisation characteristics when travel data remains primarily on the medium.
- Reduces reliance on continuous real-time communication infrastructure.
- Production and management of smart cards generates plastic waste.

Account-based ticketing

Account-based ticketing (ABT) is a fare-collection system in which the proof of entitlement to travel and any records of travel are held in a back-office (i.e., servers) and not necessarily on any physical media held by the passenger.

ABT differs from traditional MBT schemes because the business rules and fare calculation are managed in the back-office. This means that the fare-media used by the traveller to access the system is nothing more than a unique identifier for the customer linked to their account. However, some ABT systems include the possibility to register validation data in the fare-media to improve reliability.

Main characteristics of ABT:

- Media Acceptance Devices (MAD)/validators usually do not write any data on physical media, which means that the medium is no longer the master of all data. But it remains fundamental that the medium is authenticated. Otherwise, the customer is not protected and his rights stored on the central server can be used by another person.
- Lower set-up and operational costs because there is a reduced need for heavy infrastructure and reduced costs for cash handling.
- Possibility to accept additional tokens than the ones issued by the operator.

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- Meeting the growing consumer demand to use the same convenient ways to pay for mobility as for other daily expenses.
- Can reduce congestion at faregates and improve customer experience.
- Easier integrations with third party transport systems such as Mobility-as-a-Service (MaaS) schemes and Park & Ride.
- If an open-loop global standard like Europay Mastercard Visa (EMV) is implemented, then ABT enables the use of the same media in various transport networks, improving interoperability.
- As with any large-scale digital infrastructure, centralised data environments require robust cybersecurity governance. Modern ABT and EMV architectures incorporate advanced encryption, tokenisation, PCI DSS compliance frameworks, and continuous monitoring mechanisms to mitigate these risks.
- Modern ABT architectures increasingly rely on optimised cloud infrastructures and distributed processing models that support scalable and energy-efficient operations, while minimising dependence on continuous real-time communication between devices and central systems.
- In the case of connectivity/communication loss, the granting of access is linked to a potential loss of revenue. However, modern ABT systems can operate in both an online and offline world, using risk-managed revenue protection techniques as appropriate. The system is regularly updated, and the frequency of data synchronisation depends on the network capabilities and the ABT system's technical configuration.

Hybrid solution

For more complex conditions and larger systems, a hybrid solution architecture with more than one ticketing scheme is often used. For example, smart cards for school tickets (as underage students are not allowed to buy tickets online), can work in parallel to pay-as-you-go ticketing and other ticketing schemes.

This means that although the travel right is still stored in the back-office, the information is also written on the medium itself. Balances on the medium and in the back-office are compared and verified during synchronisation. In large systems with many transactions, the amount of data flowing between all vehicles and the back-office is often too big to be constantly synchronised, necessitating a hybrid approach to provide faster validation and mitigate financial risks for the PTA.

Migration scenarios

In this section migration refers to a transition from an MBT scheme to an ABT solution, where no monetary or ticket data is written on the card. There are numerous scenarios available that depend on the size of the project, readiness for cooperation of the current system provider and other factors that drive the migration strategy. Some examples include:

Ticketing service continuity is paramount: migration should be planned carefully to ensure a smooth experience.

- Overnight go-live with parallel installation of equipment.
- Gradual go-live with temporary data-writing on the existing cards by the new ABT system
- Gradual go-live with back-end to back-end balance transfer between the systems.
- Free ride period during installation and go-live period.
- Coexistence of the previous MBT system with the new ABT one without any connection between them during the migration phase.

The migration scenario and execution design are typically decided by the PTA and suppliers during project planning. Continuity of ticketing services is paramount, so migration is planned carefully to allow a smooth experience for customers and operators while introducing new functionality and replacing existing systems in a controlled and risk managed process.

In many metropolitan areas, new ABT solutions coexist with previously deployed solutions such as smart cards. A typical example is given by Transport for London (TfL).

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Replacement of the ticketing equipment

Although there are examples of good cooperation, in most cases the willingness to cooperate from current solution providers is low and not outlined in existing contracts.

Depending on the chosen scenario, existing hardware can be replaced all at once, gradually or installed in parallel, having two sets of validators on vehicles, or current hardware can be upgraded. A migration scenario can also involve a gradual reduction of installed hardware and a shift towards a primarily mobile setup. In such a model, the same number of validators is no longer required, since only a minority of users either cannot or do not want to use the digital solution (in this case the app / mPAYG).

Gradual replacement generally means that there is periodic data transfer between the back-offices of both systems, or temporary writing on the cards (limitations apply in terms of intellectual property of the card structures). If the vehicle number is too high for the 'all at once' option, then gradual replacement causes the least confusion for passengers, as there will be only one set of validators on the vehicle.

Migration of existing tokens and balances

Regarding tokens, the easiest way is to issue all new tokens and phase out existing cards. However, this implies that all customers need to obtain a new token. This may cause inconvenience for customers, but also a substantial workload on card issuing and distribution network. Thus, the smoothest transition is to start using existing cards as tokens. The list of existing card numbers can be imported into the new system and, depending on the card type, availability of cryptographic keys and data written on the card, the card's Unique Identifier (UID) or other information would be used to access the account, connected to the card.

Validation technologies and ticket carriers

Paper tickets

Paper tickets are a traditional, but still widely used means, which have been used since as early as the 1840s. They are often still used in parallel with more modern carriers. The details of validity (data) are written or typed or printed onto the ticket. They can be single, multiple use, or season tickets. They are purchased in advance or before the time of journey, and are disposed of once their validity is expired.

Single and multiple use tickets may be subject to validation through on-board validation machines, or on inspection by a staff member. Season paper tickets are generally not subject to physical validation.

Paper tickets in some long-standing public transport networks are considered iconic. The main advantages of paper tickets lie in their simplicity. On the other hand, disadvantages include susceptibility to fraud, such as counterfeiting as well as identity fraud by travelling using another person's season ticket.

Magnetic stripe cards

Magnetic stripe cards, also known as swipe cards or magstripes, are effectively an early smart card on which data can be stored and read by a machine. They have been common in public transport since the 1970s.

They are typically paper tickets or plastic cards featuring a band of magnetic material which stores the data. Apart from ticketing in public transport, they are common in credit cards, ID cards, hotel room keys and so on.

Advantages of magnetic stripe cards include product cost efficiency and reusability. In the public transport environment, they can be read and processed by validators. Disadvantages include the cost of maintaining the equipment and the fact that the magnetic stripe can be relatively easily damaged (proximity with magnetic fields can render them unusable and only limited data can be stored on them). Counterfeit can also be an issue.

For magnetic stripe cards several ISO standards are relevant: ISO/IEC 7810, ISO/IEC 7811, ISO/IEC 7812, ISO/IEC 7813, ISO 8583, and ISO/IEC 4909. These standards define the physical properties of the card, including size, flexibility, location of the magstripe, magnetic characteristics, and data formats.

Contactless smart cards

A smart card is a device, generally bank card size (standardised format), made of an embedded integrated circuit encapsulated in a plastic body. The contactless smart card communicates with and is powered by the reader through radio-frequency (RF) induction technology, within a few centimetres distance. It is a miniaturised computer with its own computing power and applications.

The contactless smart card is a durable support with a life span of many years. It is secure, affordable and can be used for many services: the same smart card could be used for public transport, payment services, loyalty, and so on with a dedicated application for each service.

Public transport contactless smart cards

Globally, contactless fare collection systems are basically used for efficiency in public transport: Validation transactions must be secure, and above all, fast. All equipment, even on-board equipment like validators, are autonomous and able to make decisions on their own. This is mainly because, at the time this technology was developed, there were no possible real-time connections with a distant ticketing server for processing.

The smart card is used to hold ticketing data (loaded value, tickets or passes) in a secure way and every transaction (product loading or validation) is done through an encrypted secure session. Several formats were created to meet this need, some proprietary (e.g. MIFARE) and others open (e.g., Calypso, CiPurse). These formats are too different to be compatible with one another, despite standardised RF communication. In some countries, this has led to monopolistic situations and consequently an explosion of costs associated to the implementation and maintenance of such systems.

In addition to public transport cards, many cities have launched 'city cards' for visitors that provide convenient public transport as well as

entry to major attractions and events, sometimes with discount for certain venues or services.

The ISO 24014 Public transport — Interoperable fare management system defines the minimum common ground for public transport smart card, allowing further interoperability and integration with regulated payment and banking schemes.

Contactless Paper Tickets are similar to contactless smart cards since they embed a chip with an antenna. But the chip is simpler and smaller, which allows for it to be embedded in a paper and not a plastic medium.

Therefore, the contactless paper ticket is low price compared to a card, but not adapted to all kinds of tariffs. For example, it is well adapted to single tickets or one day tickets, but it is not as well adapted to season tickets or pay-as-you-go tickets. Many networks complement their contactless card system with contactless paper tickets to keep a single technology and to avoid the high maintenance cost of magnetic stripe equipment.

Contactless paper tickets can be reloaded a certain number of times, so have a strong advantage of sustainability compared to magnetic paper tickets. Some also, if enough secure, can be reloaded with a smartphone in a top up mode like a card. Well known contactless paper tickets are Calypso Basic, Mifare UltraLight, ST 25, etc.

Online remote loading is a feature of ticketing systems that allows customers to buy and load tickets and passes on their smart card remotely by accessing a website or app on their personal computer or smartphone or by using a smart card reader.

The website has the same feature as a ticket vending machine for reloading smart cards. It can read and dis-play the content of a smart card, the customer can then choose a ticket/pass, buy it with a credit card and have it loaded on the smart card remotely.

This service can be convenient for customers who buy tickets frequently or for multiple smart cards (e.g. a parent buying tickets for other family members). However, a smart card reader is necessary, generally available at sales agencies for an affordable price. Moreover, this system requires the PTA to provide and maintain specific versions of the website or app for each operating system and browser, with frequents upgrades. .

Contactless Payment Cards (Open-Loop)

Contactless payment cards used in public transport are EMV-compliant payment credentials issued by financial institutions. The term “payment card” includes debit, credit, pre-paid and charge products, whether presented as a physical card or hosted digitally within a near field communication (NFC)-capable mobile wallet.

When such a payment credential is accepted directly for access to public transport services, this constitutes an open-loop model, as the medium is issued and governed by the financial sector and can be used beyond transport.

In transit environments, the payment credential is typically presented via contactless NFC technology, either as a physical card or as a digital equivalent in a mobile wallet.

There are two primary usage patterns:

→ Pay-as-you-go (PAYG): Passengers tap the card at entry, or at entry and exit depending on the system design. Fares may be authorised per ride or aggregated and calculated in a back-office system, where fare capping or discounts may be applied.

→ Pre-purchased products linked to a payment credential: In most modern implementations, payment cards do not store transit value or ticket data directly. Instead, the card's identifier is linked within an account-based system to pre-purchased tickets, passes or concessions. The card functions as an access token rather than as a storage medium.

QR Codes / Tokens

QR-based fares and dynamic tokens expand accessibility by allowing passengers to use any smartphone (without specialized cards) to authenticate trips. They support online and offline validation, integrate easily with mobility apps, and reduce issuance and operational costs. Dynamic tokens (single-use or time-bound) also strengthen security against cloning and enable seamless multimodal interoperability across bus, metro, BRT, and micro-mobility services. QR Codes can be used for pre-paid mobile ticketing, but they can also serve as travel authorization for post-paid mobile pay-as-you-go (mPAYG), where the final product is not defined at the start of the journey.

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Biometry for Payments

Biometric validation—fingerprint, facial recognition, or palm-vein ID—offers a frictionless, card-free and phone-free boarding experience, particularly valuable in high-flow stations. When implemented with strict privacy and consent frameworks, biometrics enhance passenger convenience, reduce fare evasion, and improve accessibility for users who may have difficulty managing cards or devices. Biometry can act as a complementary layer to existing media (EMV, NFC, QR), enabling faster throughput and universal inclusion in public-transport payment ecosystems..

Smart ticketing organisations

Smart Ticketing Alliance

The Smart Ticketing Alliance (STA) is established to support the development of interoperable Smart Ticketing. The STA's goals are:

- Co-operation between national and regional smart ticketing schemes
- Development, agreement, publishing and promotion of requirements for smart ticketing interoperability
- Co-operation for the establishment of trust schemes, specifications and certification
- Liaisons with relevant European and international bodies to promote interoperability

The STA is a direct follow-on from the European Commission FP7-funded Interoperable Fare Management Project[2]. The STA is an international non-profit distributing association under Belgian law founded in 2015. Founding members were UITP, Calypso, ITSO (UK), AFIMB (France) and VDV eTicket Service (Germany).

For a cross-network or multi-modal journey, or one crossing multiple borders, there are two options open to the operators involved: to offer the customer the simplicity of holding just one single ticket for the entire journey; or to offer separate tickets or tokens for each network or mode of the itinerary held in a secure Smart Ticketing Wallet. A further option under ABT schemes is to provide the customer with a unique token that allows travel in all participating networks and the customer is billed later when the trip is completed.

The STA has published the open specifications necessary to allow Smart Ticketing Wallets and tokens to be used across border, across networks and across mode. It is working in alliance with the NFC Forum (representing mobile handset manufacturers), the GSMA (representing Mobile Network Operators), GlobalPlatform (representing chipset manufacturers) and CEN/ISO to bring about harmonisation of specifications with regard to smart card and NFC technology for the public transport industry.

STA has published open specifications for smart ticketing wallets and tokens that can be used across borders, schemes, and modes. quickly shares benefits of the STA.

Smart ticketing originated from the wish to have interoperability between regional and national public transport electronic ticketing systems. To achieve this, the STA's focus has been on customer media while allowing for the concept of dynamic and multiple applications. The STA has intensively been working to define the many use cases for integrated ticketing and how these may be loaded and securely stored on the customer's preferred contactless media or serviced by an ABT solution.

Recent STA achievements have been realised in terms of certification, which provides public authorities and users confidence and trust in the quality of contactless communication between contactless readers and fare media. The STA certification program consists of a Group of Certification Bodies (STA GCB) authorised to certify compliance of transportation and acceptance media with the CEN technical specification TS 16794 on contactless communication[3].

Urban Mobility Open Payments Forum (UMOPF)

The Urban Mobility Open Payments Forum (UMOPF) is an initiative of and hosted by UITP. It is a global multi-stakeholder platform focusing on the strategic and operational aspects of open-loop (EMV-based) payment implementation in public transport.

Unlike formal standards organisations, UMOPF does not develop technical specifications. Instead, it provides a neutral forum for public transport authorities, operators, financial institutions, payment schemes and technology providers to exchange implementation experience, address governance and risk-management questions, and explore emerging models related to open-loop fare payment systems and their interaction with broader ticketing architectures, including ABT systems[4].

ITSO Limited

The ITSO Specification is the British open national standard for smart ticketing. The specification was developed with the aim of ensuring that PTOs throughout the United Kingdom can develop compatible smart ticketing systems. That means that, where necessary or desirable, different operators' smart ticketing systems can 'talk' to each other so that a passenger can use just one smartcard no matter which operator is providing the service or where the ticket was purchased. ITSO also assures the integrity of its members' transport smart ticketing schemes through the ITSO security management service (ISMS).

ITSO Ltd is a non-profit membership organisation which aims to make travelling on public transport throughout the United Kingdom seamless and easier by using smart technology.

ITSO smart ticketing schemes have been in operation across United Kingdom since 2002. PTAs first established the smart processing of concessionary bus passes using ITSO-compliant technology (English National Concessionary Travel Scheme), with many commercial schemes following. Across concessionary and commercial schemes and different modes of transport, there are over 16.5 million ITSO smart cards that support over two billion journeys every year. ITSO also operates a testing service to certify smart ticketing equipment to ensure it meets the ITSO Specification. Working with technical experts in both the transport, mobile and wallet payment industry, ITSO is leading the development of ITSO on Mobile – an end to end mobile ticketing solution that delivers secure ticket fulfilment within the trusted ITSO environment.

ITSO is an active participant in several relevant committees of both CEN and ISO. ITSO also uses standards issued by other standards making bodies such as the NFC Forum and Global Platform.

Calypso Networks Association

Calypso is an open, globally adopted set of ticketing specifications suited to transport and mobility needs. Widely distributed and field proven in more than 215 schemes in 25 countries around the world with more than 150 million portable objects on the field. Successfully running schemes in cities like Lisbon, Paris, Milan, Venice, Turin, Montreal, and Riga and countries like Belgium, Latvia, Algeria, Mexico, Morocco and Israel. It is an open technology, free from any manufacturing monopoly, making it both economical and adaptable to evolving future technology changes. Calypso offers a standardised and multi-application solution while preserving individual data protection.

CNA's ticketing specifications have been adopted in 215 schemes in 25 countries around the world.

Calypso can be regarded as a set of technical specifications describing a fast and secure contactless transaction between a terminal and a portable device. Technologically, it represents a coherent aggregation of its specifications with the use of all existing standards. With CNA, a Belgian non-profit association, the users decide on the evolutions of the specifications and of their security, ensuring that the specification remains open, with no monopoly and an extensive panel of providers.

Through Hoplink, Calypso can provide an interoperability solution that is adopted in many regions and agglomerations in France and on a cross border level between France and Belgium. Hoplink is a scheme of interoperability based on the principle that interoperability is based on media and not of tariff or commercial nature.

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To better reflect market challenges, CNA has developed since 2017 an Open Source API for terminals, called Keyple. It manages all generic and necessary commands to process smart cards or any other NFC contactless object commands. It is completely free, modular, compatible with various OS (Windows, Linux, Android), delivered with various plugins (OMAPI, PC/ SC, NFC..) and languages (Java and C++). The software development kit (SDK) for Keyple is available through the Eclipse foundation. To complement this evolution in terms of sustainability and trust, CNA provides a certification scheme[5].

In conclusion, the main concern of CNA is to avoid any vendor lock-in by defining card-reader specifications and creating an open-source software, Keyple at the level of the equipment (e.g., validators and sale machines). And today CNA is strongly working on standardization and prevention of vendor lock-in of ABT systems at three possible levels: (i) token, (ii) communication between device and server, and (iii) communication between servers..

VDV eTicket Service

The standard for electronic fare management (EFM) valid in Germany is the VDV Kernapplikation or VDV-KA. It is an open standard which was developed as part of a research project initiated by the Federal Ministry of Education and Research (BMBF) and completed in 2005.

The VDV-KA has created a common technical basis for German public transport in the long term. VDV-KA provides the central background systems that support the communication of the individual EFM systems, which are set up locally by the PTAs. Furthermore, it operates security management for eTickets from a central location, avoiding the complexity of implementing IT security locally.

The VDV eTicket Service, which was created by the Association of German Transport Companies (VDV), among others, now operates and coordinates this technical platform for electronic tickets under the name eTicket Deutschland. Every participant has the possibility to choose between different expansion levels of the VDV-KA.

Travelling across the border with only oneticket – the easyConnect project has set up an interoperable ABT ticketing solution between Germany and the Netherlands. Being able to take the train from Aachen to Maastricht with a smartphone ticket paves the way for truly seamless travelling, without even noticing there is a border.

The preferred user medium on which an e-ticket is stored is the smart card. In total, more than 25 million contactless smart cards are currently used in Germany. Also, smartphones play an increasingly relevant role for eTickets, related information and additional services. Furthermore, eTicket Deutschland uses VDV barcode for issuing mobile phone tickets. The possibility of networking between transport companies is always available and multimodal options (such as the integration of bike sharing, car sharing or even tickets for car parks, zoos or concerts) can also be implemented.

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Support for media and mobile devices

1D/2D barcodes

There are several widely used standards for 1D/2D codes, including: a simple one-dimensional barcode, QR-code or Aztec code. Depending on the printing capabilities at the points of sale, the 1D/2D codes can be printed out and used as a paper ticket or 2D codes can be used as a mobile ticket.

After downloading a mobile application from the trans-port operator or from a service provider, the users will be able to purchase the tickets in the form of 2D barcodes. The payment can be done using a credit card or others payment solution available in the app.

In case of pre-paid mobile ticketing, the payment needs to be triggered for each purchase. In mobile post-paid ticketing, the payment is triggered automatically without any additional interaction by the user, also called recurring payment.

As 2D barcodes are already used in various areas such as for tickets in the entertainment sector (e.g., for concerts, sports events, etc.), people are familiar with this digital ticket carrier and its usage. Moreover, as most mobile phones are already able to display 2D barcodes, this solution becomes more and more universal.

AQR code, or more generally a barcode, can also be used in a different way: a QR code can be printed at the entrance of the network on fixed equipment or a wall, with information of location (and not ticket information). The customer scans this code with their smartphone, and the validation is processed by an app. It can work for open networks without gates.

←
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With the spread of AI tools, animated graphic elements are no longer an adequate form of protection for 2D codes.

The main weakness of 2D codes is that they can easily be reproduced by a simple screenshot of the user's phone screen or copies of paper ticket. To make it more secure, 2D code needs to be combined with others security mechanisms. Until now, animated graphic elements have been incorporated that cannot be copied via screenshot. However, with the spread of AI tools, this is no longer a form of protection.

The greatest protection against misuse currently achievable comes from technically linking the barcode ticket to the smartphone. The ticket is stored in a secure area on the phone and is only generated and displayed as a barcode at the moment of ticket inspection. Security features of the operating system (iOS and Android) are used so that the barcode cannot be displayed on another smartphone without the inspection device noticing. This protection is particularly important for tickets that are valid for more than a few hours or can be used for multiple journeys (e.g. day tickets or week passes). In Germany, such a security mechanism known as "Mobile Ticketing Crypto Service" (Motics) is currently being introduced.

The popularity of 1D/2D code usage in public transport varies heavily by region. For example, Sweden has a national standard for compiling Aztec codes for public transport use and it has become a normal everyday form of validation. On the other hand, in many countries 2D codes are considered an obsolete technology for public transport purposes.

It is, however, a simple and cheap way to start using mobile phones in public transport ticketing and validation. Depending on the validation method and local regulations, inspection based visual validation can be implemented without additional costs for vehicle equipment. Alternatively, specific 2D readers can be installed in public transport vehicles for self-service validation. While in the past, the duration of the transaction with 2D codes was rather slow and could impact the necessary flow of passengers, nowadays 2D validators on the market are fast (think about those at the supermarket).

Mobile NFC

NFC technology is used to support the majority of public transport networks with contactless cards or tickets. To benefit from the service, the user downloads a mobile app from a store. In a second step, a digital card is created in a secure space on the smartphone. No longer tied to issues related to plastic card distribution, the whole range of tickets can be sold anytime and anywhere. To validate or to be controlled, it is simple and fast: the user validates their smartphone on the equipment.

NFC technology presents two big advantages:

- It reuses the equipment in place. It means that PTOs don't need to invest in any additional equipment for validation or control operations.
- It reproduces the same travel experience. The user uses their own smartphone as a contactless transport card; it is simple and fast. Moreover, the transport operator transfers the ownership of the medium and no longer manages the life cycle of plastic cards (e.g., creation, loss, theft, and replacement).

NFC technology reuses existing equipment and reproduces the same travel experience.

Until recently, two limitations have slowed down the spread of the NFC mobile ticketing:

- Until some years ago, unlike Bluetooth or WIFI, NFC technology was not implemented on all smartphones having suffered from problematic implementation by some mobile manufacturers. But in the last three years, driven by a strong payment market, the NFC standardisation on mobile phones has rapidly improved the performance and the spread of NFC technology into the entire smartphone range. Moreover, the native integration of NFC API in Android version 9 contributes to a harmonised NFC mobile performance.
- Apple phones do not provide an open NFC architecture. However, Apple integrated the Japanese transport card Suica in September 2016 and followed with systems like Shanghai, Beijing and Portland. In Europe, the Navajo card from Paris region has been integrated in the iPhone wallet from May 2024; it fully emulates the card with all the tariffs.

There are currently two ways of storing and securing information:

- Within a physical part of the smartphone called a secure element (or SE). As with a bankcard, the in-formation is stored and secured within the chip. This method is the closest to that of the contactless card currently used in transport systems. It is therefore directly compatible with existing contactless equipment. It is also the one used by iOS solutions. It allows transactions (validation or control) to be carried out even when the phone is switched off or out of battery, which is a major benefit to the customer experience.
- Within part of the software of the phone called Host Card Emulation (or HCE). This method, which is offered by Google, is principally compatible with Android phones. It currently offers the widest compatibility with Android phones as no prior agreement with SE suppliers, mobile operators or manufacturers is needed.

These two different systems have been the subject of much debate between experts. The current state is a cohabitation between these two NFC technologies according to local needs.

SMS

The user sends a message (short code or text) to a number and receives an SMS that displays travel and control information and the validity period. Usually an SMS ticket must be used during a short period immediately following purchase. Depending on the code sent, different tickets can be purchased: for example, a single ticket or a daily ticket.

This solution is simple to use and can be used with all types of mobile phones. It allows buying a ticket anywhere at the moment of travel and the payment is handled directly via the user's mobile operator subscription. This solution is convenient for occasional travelers.

SMS ticketing availability is often limited to major local mobile operators because the system provider has to conclude a partnership with each mobile operator. Moreover, since this solution usually only provides tickets with immediate departure, the fare collection is restricted. Also, the distribution cost is generally high (can be between 8%-10% of ticket price). These challenges reduce the incentive for PTAs to promote SMS ticketing solutions.

BE-IN/BE-OUT (BiBo)

For the last 30 years, most of the fare collection industry has been relying on proximity smart card-based Check-in/Check-out (CiCo) validation solutions. In a CiCo (also called Tap-in/Tap-out or Touch-in/Touch-out) method, passengers present their fare media or token to a specific Media Acceptance Device (MAD) or validator that uses a short-distance reader to check the passenger into the transport vehicle or network.

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An alternative method called Be-in/Be-out (BiBo) has been tested and trialled for nearly 20 years. This paper covers the broader concept of the BiBo solution. There might be other variations of the broader BiBo solution with different implementations, each having its own pros and cons.

The main difference between CiCo and BiBo solutions is the way passengers identify their travel account. In a BiBo scheme, the physical validation infrastructure within a transport vehicle automatically detects the appearance and disappearance of a specific electronic token carried by passengers, without them needing to take any action (such as tap). It enables a truly "hands free" travelling experience. Recently, the first field tests of BiBo without physical infrastructure were carried out, based solely on smartphone technology (mPAYG). These field tests suggest that the main challenges related to battery usage and GDPR compliance have been largely addressed.

BiBo schemes are only suitable for use in honour-based non-barred transport systems, where passengers don't need to prove their ticket availability. In these systems, enforcement of the payment is either fully honour-based or by random inspection. For barred transport environments, the hands-free experience is being experimented by using a Walk-in/Walk-out (WiWo) method, where the CiCo event is recorded by detecting direction of movement through certain corridor (e.g., a faregate).

An alternative scheme to consider is Check-in/Be-out (or Assisted BiBo). Instead of fully automatic check-in, the CiBo scheme requires passenger to confirm within the smartphone application that they have started their journey. Check-out is recorded automatically. A CiBo scheme allows operators to gather and compare automatically recorded proximity recognition data with passenger confirmation data to assess accuracy of a future BiBo scheme and adjust parameters if necessary.

There are two main technologies that have been tested in-depth for feasibility for a BiBo scheme:

Long-range radio frequency identification (RFID): In a BiBo scheme supported by RFID, active RFID tokens replace passive, nearfield, smart cards and long-range sensors are placed within vehicle.

Advantages	Disavantages
The technology has been shown to work in most urban environments.	Cost of the complicated hardware installation and the distribution of active (battery-powered) RFID tags or tokens to passengers make the technology financially infeasible for most PTAs
RFID technology can be cross-utilised in gated and non-BiBo environments.	Potentially inferior user experience due to lack of communication to passenger about successful or unsuccessful check-in/check-out event and fare calculation.

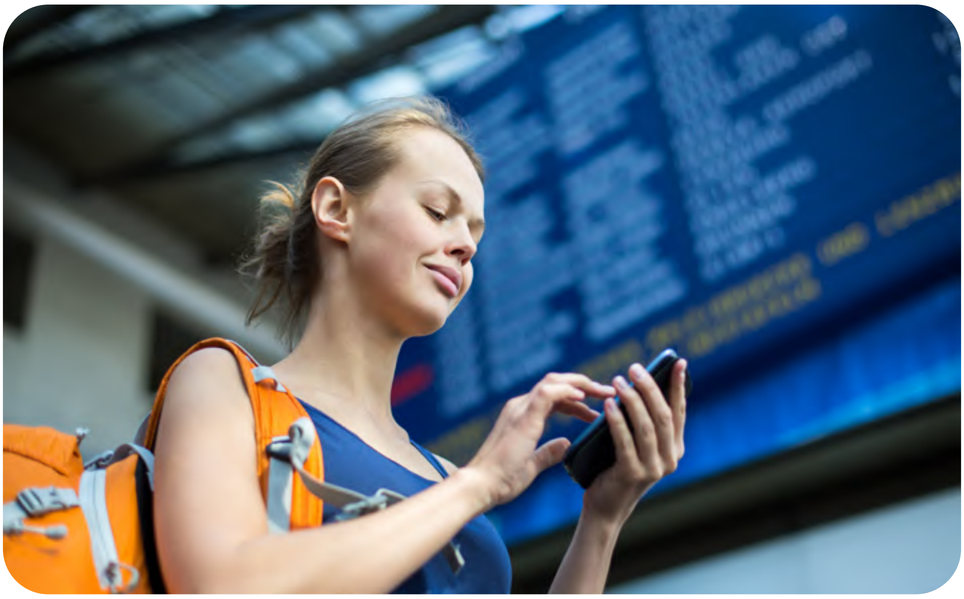
Bluetooth Low Energy (BLE) beacons: In this BiBo scheme, BLE beacons are placed within vehicles to transmit localisation data over Bluetooth protocol. This signal can be received by a passenger's own smartphone, which runs a mobile ticketing application. The mobile ticketing application collects fares for the BiBo scheme and may support improved localisation by smartphone technology (mPAYG) in high-dense areas or subway stations. In several current deployments localisation can be achieved without any hardware support by using the smartphone's Global Navigation Satellite System (GNSS) signal.

Advantages	Disavantages
BLE protocol is widely available and supported by all smartphones on the market, thus supporting a cost-effective and widespread roll-out of a BiBo scheme.	Lack of a unified BLE beacon communication and proximity detection standard for all phone manufacturers to follow. This makes BLE-based BiBo schemes still too unreliable for commercial roll-out.
A smartphone-based BiBo scheme enables proper communication to passengers regarding check-in/check-out events and fare calculation.	

Additional points to consider for BiBo schemes are:

- They require an account-based fare collection back-end to be implemented.
- They require vigorous testing and a long pilot period before full commercial roll-out.
- They need to fully comply with GDPR standards and the principle of data minimisation

Adoption and trust of BiBo by passengers will take time. If successful, a well-established BiBo scheme could be considered as a strong alternative / complementary fare collection solution.



Bank card and mobile payment solutions (Open-Loop EMV)

Open-loop payment in public transport refers to the acceptance of Europay Mastercard Visa (EMV)-compliant payment credentials issued by the financial sector. These include debit, credit, pre-paid and charge cards, whether presented in physical form or hosted digitally in mobile wallets.

The main advantages of open-loop payment are convenience and familiarity.

In an open-loop model, the payment credential is governed by the banking ecosystem and can be used beyond transport services. The PTA does not issue the medium but enables its acceptance within the fare collection system. Open-loop transit acceptance is supported globally by major payment networks, including American Express, Discover, Mastercard and Visa.

The main advantages of open-loop payment are convenience and familiarity. Passengers can use a payment credential they already possess, without needing to acquire a dedicated transit card or pre-load value. This can reduce barriers to access, particularly for occasional users and visitors.

At the same time, open-loop implementation requires EMV-compatible acceptance infrastructure and back-office systems aligned with financial security and compliance frameworks. It also relies on banking access by users, a condition that may not be accomplished either by the users or in certain markets. Where open-loop operates alongside closed-loop systems, transport authorities must manage parallel acceptance environments.

EMV Transit Models

In public transport, EMV implementations typically follow three models:

- → **Model 1** - Known Fare: A fixed fare is authorised upon tap. No complex fare calculation is required.

- → **Model 2 -** Pay-as-you-go (Aggregated Model): Validation events are recorded and fare calculation, including capping or discounts, is performed in a back-office system. Charges may be aggregated and processed periodically.

- → **Model 3 -** Pre-purchased Products Linked to a Payment Credential: Season tickets or concessions are linked in an ABT system to the payment credential. The card acts as an identifier rather than storing transit value.

Mobile wallets

Mobile wallets such as Apple Pay, Google Wallet and Samsung Wallet enable the use of virtualised EMV credentials on NFC-capable devices.

In transit environments, many wallets support dedicated "Express Transit" (or equivalent) modes that allow tap-and-go validation without requiring additional authentication. From the transport system's perspective, wallet-based credentials function similarly to physical contactless EMV cards.

Mobile wallets may also support closed-loop transit card emulation where enabled by the transport authority.

White-Label EMV

Some ABT systems use EMV protocols with transport-issued cards. Although technically based on EMV standards, such solutions operate in a closed-loop model and remain under the governance of the PTA.

APP-Based Ticketing Solutions

Mobile Pay-As-You-Go (mPAYG) systems issue riders a valid ticket through a single swipe in a mobile app. Switzerland, Austria,Denmark and many other European regions benefit from nationwide mPAYG coverage.

mPAYG is post-paid. The passenger registers once and payment is deducted after journeys are completed. The back-office calculates the right fare based on applicable policies, and the traveller is presented with the correct price post-journey.

In a CiCo model, the passenger checks in on their phone to obtain a travel authorization and to end the journey. With CiBo, the check out is automated. Finally, in a BeBo model, no user action is required to start or end a journey. In all models, transfers are detected automatically and multiple users can travel on a single device.

Flat fares as well as time- zone-, mode- or route-based pricing can all be deployed individually or in combination, overlaid with discounts for specific user groups. Daily, weekly and monthly fare capping are also possible. Travellers are automatically charged the best price and are insulated against the complexity of fare policies.

For public transport operators, mPAYG offers significant savings since there is no need to install, operate or maintain validators. Software is updated swiftly and cheaply. With no physical infrastructure required, mPAYG systems can enable multi-modal journeys between areas with different ticketing systems, provided that relevant commercial agreements are in place. Applications can also combine ticketing with trip planning. However, mPAYG and similar solutions are most suitable in contexts with high digital readiness, including nearly universal smartphone ownership and advanced telecommunications connectivity.

mPAYG allows advanced fraud monitoring. Unlike contactless EMV (cEMV) and traditional paper ticketing, mPAYG follows each journey from end to end, rather than by tap. This enables suspicious travel behaviour or patterns to be detected and flagged by fraud prevention algorithms. Tracking also unlocks the opportunity to provide personalised commercial offers to incentivise users and new insights on user travel behaviour. However, the technology must be accompanied by appropriate regulations and public accountability frameworks to ensure data protection and security.

Open National Payment Schemes

Open national payment schemes in public transport (e.g., Brazil's PIX, Portugal's MB Way, or India's UPI) are increasingly being adopted as a complementary fare-payment channel because they offer universal reach, low transaction costs, and real-time settlement without requiring proprietary hardware. Systems like PIX, MB Way, and UPI allow passengers to pay for single trips, top-ups, or mobility bundles directly from any bank or digital wallet, making transport inherently more inclusive and financially interoperable. These schemes also reduce dependence on closed-loop cards and costly infrastructure, enabling operators to broaden payment acceptance while maintaining strong auditability and revenue assurance. When integrated with ABT, instant payments provide immediate validation rights, support dynamic pricing, and unlock seamless multimodal mobility across buses, metro, rail, and micro-mobility networks, also reducing transactions costs and fees.

Fare models and policies

Fare system selection

In public transport, there are a variety of fare models in use. The different models try to reflect the actual costs of providing service per passenger, which constantly fluctuate by location and time of day. Peak period operation, longer trip routes, and premium services all cost PTOs more money to operate and often require more capital investment. Additionally, there is the issue of cross-subsidisation; since flat fares do not distinguish between time, type, or distance of travel, users traveling shorter distances, during off-peak hours, and using non-premium services cross-subsidise riders on more expensive routes.

To assess alternative fare models, the following criteria may be considered:

- → **Ease of user understanding:** To speed up fare transaction time and to minimise disputes between staff and passengers, a simple fare policy is preferred. Flat or time-based fares are generally the easiest to explain, while distance- and zone-based fares are often perceived as less intuitive, particularly for occasional travellers or visitors. However, modern ABT and mPAYG systems increasingly decouple user experience from fare complexity, allowing complex fare policies to be applied in the back-office while presenting a simple, frictionless interaction to the passenger. This enables authorities to retain fare policy flexibility and revenue optimisation while mitigating user-facing challenges such as zone boundary effects or high entry prices for short trips.
- → **Ease of fare collection:** The simpler the fare policy, generally the easier the fare collection process.

Distance-based

Distance-based fares provide a closer association between price and distance travelled than other systems, with the price per kilometre typically 'tapering off' with distance. This aligns price with the cost of service provision, betterbalancing between consumer and producer interests. In this system, each route has a series of distance-related 'fare-stages' and payment varies according to the number of 'stages' travelled. Usually there is no facility for transfer tickets, with separate fares for each vehicle boarded. However, unless the degree of taper is extreme, the price penalty for transferring is relatively small. Distance based models can generate an extensive number of fares across a network and even an extensive range of fares within one long route. However, in many regions, a base price (boarding fee) combined with a per-kilometre price is implemented, sometimes with an attenuated km rate. In such cases, traditional fare tables are not required.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As with other fare systems, the number of fares increases when special conditions apply for particular user groups, such as students or pensioners.

Zone-based

Zone based fare systems are common in many cities worldwide.

Zone-based fare systems are a combination of both flat fare and distance-based systems. They are common in many cities worldwide with fares related to the number of zones crossed on a journey. Compared to distance-based models, zone-based fares have the advantage of having fewer fare levels, while fares are still broadly related to the distance travelled. The challenge, especially for non-local passengers, is that to buy the correct ticket you must know which zone your destination stop is in. A system with too many zones is less easy to use and understand. This challenge is mitigated by post-paid ticketing systems such as mPAYG or cEMV.

The zones are typically concentric rings around the central business district that attracts the majority of commuter trips. However, some larger cities have additional travel nodes in the suburbs and, therefore, subdivide the outer zone radially to recover the cost of the resulting longer trips. Because zonal fares differ depending on the number of zones crossed, tickets are for one, two or three zones, etc. Short trips across a zonal boundary may be penalised unless a special short distance fare is available.

Zone-based fares require care in siting the zonal boundaries. It is difficult to change boundaries once established. Where a boundary is at, or close to an important traffic generator (major market, hospital or college), there may be a marketing advantage in providing a zonal overlap for the generator, so that trips to it from both zones are at the single-zone fare. The goal is to define boundaries that are reasonably equitable for all users, yet optimize revenue.

The attraction of zone-based fares is that they enable some fare discrimination between long- and short- distance travel, yet are not as complex as stage- or distance-based fares. However, there can be a high price penalty for route interchange, unless the main interchanges are at zone boundaries with overlapping zones.

Zonal fares require care in setting the zonal boundaries, as they are difficult to change once established.

Changing a public transport network to zonal fares requires high quality support and publicity to familiarise all users with the system. This should include a simple map or schematic illustrating the zones and the fares between zones. Zone number should be indicated on each stop.

User-based

User-based fares are typically combined with other fare models and discounts. The passenger groups can have a wide variety (e.g., children, students, elderly, people with disabilities, occasional or frequent users, jobseekers, and others). For each passenger group a further subset of tariffs can be offered (e.g., adult day passes or student monthly passes).

Time-based

Time-based fares allow passengers to ride a network and make free transfers for a set amount of time from initial boarding. The tickets can be anything from an unlimited weekly or monthly pass to free transfers within a one- or two-hour time period. Time-based fares may be used to address the problem of the onward validity of tickets for journeys on two or more vehicles to reduce the price penalty of transfers. The model is typically suitable for a densely served network, where connection times are short. Time-based fares require some sort of physical token or card (e.g., paper ticket with a barcode, magnetic or smart card) and on-board validation equipment or at least validation equipment at every stop to issue the transfer.

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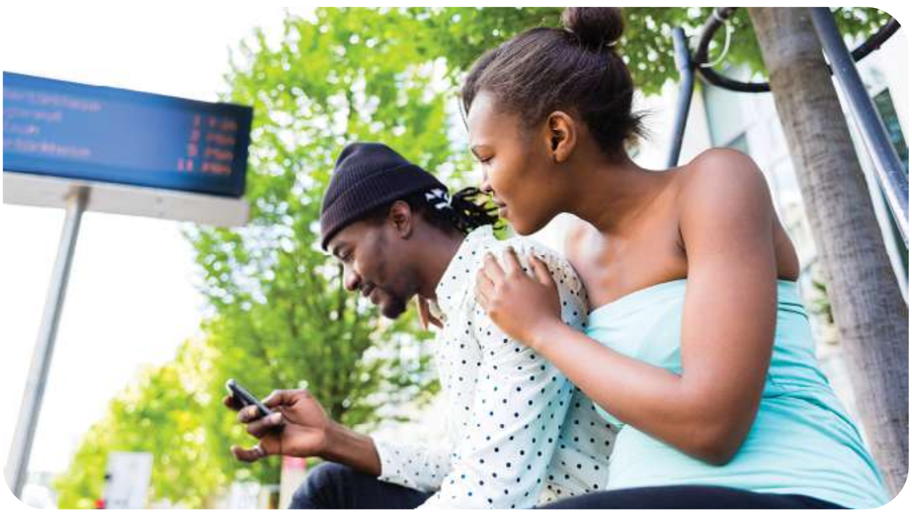

Pay-as-you-go

Pay-as-you-go is typically not a fare model, but a payment method. Recent developments allow this method to be used also with a contactless bank card. In this case the fare is deducted directly from person's bank account.

Best fare calculation

The ticketing system automatically calculates the best price. This is also more socially equitable for lower-income individuals

In terms of service orientation, the PTA can take things a step further and offer its customers the best fare calculation. This ensures that passengers always pay the most favourable price for their journey. They simply validate their card at each entry or check-in on a smartphone (mPAYG). If the journey should reach a determined cap, the system automatically ensures that charges will be made only up to this limit (fare capping). The caps can apply for different types of tickets (e.g., daily or monthly tickets). Some systems even allow users to set additional, freely definable time periods. Consequently, some transportation companies don't continue the sale of stripe cards, daily, or monthly passes. This can provide exceptional convenience because the passengers no longer have to think about which product is best for them. The ticketing system automatically calculates the best price. Incidentally, this is also more socially equitable for lower-income individuals who, studies have shown, often do not purchase a monthly ticket even when it would have been the most economical.

While being very passenger-friendly, implementing the Best Fare Calculation usually means losing ticketing revenue, as travelers only pay for the journeys they actually make. In more traditional models with period passes, the average number of actual journeys tends to be lower than the calculated price of the pass. There is also an issue of deferred revenue, as the payment for journeys is received gradually, while period passes are paid in advance; this means the PTOs are collecting the revenue sooner, than in the Best Fare Calculation model.

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Procurement models: Ownership vs Software as a service (SaaS)

Although the formal ownership of a ticketing system still lies with PTAs in many instances worldwide and is a legitimate objective for the public sector in certain institutional contests, ABT and cloud services are rapidly changing that paradigm. As ABT systems becoming more common as a serial product, rather than a specially developed solution, the idea of handing over the intellectual property (IP) rights of the source code, is unacceptable for most suppliers. At the same time, public ownership remains an objective in certain institutional contexts.

Software as a Service is becoming the new de facto standard in ticketing.

Therefore, Software as a Service (SaaS) is becoming more common in the public transport ticketing industry. There are several benefits to SaaS compared with traditional ownership of locally-hosted ticketing system, for example:

- → Constant upgrades and improvements; the system never gets obsolete.
- → Seamless scaling possibilities.
- → Dedicated hosting environments that usually provide better uptime and security than locally hosted service.

The most common concerns about the SaaS model in public transport ticketing are fear of vendor lock-in and insecurity about the supplier's ability to support the system during the whole contract period. Moreover, PTAs usually have a vision of continuously developing the system by adding functionalities that keep up with general evolutions in technology. There can be concerns that such extra developments would be very costly if provided by the same supplier.

However, it needs to be considered that even if the IP rights would allow the PTA to procure the development from third parties, it usually concerns only either customer facing applications – web portals and mobile applications – or completely new functionalities, which are added to the existing system by API integrations.

In the case where the core ticketing system architecture, source code and business logic are still vendor-specific, it might not be feasible to assume that a third party could actually develop the system further without extensive support from the initial supplier.

There are initiatives to standardise different parts of the ticketing solution, which could help to avoid vendor lock-in situations, such as:

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- **ITxPT:** standardised communication protocols and hardware interfaces for vehicle onboard equipment
- **BoB** (Billjetoch Betalstandard): Swedish national standard for ticketing and payment in public transport
- **Keyple:** An open source SDK developed by CNA and property of the Eclipse open source foundation. By proposing an API with a library of functions, Keyple avoids a lock-in from vendors and also opens ticketing to a wide range of new actors

Often, an escrow method is used to ensure the PTA's ability to keep supporting the current SaaS model ticketing system, even in case of supplier bankruptcy. The system's source code is stored in the independent code, and the PTA has the right to use the code if the supplier fails to fulfil the contract.

Capex/Opex model

Capex/Opex is the most commonly used contract model for public tenders. In many occasions the part of the funding is provided by public structural and investments funds and the prerequisite for receiving such fundingis gaining an ownership of some part of the procured system, rather than purchasing service only.

Usually, the Capex side of the contract consists of needed onboard and offboard hardware (e.g., vending machines, inspection devices, etc.) along with installation and initial setup of the ticketing system for launching the service. The Opex part then consists of recurring fees for licences, hosting, maintenance, service and support. Key points to consider:

- With the Capex/Opex model the purchaser will have the ownership of the hardware and, in some cases, also other parts of the system.
- There is a need for sufficient funds for one-off payment after the delivery of hardware and launching the system. .

Full opex (rental) model

An alternative is the full Opex model, where typically the operation is partly funded by ticketing revenue. The full Opex model distributes the implementation costs of the ticketing system throughout the whole contract period and allows for annual budget planning accordingly. The Opex model can also provide a stronger position for the PTA when negotiating over possible faults or misdoings in the system and service.

On the other hand, as the supplier is not reimbursed for implementation costs upfront, it may need additional financing, making the overall delivery more expensive. In most cases, the Weighted Average Cost of Capital (WACC) of the PTA is cheaper, compared to any private company, due to the element of equity requirements by shareholders and regular access to capital costs. Key points to consider:

→ The Opex model is financially suitable for smaller tenders where the cost of capital does not substantially influence the contract value.

→ The ownership of the equipment and the system remains with the supplier, at least until the end of the contract. Possible handover after the contract period is subject to the negotiated terms of the contract.

Revenue sharing model

In the revenue sharing model, the supplier of the ticketing system receives a fixed percentage of the periodical (usually monthly) ticketing revenue to cover the cost of system delivery. It is similar to the Opex model, but involves more risk for the supplier, since local revenue collection rules and regulations and enforcement activities are not under the control of the supplier. As public transport fares tend to be a highly political topic, there may be high consequences toany drastic changes in the basics for the revenue collection (e.g.,ticket prices, entitled passenger groups, etc.).

On the other hand, for the PTA it is a low-risk business model. However, there may be contractual considerations for fluctuations in revenue collection that require financial relief if the ticketing revenue goes down.

Key points to consider for the revenue sharing model include:

→ Need to provide transparency for the expected contract value

→ Due to the high (political) risks, the tender participation interest may be low and limited only to a small number of possible suppliers. This may lead to compromises in the technological level of the ticketing system and compliance with initial requirements unless financial relief for severe fluctuations in revenue collection are explicitly handled in contractual terms and conditions.

Full capex model

This is the most uncommon business model. It involves upfront payment for both implementation costs (including delivery of equipment) as well as fees for hosting, licences and support. However, in some cases there may be specific funding reasons (e.g., availability of the budget, received grants, etc.) which encourage covering periodic operational fees for the whole contract term as a part of the Capex payment. The full Capex model could also be used for supplier's financial risk mitigation, when delivering to authorities or regions without sound financial background.

This model could be used for the supplier's financial risk mitigation, when authorities or regions lack sound financial backgrounds.

Key points to consider:

- → There is a need for sufficient funds for a one-off payment for the whole contract value;
- → The purchaser does not have leverage against the supplier, in the case of possible failure in maintaining the delivered system over time.

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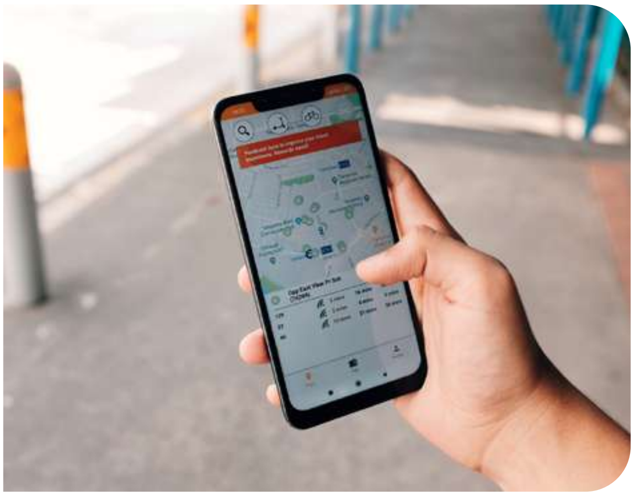

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Adaptations to new public transport business models

Mobility as a service (MaaS)

Typically, providers of MaaS require ticketing data from participating operators along with other key datasets[6]:

- Service availability data: Real-time data on the availability of the mobility service via secured APIs
- Access/ticketing data: Data to (re)sell access to the mobility service, mobile ticketing, and online booking through secured APIs.
- Passenger data: Private data on the traveller may be needed to clear them for the use of the mobility services (e.g., driving license for car-sharing).

There needs to be a collaborative approach, as setting up a MaaS solution is all about cooperation.

Not all operators have this data available in the required format or are willing to share it with a third-party MaaS provider. Most transport operators are concerned about losing the customer relationship if they open their data, especially ticketing/ access to APIs. Indeed, they need to have full trust that the MaaS provider will give a quality, value-add service to their clients. The fear to lose control and contact with the customer is a barrier to building MaaS. Thus, the real question is less about opening data and more on how to share the customer.[7]

Building Trust: Data sharing concepts & algorithms

Transport operators might feel reluctant to open their data to MaaS integrators due to the following perceived risks:

- **Losing the customer relationship:** Community building and customer care are essential to the success of the service and yield management.
- If the MaaS offer is successful, the MaaS provider may become the **gatekeeper to all demand and usage data.**
- **Disclosing the business model:** By sharing service availability data their business model becomes visible to competitors and to other businesses who might enter the market based on that data.
- **Independence of the algorithm:** How can transport operators ensure that the integrator will not prioritise one or the other transport solution according to its own interests?

In order to build the trust needed among all partners, these risks need to be addressed. This can either be done by:

- → The MaaS integrator proposing fair business rules, including clear terms and conditions for the reselling of participating transport services (such as a share-alike license set by the transport operators).
- → Regulation and standards on data format, algorithm protection, and cybersecurity (see below).

To build trust, the MaaS provider should share customer and usage data with PTOs

The integrator needs to find a way of enabling participating transport providers to keep their customer relations. To build the needed trust, customer and usage data should be shared by the MaaS provider with the transport operators as it empowers the whole ecosystem and contributes to better cities, which in return is beneficial to the MaaS service. This would also build on the reciprocity principle in the opening of data.

Regulation and standards

The quality and consistency of shared data and the data format are essential for MaaS. A standard to share data should be set up, for every actor to adopt voluntarily. Forcing transport operators to open their booking and/or ticketing data via regulation is difficult and will not necessarily address the above-mentioned risks. Instead, new forms of regulation, such as the possibility that public authorities establish a 'public data cache' for mobility data and regulate input and output, should be taken into consideration. Therefore, PTAs need to have the necessary capabilities and resources to understand and manage the risks and stakes for the broader mobility system and from an IT and data analysis perspective. It is also essential that data is shared back to authorities to enhance overall mobility coordination and planning.

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Demand-responsive transport

Today, there are roughly 150 different types of demand-responsive transport (DRT). Of these, ridesharing is increasing in popularity. Ridesharing can be in the form of car or van pooling, ride-hailing, or peer-to-peer arrangements. Here we focus on public fleets of vans (or shuttles, with 6-12 seats) especially designed for ridesharing, coordinated in a central place, and operating in or between specifically assigned areas, at certain periods of the day, and often embedded in the public transport network. Examples of these services include TAD IDFM (Paris), IsarTiger (Munich) and SSB Flex (Stuttgart).

Compared to traditional dial-a-ride or taxi services, on-demand services are based on intelligent algorithms that change the way resources are utilised. These services dynamically optimise routes and combine multiple passengers in a single vehicle, while adhering to the arrival time specified for each user. This not only maximises the efficiency of resources such as vehicles, fuel and staff but also ensures a higher level of user satisfaction compared to rigidly scheduled services that are limited to predetermined routes.

Public transport companies use on-demand services as a strategic extension of their existing services. For example, they deploy on-demand vehicles to close transport gaps in underserved areas or during off-peak hours and at weekends. The key lies in the application of intelligent on-demand software that seamlessly complements the regular bus service without cannibalising it. In addition, on-demand apps can redirect passengers to alternative means of public transport when available, seamlessly combining the convenience of on-demand services with existing public transport offers. This can be in the form of a deep link, for example, which redirects the user to the public transport operator's site.

On-demand services are usually booked via an application developed by an on-demand software provider on behalf of a transport authority. Users must create a personal account before booking a service and can then decide during the booking process which payment methods they wish to use. This depends on the options offered by the respective on-demand transport provider. The payment model can take any modern form: one-off-payment, pay-as-you-go, up to subscription models with monthly billing. Public transport tickets can also be integrated in the services' fare structure.

Transport associations are flexible in their pricing but often follow local public transport regulations. For example, the VGI-Flexi service in the Ingolstadt region in the German state of Bavaria accepts the use of the Deutschland-ticket introduced in spring 2023, a ticket that allows the use of local transport throughout Germany for a flat rate of 49 euros per month, at no extra charge. Other monthly tickets available in the region are also valid at no extra charge. Passengers without a season ticket pay a fixed price, regardless of the distance travelled. In the "callheinz" service, on the other hand, which is operated in the districts of Schweinfurt and Kitzingen, Bavaria, the fare for a journey is generally based on the distance travelled; monthly travelcards and the Deutschlandticket are also valid, but at a surcharge of 1 euro (adults) or 50 ct (children).

Across Europe, there are some interesting examples of how policy measures can influence the accessibility of on-demand services. For example, in 2024, the UK Department for Transport (DfT) introduced a national fare cap of £2 and is working with operators who have signed up to the scheme. Hertfordshire County Council, along with several transport operators operating in the county, supports the £2 fare cap and therefore offers the 'HertsLynx' on-demand service at this

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fixed price. Fares are automatically set at £2 at the time of booking. SaverCard holders and children who qualify for a lower fixed fare can indicate this at the time of booking.

In addition to booking via an app, most on-demand services also offer booking via a website or call centre. If a user chooses one of these booking channels without already having a valid ticket(e.g., a monthly pass) they have the option of selecting the "on-board payment" method or can purchase a ticket directly online (e.g., by credit card or via a third-party payment provider).

In principle, the only required input for booking a ridesharing service is the (approximate) destination. The app will reply with the closest pick-up point (often based on the coordinates of the booking device) and an appropriate pick-up time. And of course: the drop-off point, approximate arrival time, and price (plus some information to identify the vehicle, the name of the driver, etc.).

- In some services, passengers may include additional variables or preferences for their ride such as: Number of passengers, luggage, animals, need for an accessible vehicle, preference for a specific driver, gender of the fellow passengers, and so on.
- Typically the service level will be defined by: Minimum head time to order a vehicle; maximum waiting time for the vehicle to actually depart; and/or maximum travel time to destination.
- The use of the app may be subject to age restrictions and require consent.
- Pick-up and drop-off points (or 'pudos') can be regular public transport stops, but in addition, a great number of 'virtual stops' are defined. These can be street corners or other places easily identified. They are also based on a direction of travel to accommodate efficient routing. Pudos can make ridesharing a different system from taxis as they may not correspond to a door-to-door service. The pudos can be several walking minutes away from the customer's position.
- The customer can be updated shortly before the expected departure time and informed once the vehicle has arrived.
- Should a passenger not appear for pick-up, the trip is continued after a short time, and usually the normal price is due.

In general, the price for a ridesharing trip lies between the price of a similar trip with public transport and a taxi ride. Usually, the price is fixed at the time of booking.

As on-demand services often serve as an extension of existing public transport services—for example by serving the first and last kilometre between a main stop and a residential area or by operating outside of normal service hours—many providers base their services on the existing fare system. This means that on-demand journeys may be available at no extra charge when the service has been optimally integrated into the regional public transport offer and no alternative services are operated in parallel. Additionally, as with scheduled public transport services, fares can also be set for certain user groups for on-demand transport. These fares can be discounts on the original fare or fixed fares for certain user categories (e.g., children, seniors, students, etc.).

→ There can be a minimum or boarding price. At the same time, the price can be variable: distance based, on/off peak, specific corridors (e.g., airport-business district), selected pick-up and drop-off areas, or special prices.

→ The final price can also be less, for example when service level agreements were not met or based on the number of (additional) fellow passengers sharing the ride. There are no examples (yet) where the price can also be higher, for example due to congested traffic conditions as can be the case with taxis.

A breakthrough of ridesharing is expected to occur when vehicles become autonomous because a major driver of ridesharing costs is the driver.

Artificial intelligence in ticketing

AI is increasingly transforming public transport ticketing systems, pushing these systems beyond simple fare collection toward intelligent, adaptive, and customer-centric mobility services. It enhances automation, personalization, fraud detection, and operational efficiency across the entire ticketing life cycle.

It also integrates closely with smart ticketing platforms, MaaS systems, and ABT infrastructures. Some key applications of AI in ticketing include[8]:

- Dynamic and personalised pricing;
- Fraud and fare evasion detection;
- Travel mode detection;
- Predictive maintenance for ticketing hardware;
- Passenger flow and demand prediction;
- Seamless mobility and MaaS integration;
- Customer service and virtual assistants;
- Accessibility and inclusivity.

EU regulations impacting ticketing and booking services

The European Union is actively reshaping the regulatory environment for public-transport ticketing, booking and payments to enable truly multimodal, digital and customer-centric mobility services. Policy initiatives—notably ITS Directive and the Multimodal Digital Mobility Services (MDMS) initiative and a proposed Regulation on passenger rights in the context of multimodal journeys—sit alongside existing legal frameworks (e.g. GDPR, the Open Data Directive and the Commission's MMTIS delegated regulation) and initiative like European Mobility Data Space.

In addition, even though it is still under development, the emerging Single Digital Booking and Ticketing Regulation (SDBTR) could become another important component of the EU framework related to enabling multimodal digital booking and ticketing for rail, complementing the initiatives already cited.

Together these instruments shape data sharing, transparency of contract types, payment security and consumer protection, and will require ticketing and booking systems to embed metadata, interoperable APIs, accessible information and clear liability rules for combined multimodal offers.

These instruments are driving obligations on data sharing, contract type transparency, payment security, and consumer protection.

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Conclusion

Ticketing and payment systems are key elements of a public transport system. Around the world, these systems have invested heavily in infrastructure (front-end devices and back office) and different fare media based on various generations of technologies and architectures. New demands for both an improved customer experience (multimodality, interoperability, etc.) and new public transport business models such as MaaS, DRT and others require future-proof solutions which must be easy and fast to use and accessible to all, regardless of the medium they carry with them. This necessitates an understanding of what technologies are available and how to handle the transition from a legacy to a new environment. In addition, considering the most appropriate ticketing and payment system for a given context goes well beyond considerations of technology, data protection, and cybersecurity, it also involves important considerations of institutional capacity, procurement complexity, governance, and local market conditions. Ensuring that public accountability frameworks and regulatory environments are able to support a given technical solution materially affects the outcomes of new technology adoption.

What solutions are available and required?

As described in the previous chapters, various proven concepts and solutions are on the market. For a local PTA, a state-of-the-art ticketing system must be flexible, open, expandable and economical. Flexibility is key for easy introduction of fare changes and to shorten time-to-market for new fare products that respond to dynamic market demands. Openness and expandability are important for easy integration of new modes, business models, schemes, media, services, vendors and sales channels as well as for geographic and organisational expansion. And solutions should be economical, while ensuring sufficient resources for operation, maintenance, and upgrade.

The careful governance and use of standards, open interfaces, open access to API's and multi-vendor-model options can help achieve these characteristics. From today's perspective, ticketing systems based on open standards and open APIs, with an intelligent balance between media-centric and account-based architectures, and the integration of media such as open-loop contactless cards, contactless EMV credit cards, mobile NFC, and mobile ticketing (pre-paid/post-paid) are forming an environment which offers PTAs and their customers an affordable, secure and convenient service.

From legacy to a new environment:technical and commercial aspects

The implementation approach should consider the technical practicality, the commercial impact integration of new products with existing system components and the benefit of a smooth and convenient transition for users—all while recognizing the potential drawback from an extended implementation time as well as one-off integration efforts. On the other hand, a sharp cut-off of an existing, legacy implementation requires extensive planning, testing and preparation and carries a bigger risk. All these aspects should be considered within the institutional and regulatory context of the public transport system while also accounting for criteria such as network size, age and type of a legacy system, and technology, that play a crucial role in determining the need for a gradual go-live and parallel operation of the existing and new solutions.

The commercial approach determines under which business model the selected technology shall be procured, contracted and operated, ideally to the benefit of both the buyer and the vendor. In an environment where infrastructure investments for ticketing systems are typically publicly funded, a CAPEX/OPEX model is most common due to its balance risk exposure between buyer and vendor. This model covers onboard and offboard hardware (e.g., vending machines, inspection devices, etc.) with installation and initial setup of the ticketing system under CAPEX and other parts, such as recurring fees for licenses, hosting, maintenance, service and support, under OPEX.

Other models such as a full OPEX (rental) model or a revenue sharing model offer potential for the buyer to optimise and stretch their exposures over a longer period of time, up to the full lifetime of the system implemented. At the same time, these models often require vendors to shoulder more risk, which they may not be able to fully predict, carry or afford. This can lead to both additional costs and limited competition.

Choosing the right commercial setup is about maintaining a balanced, trans-parent, predictable and attractive business for both the buyer and supplier and creating the environment where both parties are interested and able to support continuous, long-term development of the new services their customers are demanding.

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Annexes

Relevant Standards

Smart Ticketing is currently governed by the following International (ISO) and European (CEN) Standards:

→ Media: ISO 14443 and ISO 24192
→ File Structure: ISO / IEC 7816-4
→ Secure Element Security: ISO 15408 (Common Criteria)
→ Roles and Use Cases: ISO 24014 Part 1
→ Transport Applications: EN 15320 (IOPTA)
→ Transport Data Elements: EN 1545
→ STA Reference documents e,g, Part 3 (IFM) / STA use case document
→ All standard can be bought from the ISO store or the relevant national standardisation bodies

Glossary of Terms

1D	**One-dimensional**
2D	**Two-dimensional**
ABT	**Account-based ticketing** A fare collection system in which the proof of travel entitlement and any travel records are held in a back office (i.e., servers) and not necessarily on any physical media held by the passenger. ABT differs from traditional card-based schemes in that the business rules and fare calculation are managed in the back office, and the fare is calculated and billed after the trip is complete. This means that the fare media used to tap in and out of the system is nothing more than a unique identifier forthe customer linked to their account.
API	**Application programming interface** An interface or communication protocol between different parts of a computer programme intended to simplify software implementation and maintenance.
App	**Application software** A programme or group of programmes designed for end-users.

Aztec code	A type of two-dimensional bar code.
Bar code	A method of representing data in a visual, machine-readable form.
BiBo	**Be-in/Be-out** Validation system whereby the physical validation infrastructure in the transport vehicle or smartphone device sensors (without physical validation infrastructure) automatically detects the appearance and disappearance of a specific electronic token carried by passengers, without them needing to take any specific action. It enables a 'hands-free' travelling experience.
BLE	**Bluetooth low energy** Formerly known as "Bluetooth smart", this provides a good communication range but with reduced power consumption.
CAPEX	**Capital expenditure** The cost of developing or providing non-consumable parts of the product or system.
CiCo	**Check-in/Check-out** Also called Tap-in/Tap-out or Touch-in/Touch-out. In CiCo, customers present their fare media/token to a specific media acceptance device/validator that uses a short-distance reader to check the passenger into the public transport vehicle/network.
Closed-loop payment	In public transport, closed-loop payment refers to the use of payment instruments solely for transit purposes. That means that these payment instruments can only be used for services provided by the public transit authority or operator and not for generic payments outside public transport. The public transport authority or operator is responsible for the system's governance.
Contactless smart card	A smart card is a device, generally bank card size (standardised format), made of an embedded integrated circuit encapsulated in a plastic body. The contactless smart card communicates with and is powered by the reader through radio frequency identification technology, within a few centimetres' distance. It is a miniaturised computer with its own computing power and applications.
CNA	**Calypso Networks Association**
DLT	**Distributed ledger technology** A virtually organised database or ledger, maintaining a permanent and tamper-proof record of transactional data.
DRT	**Demand-responsive transport** Public fleets of vans (or shuttles, with 6-12 seats) specifically designed for ridesharing, coordinated ina central place, operating in or between assigned areas, at certain times, and often embedded in the public transport network.
Escrow	Contractual arrangement in which a third party receives and disburses money or property for theprimary transacting parties according to conditions agreed on by the contracting parties.
cEMV	**Contactless EMV**
EFM	**Electronic fare management**
EMV	**Europay, Mastercard, and Visa** EMV stands for Europay, Mastercard, and Visa, the companies who developed the technical specifications for this global payment standard. From a technical point of view, it is a method that ensures smartcards and payment terminals are compatible.
GDPR	**General Data Protection Regulation** Regulation (EU) 2016/679 (GDPR) is a regulation on data protection and privacy in the European Union and European Economic Area. It also addresses the transfer of personal data outside these regions. The GDPR primarily aims to give individuals control over their personal data and simplify the regulatory environment for international business by unifying the regulation within the European Union.
GSM	**Global System for Mobile Phone Technology**
GSMA	**GSM Association** The association that represents the interests of mobile operators worldwide, uniting nearly 750operators with almost 350 companies in the broader mobile ecosystem. www.gsma.com
HCE	**Host card emulation** This technology, developed by Google and available on Android phones, uses a software security domain to store sensitive data by opposition to solutions using a hardware component (SIM or security element).

ICT	**Information and communication technology** An extensional term for information technology that stresses the role of unified communications and integration of telecommunications (telephone lines and wireless signals) and computers, as well as necessary enterprise software, middle-ware, storage, and audiovisual systems, which enable users to access, store, transmit, and manipulate information.
IP	**Intellectual property** A category of property that includes intangible creations of the human intellect.
ISMS	**ITSO Security Management Service** This enables ITSO-compliant smart ticketing systems to be set up, guaranteeing high security surrounding the data it processes.
Machine learning	The scientific study of algorithms and statistical models that computer systems use to perform a specific task with-out using explicit instructions, relying on patterns and inference instead. It is seenas a subset of artificial intelli-gence.
Magstripe	A paper ticket or plastic card featuring a band of magnetic material on which data can be stored andread by a ma-chine.
MBT	**Media-based ticketing** A system whereby a card (or other medium) is used as the travel entitlement, as opposed to a physical ticket.
MAD	**Media acceptance device** A ticket validator.
Mobile ticketing	The process whereby customers purchase and validate tickets using mobile phones instead of a physical ticket. Ticket purchase can be prepaid or postpaid.
MaaS	**Mobility as a Service** The integration of and access to different transport services (such as public transport, ridesharing, car-sharing, bike-sharing, scooter-sharing, taxis, car rental, ride-hailing, and so on) in a single digital mobility offer, with active mobility and an efficient public transport system as its basis. This tailor-made service recommends the most suitable solutions based on the user's travel needs. MaaS is available 24/7 and offers integrated planning, booking, and payment, as well as en route information to provide streamlined mobility without car ownership.
NFC	**Near field communication** A set of communication protocols that enables two electronic devices to establish communication bybringing them within 4 centimetres of each other.
Open-loop payment	In public transport, open-loop payment generally refers to the use of bank-issued contactless credit or debit cards, NFC-enabled smartphones with credit card emulation, or payment apps offered by the industry, which can also be used for generic payments outside of public transport. The finance sector is responsible for the system's governance.
Opex	**Operational expenditure** The ongoing costs for running a system
PAYG	**Pay-as-you-go** A fare payment approach where a travel medium (most commonly a smartcard) is tapped at the time of entry and exit (if check-in/check-out is implemented) and the fare is deducted from the tokenholder's wallet or bank account, without the need for pre-purchasing a ticket. PAYG can be contactless (cPAYG) or mobile-app based (mPAYG).
PII	**Personally identifiable information** Any information that can identify a specific individual. Also known as personal data.
POS	**Point of sale** The time and place where a retail transaction is completed.
Prepaid	The service is paid for in advance and typically stored on a medium until validation.
Postpaid	The service is paid for after the journey has taken place.
PRM	**Persons with reduced mobility**
PSP	**Payment service provider** An entity that connects merchants to the broader financial system to accept payments fromcustomers. PSPs connect merchants, consumers, card brand networks, and financial institutions.
PTA	**Public transport authority**
PTO	**Public transport operator**

PUDOs	**Pick-up and drop-off points**
P2P	**Peer-to-peer**
QR code	**Quick response code** A matrix barcode or two-dimensional barcode with a machine-readable optic label that containsthe data.
Ridesharing	On-demand ridesharing (also referred to as microtransit, ride-pooling, app-based on-demand buses/ shuttles/minibuses, mini-bus taxis, etc.) is an information technology-based shared transport service operated by a company with professional drivers with no fixed schedule, not necessarily fixed stops, and dynamic routing. Vehicles can range from cars and large SUVs to vans and shuttle buses. On-demand ridesharing serves multiple individual passengers using dynamically generated routes and may require passengers to go to common pick-up or drop-off points. It is either run as a complementary service to public transport or in competition with existing public transport lines by private companies.
Ride-hailing	Ride-hailing, also known as 'transactional platforms for the ride-selling' or 'ride-selling', refers to mobile applications that match customer demand for a ride with private drivers or drivers of vehicles for hire through GPS tracking. Other terms used in the literature include 'ride-sharing apps'" 'transportation network companies' (TNCs), and 'applications for ride sourcing'.
RF	**Radio frequency**
RFID	**Radio frequency identification** RFID uses electromagnetic fields to automatically identify and track tags attached to objects.
SaaS	**Software as a Service** A software licencing and delivery model in which software is licensed on a subscription basis andcentrally hosted. It is sometimes referred to as 'on-demand software'.
SDK	**Software development kit** A collection of software development tools aggregated in one installable package.
Smartcard	A smartcard is a device, generally bank card size (standardised format), made of an embedded integrated circuit encapsulated in a plastic body. In public transport, smartcards are used to control access to a public transport network.
Smart ticketing wallet	An online service that allows individuals to make electronic transactions. Also known as an e-wallet. In public transport, it refers to a digital wallet that holds a passenger's funds, which can be used to purchase transport services.
SE	**Secure element** A hardware component designed to protect assets (e.g., sensitive data) from unauthorised access.
SIM	**Subscriber identity module** An integrated circuit intended to securely store the international mobile subscriber identity numberand its related key, which are used to identify and authenticate subscribers on mobile devices.
SMS	**Short message service** A text messaging service component of most telephone, internet, and mobile device systems. It uses standardised communication protocols to enable mobile devices to exchange short text messages.
STA	**Smart Ticketing Alliance** www.smart-ticketing.org
TCO	**Total cost of ownership** A financial estimate intended to help buyers and owners determine the direct and indirect costs ofa product or system.
TMV	**Ticket vending machine**
UID	**Unique identifier** An identifier that is guaranteed to be unique among all identifiers used for the same purpose.
WACC	Weighted average cost of capital The rate that a company is expected to pay on average to all its security holders to finance its assets. The WACC is commonly referred to as the firm's cost of capital. It is dictated by the external market and not by management. The WACC represents the minimum return that a company must earn on an existing asset base to satisfy its creditors, owners, and other providers of capital and make the investment attractive to them.

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Legal deposit: D/2026/0105/16 - Rue Sainte-Marie 6, B-1080 Brussels, Belgium | Tel +32 (0)2 673 61 00 | info@uitp.org | **www.uitp.org**