Automatic passenger counting (APC) and automatic fare collection (AFC) technology

Benefits, technologies, components, data standards, experiences, and recommendations

Developed for ODOT by Trillium

Contents

About this white paper

Topic
Automatic Passenger Counters (APCs) are a variety of different sensors that count passengers boarding and alighting transit vehicles. Automatic Fare Collection (AFC) gathers passenger counts and other data from ticket validation as a rider's board. Both can be used to collect data to fulfill reporting requirements, optimize operations, and inform planning decisions to meet transit demand better.

Audience and purpose
This paper was prepared for the Oregon Department of Transportation (ODOT). The intended audience is small to medium fixed-route transit providers (with fewer than 200 vehicles) that are exploring ways to collect better passenger data.

ODOT has expressed interest in more and higher quality transit ridership data. High quality information will require consistent practices across transit agencies in Oregon; this can be achieved by using APCs and AFCs that produce data in standardized formats (see procurement and GTFS-ride). This information will help the state to coordinate transit services better to serve travelers' needs and demand.

AFC has additional value since fare payment technology was a key theme in the recent Oregon Public Transportation Plan (OPTP).

Authors
This white paper was written by a team of consultants with Trillium Solutions, Inc. ("Trillium"), a transit technology service provider and consulting firm based in Portland, Oregon. Trillium maintains GTFS data and provides consulting services related to transit technology and data for ODOT. Modular system design and open and interoperable data have been a core part of Trillium's approach and philosophy since its founding in 2008, which is reflected in the recommendations in this white paper.
Trillium interviewed many vendors, consultants, and transit agencies in the course of writing this white paper.

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Paper sections

Summary

Definitions and Components

Automatic passenger counting (APC) is a system of sensors that count passengers boarding and alighting transit vehicles.
Automatic fare collection (AFC) can include functions for selling, validating, and collecting fares and tickets, including fareboxes that collect cash fares. AFC can provide passenger count and traveler flow data for planners.

Components of an APC system may include:

- Door sensors in the form of infrared beams, which can be arranged in a variety of different arrays
- Cameras
- Ramps/bike rack sensors
- Passive Bluetooth-enabled device tracking, which only tracks a subset of riders but may provide more detailed data on passenger behavior
- On-board connectivity to backend systems

Components of an AFC system may include:

- On-board card or mobile ticket readers
- Bluetooth beacons for ticket validation
- Farecards (to store value or be linked with customer accounts)
- Mobile ticketing apps
- On-board connectivity to backend systems

Benefits/Uses

Automatic Passenger Counting

APC systems provide passenger counts, and depending on the system may capture information such as passenger type, and origin and destination stops.

Transit providers may find this data useful for:

- NTD Reporting
- Local transit service planning
- Determining load levels on vehicles
- Tracking ridership changes

ODOT/regional organizations can use this data for:

- Regional/state transit service planning
- Understanding transit demand across services

Automatic Fare Collection

AFC can capture passenger data such as:

- Fare type (e.g. pass vs. single-ride) and category (e.g. adult, youth, disabled, etc.)
- Travel behavior including origins, destinations, and transfers (also called ODX)
- Purchase and activation dates
- Purchase method
- Ticket status: used/unused
- Customer information

AFC and APC data can be synthesized to:

- Validate AFC data
- Estimate fare evasion rates

Aside from the data captured, AFC systems can provide other benefits such as:

- Equity for riders if fare-capping is implemented
- Improved passenger experience, both through ease of use and through the potential for multiple agencies or modes to share fare systems
- Improved operational efficiency through faster boarding
- Reduced costs for cash handling

AFC System Design

Transit agencies should consider the following system design attributes when planning an AFC system. Certain attributes are more compatible depending on the type of system desired. Find more information in the discussion here.

- ***Transit system scope***
    - **Single agency**
    - **Multiagency:** a lead transit agency with partners(such as TriMet's HOP), or regional authority
- ***Design and technology***
    - A **Proprietary system** or design is developed and owned by a contracted vendor and sold or licensed for use by a transit agency.
    - A **Standards-based system** or design follows public, non-proprietary standards and specifications established for the financial payments industry.
- ***Fare system architecture***
    - **Card-based** transit fare payment systems are those in which the fair medium itself carries fare value.
    - **Account-based** transit fare payment systems are those in which the fare medium (such as a card of virtual mobile wallet) serves as to associate the rider with information held in a separate account. The fare medium itself does not carry any fare value.

- ***Payment architecture***
    - **Closed payment (closed loop) system**: a transit fare payment system that uses fare media that can only be used within a single transit system or partnership of transit systems. All proprietary fare payment systems are closed loop systems.
    - **Open payment (open loop) system**: an account-based transit fare payment system that is able to accept third-party payment media such as bankcards and mobile devices as its fare media. All open payment systems are both standards- and account-based systems.

Recommendations

Recommendations for transit providers

Planning and design

1. Consider and be clear about objectives to guide the project
2. Identify and document existing resources
    a. Technology
    b. Staff time and expertise
3. Consider an industry survey
4. Assess and prepare for capacity to maintain the system
5. Prepare for the procurement or pilot(s)

Procurement

1. **Issue a procurement instrument (RFP/RFQ):** Lead with a statement of objectives followed by core requirements.
2. **Consider a limited-scale pilot**

Implementation

- **Schedule data preparation:** If GTFS data is used as an input (as is generally recommended), it may need to be modified:
    - block_id values need to be present.
    - stop locations, schedules, and patterns need to be accurate.
- **Hardware installation:** Devices need to be installed on-board the vehicles, either by the vendor, a local installation contractor, or maintenance staff. This is a good occasion to begin maintenance and operations training for hardware.
- **Back end payment options (AFC only):** The payment options selected need to be established and operational.
- **Develop policies (AFC only):** AFC offers an opportunity to transition to a proof-of-payment fare system, which offers significant efficiency advantages. It is important to consider fare inspection policies carefully to ensure equitable implementation.
    - Train and deploy proof-of-payment fare inspectors for consistent inspection across routes and time of day to avoid targeting specific neighborhoods or communities.

    - Fairness and the safety of both inspectors and riders is paramount; criminalizing riders will not result in an equitable transit system.
- **Testing:** When the system is implemented, test the accuracy counts and/or the responsiveness of fare payment mechanisms.
- **Full public rollout (AFC only):** Once the agency has confidence in the reliability of the system, announce that it is fully implemented and implement a large publicity campaign to encourage use of the new system. To avoid overwhelming riders, consider the following guidelines for implementation:
    - Deploy the new payment system in stages;
    - Do not deploy the new system until all problems are worked out;
    - Increase outreach and education efforts.

Operation

1. Keep data inputs up to date
2. Monitor passenger usage and feedback (AFC only)
3. Monitor APC accuracy
4. Use data for service enhancement
5. Communicate changes effectively

Recommendations for ODOT & Regional Organizations

Standards-setting: Recommend or require APC systems that comply with industry standards for interoperability and AFC systems that use standards-based, account-based, open payment, in order to support system modularity and compatibility with statewide and third-party applications. Provide education for transit agencies on the purpose and benefits of interoperability.

Allow for piecemeal (local) procurement of modular systems. Modularity and interoperability, rather than a top-down or monolithic decision-making model, can achieve regional integration by pursuing the guidelines and processes outlined in this white paper.

Statewide contracts with standards-compliant vendors: By securing contracts with standards-compliant vendors and allowing transit agencies to purchase through those agreements, transit agencies could save significant staff time.

Knowledge sharing: Encourage transit agencies that implement APC and AFC systems to share procurement documents and notes on their experience.

Overview

Uses of passenger data for transit agencies

Passenger and fare count data, at varying levels of detail, is useful for local and regional planning and is necessary for reporting in many circumstances. For transit agencies that receive federal funding, ridership data is required for the Federal Transit Administration's National Transit Database (NTD) reporting. Agencies that are Full Reporters to NTD are required to provide Passenger Miles Traveled (PMT), defined by the total number of miles traveled by all passengers. Automatic passenger counters are especially helpful with the calculation of PMT, since most agencies do not have another way of automatically measuring alightings. Agencies can also benefit from collecting and analyzing passenger and fare data in order to determine load levels on vehicles and to track ridership changes. With this data, agencies can have better information before making changes to stop locations or service levels, or adjusting schedules to run more accurately.

Uses of passenger data for ODOT and regional organizations

Regional organizations such as the Oregon Department of Transportation can use ridership data to understand demand for transit services. If payment technologies that could track riders or payment instruments across different transit services were implemented more broadly in Oregon, it would become possible to analyze travel behavior and connections between services.

APC technology

There are several types of technology associated with automatic passenger counting. The most common are infrared (IR) door sensors that keep count with beam breaking technology as each passenger boards and alights the vehicle. Cameras can also be used to count riders. Many agencies supplement and verify their passenger count data with fare collection data. Automatic Fare Collection (AFC) can gather passenger counts from fare sales and ticket validation, which can then be compared to or combined with manual or APC data (i.e. to include passenger alightings gathered by APC in cases where AFC gathers only boardings). Bike and ramp sensors that track bicycle and wheelchair numbers may provide other useful data points for ridership information. The vehicle's GPS can be another data source, allowing the correlation of passenger counts with the specific stops where the passengers board and alight.

Fare collection and passenger experience

Automated fare collection (AFC) technologies include electronic fareboxes that count cash and coins, electronic farecards and readers, and mobile fare payment apps and validators. AFC can provide riders with a simplified, convenient, and consistent experience during their travel and even between modes of transit throughout a region that is using the same system. Electronic farecards save riders from pre-planning to pay a cash fare or, if the system supports fare capping, from selecting a pass product. When regional transit agencies share AFC standards amongst each other, a rider can expect the same policies and fare structures wherever they ride. This convenience can enable riders to increase their use of transit services.

Passenger count & fare collection data

Passenger count and fare collection data can be collected through a variety of technologies and methods and can be used for a variety of purposes. This section describes options and opportunities.

Functions & uses of data

Agencies of all sizes have found that they can better meet their requirements and improve overall service efficiency by utilizing fare and passenger count data. Common uses:

- Local transit service planning
- Regional and state transit planning
- National Transit Database (NTD) reporting

These functions can be accomplished using various sources, including data from Automatic Passenger Counters (APCs), Automatic Fare Collection (AFC), and manual counts. Each source presents different opportunities and involves different costs.

Local planning

Capturing boarding and alighting data at the stop and route level can be accomplished by integrating APCs with GPS and data (for example in General Transit Feed Specification (GTFS) format) that describes stops and schedules. This can help determine demand for stops, routes, and time of day.

Stops with very low demand can be identified and eliminated from routes to make service faster. Services (trips and routes) with low demand that do not serve identified coverage goals[1] can be eliminated to make resources available to serve greater passenger demand. (Note that passengers may travel on high-demand peak service and then make a return trip on a low-demand off-peak service, or vice versa, so cutting low-demand service can affect ridership on other trips.[2])

Demand data be useful to mitigate and manage the effects of temporary detours and to inform possible expansions or improvements. For example, routes with very concentrated boarding and alighting activity at particular stops may benefit buses with larger doors. Demand informs transit agencies of what temporary measures are necessary when a station or stop is temporarily closed due to construction detours or other obstructions. Stop level data can also help transit agencies allocate amenities such as shelters, benches, and lighting. Finally, some APC technology provides more differentiated data, such as wheelchair ramp deployment or bike rack use. These indicators can similarly help transit agencies improve these accommodations.

[1] http://humantransit.org/tag/coverage
[2] The Transit Ridership Recipe: http://humantransit.org/2015/07/mega-explainer-the-ridership-recipe.html

Regional and state planning

ODOT is interested in easy access to more and higher quality transit ridership data through a standardized format used by all Oregon transit providers. This data should be generated with a spatial component, typically at the route level and higher levels of aggregation, and sometimes at the stop or stop cluster level (see the discussion of GTFS-ride). ODOT is interested in ridership data aggregated by these geographic areas: statewide, urbanized area, urban cluster, county, ODOT transit region, and corridor.

ODOT's modelers are interested in *passenger miles traveled* (PMT) and ridership by route and time of day and in understanding of impacts of transit investments. For their analysis, they need to know what portion of Oregonians use transit and the average number of transit trips per Oregonian. It is important to know which rides provide access that would not otherwise be available and to identify under- and over-performing transit segments. ODOT's modelers also have an interest in the impacts of greenhouse gas emissions (GHG) and congestion from public transit. Building an understanding of the state transit network involves learning the relationships between travel demand, transit capacity, and transit use.

Passenger surveys can supplement ridership data. Surveys can capture valuable data points on rider characteristics (age, disability, veteran status, income, etc.), trip purpose, and alternative travel choices.

National Transit Database (NTD) reporting

The most commonly reported reason for using APCs is to comply with NTD reporting. NTD requires transit agencies receiving any federal funding to report a variety of details about their services. "Full Reporters," urban agencies with thirty vehicles or more and/or fixed guideway systems, are required to report passenger miles traveled (PMT), which means they are required to collect both boardings and alightings. Traditionally this has been measured by human counters, using statistical methods to estimate annual boardings and alightings.

APCs offer an automated solution to an otherwise labor-intensive requirement. However, APC accuracy can be dependent on a number of variables that may be specific to agencies. To account for the variability, NTD requires each agency to validate its APC system once every three years[3]. The validation process requirements include:

- Manual counts of half the trips in the system, with a minimum of 15 vehicle trips required. No more than 50 vehicle trips are required to be sampled.
- The routes must include some heavy ridership routes, a variety of vehicle modes, and a variety of APC models where applicable.
- Manual counts must be done by a human who is not the driver, although using recorded video to count is allowed.

[3] 2020 NTD Policy Manual https://www.transit.dot.gov/ntd/2020-ntd-reporting-policy-manual

- Unlinked Passenger Trips (UPT) (i.e. boardings) and PMT collected through manual counts must be within five percent of the values collected by the APC system.
- If 98 percent of the data or more is kept, the data may be presented as complete and submitted to NTD. If two percent of the data or more has to be thrown out (more common), the data has to be run through a statistical model to estimate UPT and PMT.
- Agencies must validate their systems before they can be used for NTD reporting and again on all years divisible by three thereafter.

The above validation requirements can sometimes be as onerous as using manual counts alone. For larger agencies, the labor costs saved on non-validation years can be significant. Some smaller agencies have indicated that the additional cost and complication of validating the system are enough that it is more cost effective for them to continue with manual counts. Still other agencies may get benefits by working with an APC vendor to help them through this process.

Accuracy of counts

Generally, APC accuracy is measured against manual counts. Since a major incentive for APCs is NTD reporting, NTD standards are commonly used to determine what is accurate. NTD requires <= 5 percent discrepancy between manual counts and APC counts. In other words, if manual counts are considered perfect, 95 percent or better accuracy for APC is considered sufficient. Important to note for accuracy is also the overall sampling rate. If 98 percent or more of all trips are captured by the APC system, the agency can factor up to 100 percent based on the sampled data. If fewer than 98 percent of all trips are captured, agencies must sample their data using statistical methods, which must be approved by a qualified statistician.

APC vendors all claim that their technology regularly meets the NTD 95 percent reporting accuracy. However, a number of agencies using APC technology reported accuracy issues, to the point where some find APC data unusable for NTD reporting. The discrepancy may be the result of many of the agencies reporting accuracy issues using older, lower quality technology. Some agencies had not fully integrated their systems such as GPS, vehicle/trip assigning, and APC, which may also lead to inaccuracies. Accuracy issues also resulted when units did not receive regular maintenance and calibration, which can be needed more frequently than anticipated due to the rough conditions of travelling on a bus every day, or when other hardware and wiring issues emerged. Another regular cause for inaccuracy emerged when buses would run off their regular routes.

It may not be necessary to equip the entire fleet with sensors. Many agencies are able to generate the required data with 25-50 percent of their fleet equipped, provided the vehicles are assigned to cover the required number of trips to be sampled.[4] The APC software can then provide statistically valid projected values for a wide range of key figures.

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[4] See, for example, TRB's Transit Cooperative Research Program (TCRP) Report 113: Using Archived AVL-APC Data to Improve Transit Performance and Management (http://www.trb.org/Publications/Blurbs/156999.aspx) or

Technology and Methodology

Modularity and components

APC and AFC systems comprise many components or modules. In some cases, agencies purchase all components from the same vendor. In other cases, agencies purchase components separately from various vendors and integrate them together into one system (see discussion of interoperability in the procurement section). Components include:

- Sensors:
  - Infrared beam sensors
  - Cameras
  - Ramp and bike rack sensors
  - Passive bluetooth sensors
- Onboard sensor aggregator
- Farebox, farecard and mobile ticket readers
- Router and wireless connectivity for data transmission
- Analysis software

APC components

Door sensors

Infrared beam breaking door sensors are a standard for APC and are generally reliable on buses with standard-sized doors. However, they may be inaccurate when placed in wide doors. There is also some risk of inaccurate counts in very crowded conditions. Most beam sensors provide a passenger count, with no information on characteristics of passengers. Some providers have begun offering infrared arrays that do provide some rider characteristics. For example, one vendor provides an infrared array that measures objects' relative distance to build a 3D image of the doorway. This allows for monitoring in crowded conditions, distinction of passenger type based on height, and recognition of objects such as bicycles and wheelchairs.

Cameras

Cameras create a 3D array that tracks people going in and out. They can track movement across wide doors with multiple people moving in both directions. This can be useful for vehicles that have wide doors, such as those operated on LRT, BRT, or subway services. Some cameras can detect information about users, such as recognizing a wheelchair or someone boarding with a bicycle.

Camera-based systems tend to be more expensive, but the cost is often offset by the fact that a single camera is required for a wider doorway where otherwise two or more sensors would be required. Cameras also have a more difficult time counting passengers in low light settings. There are few transit agencies that use these, especially in the US, creating some fear around the risk of using technology

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TRB's Transit Cooperative Research Program (TCRP) Synthesis 77: Passenger Counting Systems (http://www.trb.org/Publications/Blurbs/160654.aspx).

with a limited track record. Cameras have nevertheless been successfully implemented by some transit agencies.

Ramps and bike rack

Knowing at which locations passengers boarded with a bike or a wheelchair can give planners a better understanding of their riders' needs. There are a several types of technology that can collect this information. A connection to pre-wired onboard signals (if installed) is often sufficient. Some more sophisticated APC units such as the infrared arrays and cameras may recognize bicycles and wheelchairs as they pass through the door, as described above. For many agencies, it is specifically useful to know when bike racks and wheelchair ramps are deployed.

Metro Transit (Minneapolis, MN) worked with a vendor to run a pilot installing bike rack sensors on their buses.[5] Magnetic sensors were attached to each wheel arm and tray in Sportworks[6] two-place bike racks. A wire travels through the bumper and connects to the radio cabinet and data is transmitted with all other vehicle and passenger data. In some cases this data can be incorporated into the real-time data feed for passenger-facing applications, providing riders with information about bike rack availability or bus crowding.

Wheelchair lift/ramp operation sensors can record ramp usage for historical analysis and optimization of schedules. Knowing which stations have more ramp deployments can also help prioritize stops for ADA enhancements.

Passive Bluetooth-enabled device tracking

Bluetooth-enabled mobile devices that transmit a unique ID can be tracked to understand traveler flows. With the installation of onboard bluetooth sensors, it is possible to passively track where passengers board, alight, and transfer. In order to protect privacy, device IDs generally are not and should not be attached to passenger identities. Since not all travelers carry bluetooth-enabled devices or leave bluetooth turned on, this method tracks only a subset of travelers. Therefore, this method would not meet thresholds for NTD reporting purposes, but could still provide useful data for planning purposes. Total flows can be extrapolated through other datasets such as from APC. Some mobile ticketing apps that utilize a passive bluetooth beacon as part of the validation process can provide additional information such as ticket type.

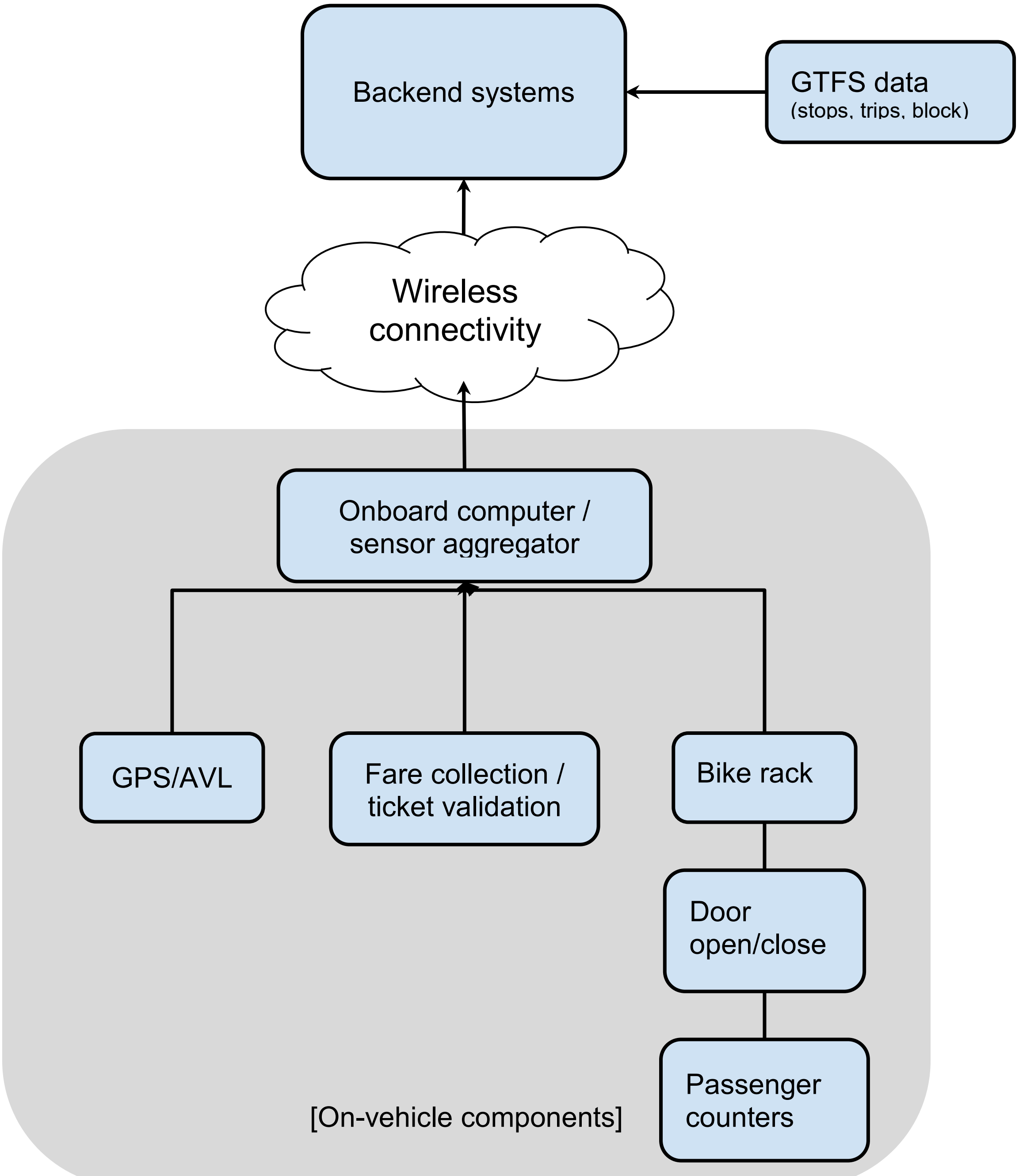
Architecture

Here are two possible options for modular APC data architecture with benefits and drawbacks:
#1 Integrated with onboard AVL: Passenger count and AVL data is synthesized in an onboard computer.

> *Disadvantages:* It may be unclear which vendor is responsible for an APC failure. An ITS integrator might not prioritize APC issues among other subsystems.

[5] https://bit.ly/2K5DH8J
[6] https://www.sportworks.com/about-sportworks/blog/integrating-bike-rack-usage-with-automated-passenger-counting

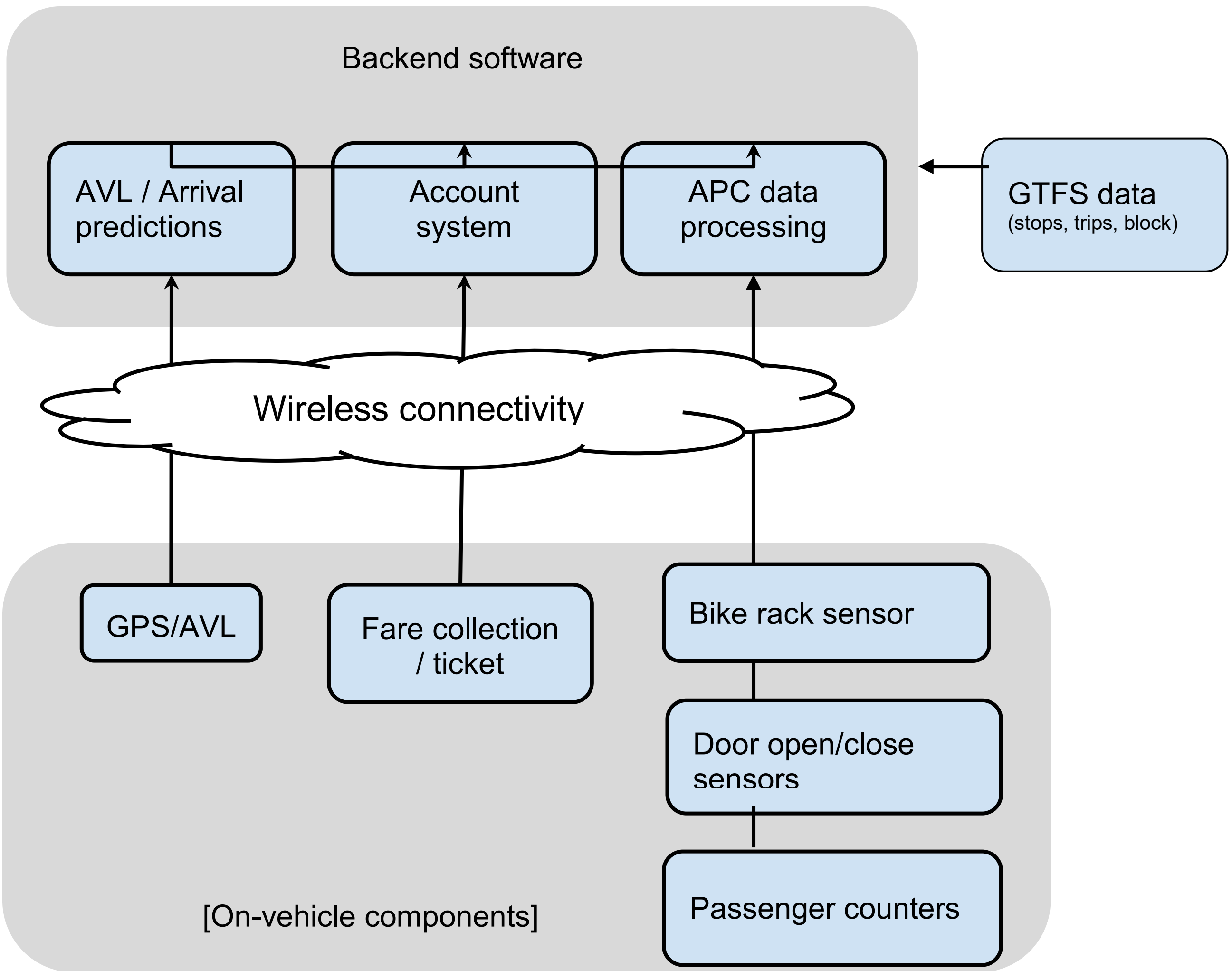
Advantage: Less redundancy of systems



#2 Stand-alone APC: APC device or system that may include its own CPU, GPS, and time tracking system. A common wireless connection might be used, or each system may have its own wireless connection.

Disadvantage: Redundancy of systems.

Advantage: An APC vendor might be able to provide better data and support since it is their area of focus.



From raw data to useful reports

There are a number of steps between the collection of raw data and the production of useful reports. These steps may differ slightly depending on the type of APC system. In general, passenger count data is collected by the sensor(s) along with GPS locations and time stamps onboard each vehicle. The recorded data is offloaded, usually via a wireless connection, to a central server. At this point, the data can be matched against the schedule (for example, a GTFS feed) to allow for reporting of ridership by route, trip, stop, and many other criteria such as on-time performance.

Raw data can be unwieldy. Various vendors that process raw data into useful reports. Some just offer the software for analyzing raw data, while others also offer consulting support to utilize the data. The data can lead to many types of reports, but in general agencies are interested in UPT, PMT, and on-time performance split by some combination of system/route/stop and days of the week/time of day.

Fare collection

Fare collection and ticket validation systems (Automatic Fare Collection, or AFC) provide another source of passenger data. These systems may provide some types of information that APC cannot provide, such as:

- fare type (e.g. pass vs. single-ride)
- fare category (e.g. adult, senior, youth, low-income, disabled, etc.)
- fine-grained travel behavior, including origins, destinations, and transfers, also called ODX (see below discussion)

Fare collection systems *alone* cannot count:

- Passengers that evade fares
- Alightings, since most fare collection systems collect data when passengers board, not when they alight (for example, they require the passenger to “tap-on” only but not “tap-off”)

Fine-grained origin, destination, and transfer (ODX) and traveler flow data can be available from tap-on/tap-off farecard systems, and by deriving destinations and transfers from data from tap-on only systems. Destinations and transfers are derived through analysis of traveler behavior over the service day. For example, the destination of an earlier outbound trip can be assumed to be the origin location of a later return trip. Using this method, it is not possible to derive destinations for 100 percent of trips, but it is possible to derive destinations for a majority of trips with sufficient confidence to study traveler flows. With mobile apps, ODX accuracy can be enhanced if riders consent to GPS tracking for active tickets, but this does cost the user battery power and some mobile OS’s now terminate background applications that are consuming power.

A final project summary for the “TriMet Ridership and Effectiveness Analysis” prepared by IBI Group and Trillium in June 2018 provides more information about this methodology and available tools.[7]

APC vs AFC data

APC and AFC systems each provide different data for analysis. Their datasets can be analyzed together to provide the most complete picture of traveler behavior and service utilization. The data from the systems can be compared for validation purposes: to see if an APC system is correctly

[7] To request a copy of the report, please email: aaron@trilliumtransit.com.

calibrated and producing correct information, or to track fare evasion rates.[8] Schedule data, such as GTFS, can also be used by APC and AFC systems to tie data to specific stops, routes and trips.

Manual surveys provide a different set of data that tends to focus in on a point in time and must be extrapolated, but which can provide much more detail and context if transit riders are asked trip purpose or demographic questions.

This table provides some of the differences between capabilities of APC and AFC:

	APC	**AFC**
Boardings *by stop, trip, and route*	✓	✓
Alightings *by stop, trip, and route*	✓	✓ *Only for fare systems that require tap-off with fare media
Passenger trips by origin-destination		✓ *For fare systems that require tap-off. In other cases, a destination of a trip can be inferred through the boarding stop on the subsequent trip.
Fare categories *e.g. Adult, Senior, Youth*	* Some APC can differentiate between adults and children based on height, or recognize wheelchairs and bikes. Onboard sensors can record when the wheelchair ramp or bike racks are used.	✓
Transfer behavior *i.e. tracking when passengers alight and board another vehicle*		✓*only when fare media (i.e. unique card ID) is tracked
Anonymized individual travel behavior patterns		✓* subject to anonymization and privacy practices

AFC data can also include other useful data APCs cannot capture such as:

- Ticket or pass purchase date
- Activation date
- Agency
- Purchase method
- Customer name or demographics (note that this represents sensitive personally identifiable information or PII which needs to be carefully managed)

[8] "Better boarding, better buses: streamlining boarding & fares" (https://nacto.org/wp-content/uploads/2017/02/NACTO_Better-Buses_Boarding.pdf)

Manual passenger survey methods

Many agencies employ a manual method of passenger counting with traffic checkers using pencil and paper or hand-held units. Often a manual passenger count is also a good time to perform on-board surveys to gather more information about riders. Although not every rider needs to be surveyed, every rider should be counted to determine what percentage of riders were surveyed. Total ridership count can also be used to weight collected data.[9]

Many transit vehicle are equipped with security cameras that record activity at the vehicle doors. Manual counts can also be conducted by reviewing and counting passengers using security camera footage. Advantages of using security cameras include reduced commute time and complications for staff, the ability to fast forward in between stops, and the ability to slow down footage at busy stops that may otherwise be difficult to count accurately. This method does not allow the staff person to conduct on-board surveys to gather additional information simultaneously.

ODOT is interested in using passenger surveys to supplement passenger count data. In particular, ODOT is interested in the collection of rider characteristics (age, disability, veteran status, income, etc.), trip purpose, and travel of choice if transit is not available.

More info about survey methods is available in the ODOT On-Board Passenger Survey Guide: https://www.oregon.gov/ODOT/RPTD/RPTD%20Document%20Library/On-Board-Passenger-Survey-Guide.docx.

[9] ODOT On-Board Passenger Survey Guide

This table compares what can be captured through automated versus manual methods:

	Automated Data (APC/AFC)	Manual On-board Origin-Destination Survey
Sample Rate	Continuous	No set schedule
Population Sampled	System-wide, capturing all vehicles with APCs and/or all farecard users	Targeted corridors or full system; randomly approached passengers who opt in
Trip Purpose	Not available	Yes
Travel Scope	Origins and destinations are transit stops only. APCs do not connect boarding and alightings to a complete passenger journey. AFC may not include alightings.	Includes full trip O/D (not just transit stops) and access/egress mode to transit stops.
Data Availability	Can be near immediate. Depends on data transfer and analysis software.	Within weeks of survey completion. Data cleaning, weighting done manually.
Longitudinal Analysis	Possible system wide	Only possible for corridors with repeated sampling
Demographic Information	None, possible for AFC if the information is tied to farecard and properly anonymized.	Captured

Uses of data

The data described above can be valuable for agency planning and tracking analysis. The major published studies on fare data analysis fall into three categories, according to a literature review on the subject in 2011 by Pelletier[10]:

- Strategic planning (travel time analysis, demand forecasting, mode choice, user behavior, and ridership profiles)
- Tactical planning (trip data, pattern behavior, service adjustments, origin-destination data, journeys, and transfers)
- Operational tracking (revenue, crowding, provisioning better travel time and load information to customers, and equipment performance and maintenance).

Data management - GTFS-ride

GTFS-ride is an open, fixed-route transit ridership data standard developed through a partnership between the Oregon Department of Transportation and Oregon State University. GTFS-ride allows for improved ridership data collection, storing, sharing, reporting, and analysis.

[10] "Smart card data use in public transit: A literature review" by Marie-Pier Pelletiera; Martin Trépanier; Catherine Morency. https://doi.org/10.1016/j.trc.2010.12.003

This standard uses the required elements of GTFS and adds files necessary for ridership data standardization and reporting. GTFS-ride allows transit agencies to share their ridership data with other agencies and organizations interested in collecting and analyzing ridership data.

The GTFS-ride project plans to create open source software tools that provide immediate value for transit providers that create GTFS-ride data. With these tools, planners can see how well transit networks are functioning and also easily access specific information about where riders tend to board and alight.

Specification: https://github.com/ODOT-PTS/GTFS-ride
Project Information: http://www.gtfs-ride.org/
Applications: http://webhub.gtfs-ride.org/

GTFS-ride tools will provide the following functionality:

- Validate GTFS-ride feeds
- Enter GTFS-ride feeds into a central data repository
- Create new GTFS-ride feeds
- Run analytics on ridership data contained within the data repository
    - Reports
        - Aggregate ridership
        - Performance report
        - Density report
    - Aggregation levels
        - System
        - Route
        - Stop
        - Trip

Case studies: Agency experiences with passenger counting

Seven agencies using APC technology were interviewed near the end of 2017. To make the case studies as relevant to an Oregon context as possible, Oregon agencies with APCs already installed, TriMet and Salem Cherriots, were included. Other agencies were chosen because they are not in major metropolitan areas, to reflect most of the agencies in Oregon that may use this report.

Interviews inquired about the user experience and data reliability experienced by the various agencies, as well as determining the operational and planning purposes for the data. When possible, agencies also provided the cost of acquiring and maintaining the system. These cost estimates often did not include internal staff time estimates.

Agency profiles

Agency (Person interviewed)	Location	Fleet Size*	Vendor and technology timeline
Cherriots http://www.cherriots.org/ (Ted - planner)	Salem, OR	64 buses 2,999,022 annual UPT APCs installed on about 80% of transit and express service vehicles, not on regional buses.	2011/2012: IR beam breaker APCs. Buses do not currently have an AVL or CAD system installed.
Blacksburg Transit http://www.btransit.org/index.aspx?page=791 (Tim Witten - ITS manager)	Blacksburg, VA	46 buses 3,483,014 annual UPT APCs installed on all buses, but sensor technology varies.	2006 /2007: IR beam breaker APCs installed. 2012: switched to a top beam array with a different vendor. Blacksburg uses a different vendor for ITS purposes including AVL.
Lextran http://www.lextran.com/	Lexington, KY	62 buses 3,783,730 annual UPT	Contracts with a single vendor for all ITS needs, including APC, AVL, and all software and reporting.
CityBus http://www.gocitybus.com/	Lafayette, IN	69 buses 4,765,538 annual UPT	2002: first APCs installed Currently: contracts with a single vendor for all ITS needs including APC, AVL, and software. APCs are infrared sensors, including some of the newer matrix arrays and some older IR beam breakers.
Gainesville Regional Transit System (GRTS) http://go-rts.com/	Gainesville, FL	128 buses 9,698,179 annual UPT At the time of the interview, 56 buses had APCs installed. Ten more were in line to have them added soon.	2011: installed APCs. AVL is provided by a different vendor. Other bus sensors send data twice a minute on other bus features, such as ramp deployment or bike rack use.
LeeTran http://www.leegov.com/leetran (Wayne Gaiter - Principal Planner)	Lee County, FL	58 buses 3,324,256 annual UPT Started with a 6 vehicle pilot, now all vehicles have APCs	2007: began installing APCs 2012: all buses have IR APCs Another vendor is used for other ITS options and software.
TriMet	Portland, OR	648 buses	Mid 1990s: began installing

https://trimet.org/ (Mike Gilligan - IT)		59,982,440 annual UPT 143 light rail cars 40,198,185 annual UPT Older vehicles from 80s (light rail cars) do not have APCs; all others do have them.	APCs 2001: Contracted for APCs 2008: Same vendor contracted for CAD/AVL

*Bus numbers are vehicles available for maximum service, per NTD 2016 agency profiles. Does not include demand response.

User experience and data reliability

Cherriots

The APCs Cherriots have used have been very unreliable. When compared with manual counts, the numbers do not fall within a margin of error. The technology tends to break regularly, and counts drivers as they board and alight. The agency now uses farebox counters instead.

Blacksburg Transit

The data from the APCs has not been good enough for NTD reporting. The biggest problem is that certain stops have very large volumes of people boarding and alighting. The older beam breakers did not work as well as the overhead arrays because of interference from the bus door. The sensors are still shaken up from bus operations and need to be calibrated every few months. Farebox data has generally been more reliable.

CityBus

Data has been reliable. The IR matrix array is much more accurate than the older beam breakers.

GRTS

Data from APCs has been very useful, but unusable if buses stray from their regular routes.

LeeTran

The agency has been satisfied with APC accuracy. One vendor's software has been more user friendly, offers more canned reports, and is easier to use for data sharing with other departments. However, the other vendor offers greater flexibility.

TriMet

Overall data is good however there are frequent bugs where sensors stop reporting data, bad wiring switches boardings and alightings, or invalid numbers appear, for example if boarding and alighting numbers do not match up. Maintaining good data requires regular spot-checking. The schedule matching process often requires post processing for reports and does not work at all with light rail. An internal IT person was required to do this post processing and script writing; the vendor did not provide it.

Use of data

Cherriots

Passenger counts are used to allocate stop amenities and to change stop spacing or to consolidate stops. The data is included in an annual planning process along with data on missing coverage, route frequencies, survey data, and complaints. Passenger data is also used to respond to complaints.

Blacksburg Transit

The main use of passenger counts is to understand stop demand and make determinations around stop amenities and locations as a result. For example, during a construction project, stop demand helped inform whether stops were moved or eliminated and the level of outreach necessary for different stops.

LexTran

Data is primarily used for NTD reporting.

CityBus

Passenger counts are mainly used for stop planning, and not as much for route planning. They help determine stop amenities and when to move or eliminate stops. Data is also used for NTD reporting.

GRTS

The most important use of passenger counts is NTD reporting. APC data is also pulled to determine on-time performance, which is then coordinated with operations to alter route timing. Passenger counts are used to advise notifications and temporary stops when the regular routes have to be detoured during construction. Other sensors are helpful to prioritize stop amenities, especially to support ADA access and access for elderly transit users. Bike sensors help determine where to deploy buses with newer three-position bike racks.

LeeTran

The data is not used for NTD reporting because the process is too onerous for the fleet size. APC data informs schedule adjustments, stop alterations, stop location changes, and route alignment changes. New routes are sometimes run as pilots with APC data used to evaluate them. The data is frequently shared with municipalities and other third parties.

TriMet

APC data is used for NTD reporting. It is also used to help decide where to install bus shelters and when certain routes are overloaded and need additional trips. On-time performance helps schedule more appropriate dwell times.

Cost

Accurately assessing costs is complicated because prices vary based on fleet size and which services are bundled together. Many agencies did not have cost information readily available. Cost descriptions from two agencies are provided below.

Blacksburg Transit

The Infrared Matrix Array costs about $4,000 per bus to acquire and install. Software services for interpreting APC data are about $1,000 per year.

The full package ITS device costs about $4,000 per bus with a license. Software services for the ITS cost about $550 per vehicle per year.

LeeTran

The vendor charges $10,000 per year for maintenance, updates, and reports. If any amount is not used for maintenance, it rolls over and can be used to purchase new equipment.

Future Plans and other notes

Cherriots

Cherriots is currently working on an ITS master plan that will replace APC devices in the next year. The agency is working with a consultant to investigate APC options and AVL and CAD options.

Blacksburg Transit

The fleet is transitioning to the IR matrix array sensors because of better data quality. Blacksburg has some unique challenges because the overwhelming majority of transit users are students, which creates atypical peak volumes. Students also show ID instead of tapping of farecard, which complicates the use of farebox data.

Blacksburg Transit stores its own data and does its own analytics. This allows for much more data flexibility. For example, all data can easily be made open and available to the public. Blacksburg is also working on developing a load factor rating to warn riders if the bus is getting full. However maintaining data and running analytics internally requires significant staff time and knowledge.

Ticketing & fare collection

A transit organization's choice of electronic ticketing and fare collection systems creates consequences and opportunities in various aspects:

Passenger experience / Mobility-as-a-service	Ease of purchasing and using fares and transit pass products, including across transportation services and payment instruments (e.g. farecards and mobile apps). Payment systems that work across systems can support a more seamless passenger experience, which is frequently referred to as mobility-as-a-service[11].
Operational efficiency	Reduced dwell times (for boarding) and reduced cost for cash management.
Equity	Equal access to all passengers, especially unbanked and low-income riders. Opportunities to analyze traveler behavior — see above on using Automatic Fare Collection.
Flexibility for future changes	The system allows new components (including from other vendors) to be added in the future, to keep up with current technologies and agency and customer needs.

This section discusses fare system features, components, choices, and benefits as relating to the above aspects.

Purposes and benefits

Operational efficiency

Research shows that cash-based fare payment slows down transit operations as boarding customers pay their fares. "Paying a bus fare the traditional way—at the front door, with cash or a farecard—is time-consuming, taking nearly 5 seconds, and occasionally up to 9 seconds, per passenger. …As a result, more rider and driver time is lost on the highest-ridership routes and systems, exactly where transit should be performing best."[12] On busier routes, "the time it takes for a bus to stop in order to

[11] https://maas-alliance.eu/homepage/what-is-maas/

[12] "Better boarding, better buses: streamlining boarding & fares" (https://nacto.org/wp-content/uploads/2017/02/NACTO_Better-Buses_Boarding.pdf). Original citations are Exhibit 6-4, Transportation Research Board (TRB), "Transit Cooperative Highway Research Program (TCRP) Report 165: Transit Capacity and Quality of Service Manual (TCQSM), Third Edition," 2013. Accessed via: http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_165ch-06.pdf
APTA, "Public Transportation Fact Book, Appendix B: Transit Agency and Urbanized Area Operating Statistics," April 2016. Accessed via: http://www.apta.com/resources/ statistics/Documents/FactBook/2016-APTA-Fact-BookAppendix-B.xlsx

load and unload passengers—called dwell time—can constitute up to a third of bus travel time."[13] "On the 11 busiest Minneapolis Metro Transit bus corridors, 32 percent of travel time was spent stopped waiting for customers to board."[14]

Reducing dwell time associated with fare payment is most important on the busiest routes. Off-board fare collection and two-door boarding can reduce dwell time most substantially, but usually requires the most investment. In Oregon, off-board payment is only offered on TriMet's MAX and Lane Transit District's (LTD) EmX.[15]

Even for lower ridership micro urban systems, dwell time for cash fare payment can add up. If boarding takes 9 seconds per passenger, and a route carries an average of 33 passengers per hour, then overall operating time could be reduced by five percent if boarding time is reduced to three seconds per passenger. Operating time can be improved more significantly when it matters most, during periods of peak ridership.

Achieving speed improvements and operational efficiency gains depends on passengers adopting the farecard system; it is not sufficient merely to implement the system. This is why many agencies such as TriMet invest significantly in promoting a farecard system.

Another aspect of improved operating efficiency is due to reduced driver responsibilities and distractions. Automated fare collection and passenger counting "reduced transit operator and rider interaction" [TCRP 125]. Agencies can also expect increased timeliness, accuracy, and equity in reconciling, allocating, and settling revenues to agency partners [TCRP 125]. Studies have shown that improvements to fare systems can lead to less concern over fare evasion and less instances of fare evasion [NACTO]. Despite initial investments, automated fare systems can even improve an agency's bottom line.[16] Cash payment in particular is a source both of expected and unexpected delay, adding hidden costs in the form of longer scheduled dwell times and layover times.[NACTO] Discontinuing cash fare payment has saved Transport for London nearly £26 million annually.[NACTO]

Overall, reducing dwell time related to fare payment can lead to more competitive travel times, reduced operating cost, greater reliability, and increased ridership.

Equity

Automatic fare collection allows transit agencies to institute fare capping. Fare-capping means that a passenger purchasing individual fares would not end up paying more than an unlimited ride pass for

[13] "Better boarding, better buses: streamlining boarding & fares" (https://nacto.org/wp-content/uploads/2017/02/NACTO_Better-Buses_Boarding.pdf)
[14] MetroTransit, "Arterial Transitway Corridors Study Summary," April 2012. Accessed via: www.metrotransit.org/Data/Sites/1/media/pdfs/atcs/atcs_ summary.pdf
[15] https://www.oregonbusiness.com/article/item/18058-the-bus-is-back-eugene-expands-its-emerald-express-bus-rapid-transit-system
[16] http://transitcenter.org/2016/11/16/weve-seen-the-future-of-transit-fares/

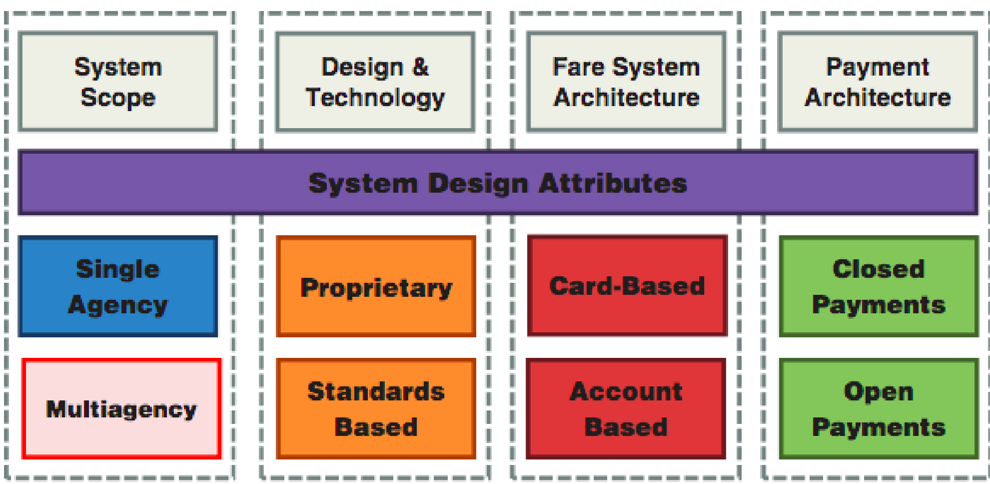
the same time-period. For example, if a monthly pass costs $100 and a single ride costs $2.50, a transit rider would no longer have to pay for fares after riding 40 times ($2.50 * 40 = $100). Low-income riders may not be able to afford the upfront cost of monthly or yearly passes or cannot justify the risk of the purchase if they end up using the full value of the pass. As a result, they pay more for transit than higher income riders do. Fare-capping makes the savings offered by transit passes available to low-income riders.[17]

Rider convenience

Use of mobile apps and fare cards can make paying for tickets easier and more convenient for riders. In multiagency fare systems, riders benefit from the enhanced convenience of being able to use a single fare instrument to access regional travel.[18]

System Design

TCRP Report 117, *Preliminary Strategic Analysis of Next Generation Fare Payment Systems for Public Transportation*, identifies four transit fare payment system design attributes[19]. This illustration is from the report:



- ***Transit system scope:***
  - **Single agency**
  - **Multiagency:** a lead transit agency with partners, or regional authority.
- ***Design and technology:***

[17] https://usa.streetsblog.org/2018/03/09/the-case-for-fare-capping/
[18] National Academies of Sciences, Engineering, and Medicine. 2017. TCRP Report 125: *Multiagency Electronic Fare Payment Systems.* Washington, DC: The National Academies Press. https://doi.org/10.17226/24733.
[19] National Academies of Sciences, Engineering, and Medicine. 2015. TCRP Report 117: *Preliminary Strategic Analysis of Next Generation Fare Payment Systems for Public Transportation*. Washington, DC: The National Academies Press. https://www.nap.edu/read/22158/chapter/1

- **Proprietary system or design**: a transit fare payment system in which the design and technology are developed and owned by a contracted manufacturer and sold or licensed for use by a transit agency. Proprietary-design based systems tend to have a low level of interoperability.
- **Standards-based system or design**: a transit fare payment system in which the design and technology follows public, non-proprietary standards and specifications established for the financial payments industry. Well-managed standards-based systems tend to have a high level of interoperability, and have been independently tested to confirm compliance.

- ***Fare system architecture:***
  - **Card-based**: a transit fare payment system in which fare value is carried on the fare medium itself.
  - **Account-based**: a transit fare payment system in which the fare medium (such as a card of virtual mobile wallet) serves as to associate the rider with information held in a separate account. No fare value is carried on the fare medium itself.
- ***Payment architecture:***
  - **Closed payment (closed loop) system**: a transit fare payment system that uses fare media that can only be used within a single transit system or partnership of transit systems. All proprietary fare payment systems are closed loop systems.
  - **Open payment (open loop) system**: an account-based transit fare payment system that is able to accept third-party payment media such as bankcards and mobile device as its fare media. All open payment systems are both standards- and account-based systems.

Example system - Hop Fastpass

In July 2017, TriMet, along with C-TRAN (Clark County, WA) and Portland Streetcar, launched Hop Fastpass (i.e., "Hop") as the Portland region's first electronic transit fare payment system. Hop Fastpass is a "Multiagency - Standards-based - Account-based - Open payment" system. This combination offers the greatest potential flexibility for transit agencies and riders. The Hop system also includes features such as:

- Open Application Programming Interfaces (APIs)
- Virtualized (mobile) fare cards, including stored value
- Fare Capping

Hop Fastpass provides a basis for a publicly-managed and operated payment platform for mobility-as-a-service, in large part because the multiagency and open payment features would allow other modes such as transportation network companies (TNCs) and bikeshare to be included in the system. Hop could also support other transit services.

For more on Hop Fastpass, see "Lessons from TriMet's Hop Fastpass", an interview with Tim McHugh and Rhyan Schaub.

Fare Validation Methods

AFC systems offer new challenges and opportunities in fare validation. Beyond traditional validation methods like visual inspection by drivers, fare instruments such as electronic farecards or virtualized farecards or tickets on a mobile phone can be validated using hardware and software that assess their validity and authenticity. Different system types provide various levels of protection against fare evasion or fraud, and various costs and benefits to riders and the agency. Agencies should weigh risk, benefits, and costs to decide which approach to use to check for validity and authenticity.

Two technical approaches are primarily used for validation of electronic fares: **automated agency-owned device-based (#1)** and **rider-owned device-based (#2) validation**.

Approach #1: Automated agency-owned device-based validation

Fare instruments are validated by onboard hardware, which is connected with the agency's back office system. This allows for in-the-moment synchronization with backend systems, meaning tickets can be checked for authenticity (i.e. forged tickets will be identified), passenger data is recorded, and rider account balances can be updated. Because this approach relies on equipment owned or under the control of the agency, it offers more security but also has increased costs.

Some automatic validation systems may include hardware that works with multiple fare types, including contactless bankcards (cEMV).

Mobile-phone based tickets face some limitations that farecards do not. There is potential for NFC to be used for automatic validation of mobile tickets, but as of January 2019, the data standard is not fully standardized in Android phones, and is kept restricted in Apple phones. There is therefore no open standard for third-party developers to work with to create validation systems using NFC. At this point, NFC has only been used for automatic validation in cases where Android and Apple have worked with companies to create "virtual smartcards."

Bluetooth LE has not been used for automatic validation, because of reliability issues and because it requires a phone's Bluetooth to be turned on.

Approach #2: **Rider-owned device-based**

This approach uses a mobile application with tickets that are first activated, either by the rider or by passive beacon technology, and then visually validated by the vehicle operator.

"Passive" beacon technologies provide one automated check to help validate tickets during boarding. Hardware can include devices such as an NFC responder, a short-range Bluetooth Low Energy (BLE) beacon, a barcoded sticker, or even a sticker with an alphanumeric code affixed to a transit vehicle or boarding point. These passive tags or beacons prompt the activation of a mobile ticket, a step that verifies that the application correctly responds to these inputs.

Manual inspection: A vehicle operator or fare inspector review the activated mobile ticket to confirm its validity. Various approaches can be used to establish the validity of a ticket:

- Animations
- Sound effects
- Changing (e.g. day-specific) images or animations

Data transmission and collection: Data about the transaction is captured on the rider's mobile application, and later transmitted to the agency's back office system. This reliance on individual rider's devices introduces the potential for lost data if the phone does not reconnect to the backend system, or fraudulent data if the user is able to manipulate the application.

In addition to data on ticket activation and usage, boarding and alighting locations can also be inferred by sensing proximity to a bluetooth passive beacon.

CAD / AVL Integration

Agencies that are interested in enhancing validation data with exact bus or route information need to have some sort of integration with either the AVL system or with a GTFS feed. Validation and back office systems can be integrated with either to provide accurate validation data that includes vehicle, stop, and schedule (trip/route) information.

Recommendations

The following sections offer an overview of how to plan for, procure, implement, and operate an APC and/or an AFC system. Because of the differences between APC and AFC systems, some of the recommendations below only apply to one or the other.

Planning and design

There are many things to consider when implementing a new APC or AFC system or modifying an existing system.

Procurement and maintenance of these systems may be supported by multiple entities, including the agency's own staff, one or more vendors, and consultants. Many vendors offer technical and software support as part of their services. Some agencies prefer to do this work with in-house staff, especially larger agencies that can afford specialized IT personnel. If an agency wants more technical assistance, it can hire an outside consultant. Consultants can assist with system design, integration, implementation, maintenance and/or data processing. Agencies may use a variety of resources, for example, sourcing their hardware from one vendor, relying on internal staff for routine maintenance, and engaging a consultant for data analytics.

Below are suggested steps to take when planning for an APC and/or AFC system.

1. Consider objectives. Is the primary objective to provide a better passenger experience? Is it to improve on-time performance or operational efficiency? Is the objective to comply with reporting requirements? How might passenger data be used? How important is designing for modularity and preventing long-term single-vendor lock in? There will likely be multiple objectives; it is useful to rank them and distinguish between core objectives (most important) and nice-but-nonessential (least important).

Answering these questions fully will help to guide system design. Providing this information to potential vendors in a procurement instrument will give them clear guidance on core objectives while also allowing them freedom to propose diverse approaches.

2. Identify and document existing resources, including:

- Technology. This inventory should include manufacturer and model for hardware, and, if applicable, available interfaces, APIs, or data formats for connections to other systems. This information is useful and necessary to decide which systems to replace and which to retain and integrate. This is a determination that could be made by the agency before procuring the system, or by a proposing vendor or system integrator based on cost efficiency or value recommendation. Existing agency technology and data may include:
    - CAD/AVL or on-board GPS
    - On-board connectivity [Many modern ITS routers include GPS functionality, which can be distributed via an Ethernet backbone.]

    - Schedule and stop data, e.g. GTFS, HASTUS or others
    - Existing APCs
    - Existing fare systems (e.g. app-based fare payment)
- Available staff time and relevant expertise for transit technologies.

3. Consider an industry survey in order to develop understanding of possible solutions the marketplace can offer, including state-of-the-practice and state-of-the-art solutions. This can take the form of a Request for Information (RFI) or a more informal survey. In addition, informal interviews with vendors and consultants, prior to the release of an RFP/RFQ, can yield insights and provide a chance to test ideas and hone thinking. This is an opportunity to signal needs, priorities, and intentions to potential vendors before the release of an RFP/RFQ, which may improve the quality and/or breadth of responses.

Conducting a broad survey makes it possible to benefit from current industry perspectives, and having conversations with vendors in a way that is fair and open, because an electronic survey with broad distribution and many respondents can be conducted without excessive effort. Free electronic forms such as Google Forms, SurveyMonkey, or SoGoSurvey are some useful tools (among others).

The survey might ask for:

- Descriptions of the products offered by the vendor
- Recommended requirements to specify in an RFP, and why
- Recommendations of what NOT to put in an RFP, and why
- Whether the vendor is able to do a limited-scale pilot, and at what cost
- Open-ended comments

The survey introduction also might supply information and statements such as:

- Background on the anticipated procurement process
- The agency's priorities and objectives for the project
- A note that explicitly positions the survey outside of the official procurement, e.g. "A response to this survey is not necessary to be eligible to respond to any RFP that may be released. Responses to this survey will not factor into any later proposal scoring process. No statements made by [agency] during this survey process shall constitute a later commitment for this project or any procurement process."

For an example of an industry survey that followed the above process, see this survey instrument for ride-matching software conducted by the Vermont Agency of Transportation: https://goo.gl/forms/CvXEzuiGSzTS9BZw1 or this survey conducted by PVTA for paratransit scheduling software: http://www.sogosurvey.com/preview.aspx?k=YsYYVSXsR.

The survey can be distributed to a list of vendors (see vendor survey for some possibilities) and to mailing lists.

Summarize responses from the electronic survey, and schedule follow up calls with respondents with compelling perspectives or whose responses generate additional questions.

Finally, synthesize lessons from the industry survey: Are there new opportunities or notes of caution to consider? Some respondents may offer recommendations that are at odds with one another. The procuring agency will need to either make a determination of which respondent is more trustworthy, or decide to side step the question and avoid specifying a requirement in the procurement instrument.

4. Assess and prepare for capacity to maintain the system. Consider the tasks which would not be performed by the vendor(s)/consultant(s), or which will need significant input and participation from the agency staff. What does ongoing support for an APC or AFC system typically mean for agency staff (drivers, operators, and planners)? Potential for staff turnover and training time should be evaluated. If there is limited staff time, specify requirements to make the best use of available staff time. Potential new tasks for transit agency staff might include:

- Ongoing monitoring to ensure accuracy and reporting of all ITS components.
- Reviewing system reports to track key findings and offer suggestion to optimize service and rider experience.
- Training new drivers/dispatchers to use the system.
- Hardware maintenance - road calls, RMAs to return equipment, equipment replacement.
- Monitoring count quality.

For agency experiences with these tasks and associated time, see the Agency experiences section.

5. Prepare for the procurement or pilot(s) by synthesizing requirements out of the above steps.

Procurement

Depending on the components desired, a transit agency may choose to procure a contract with a single vendor or multiple vendors to implement the best value, best-of-breed system. The agency may release several distinctly-scoped requests (procurement instruments) for specific functions and modules or may release a consolidated request that allows vendors to bid on single or multiple component parts. Procurement instruments for distinctly scoped components should require vendor-neutral interoperability through the support of standardized data and APIs. This prevents pre-ordaining an outcome through vendor-specific interfaces.

Procurement can be conducted by a Request for Proposals (RFP) or Request for Quotes (RFQ). A two-step procurement is allowed through the FTA 4220.1F, but Oregon 279b is more restrictive. FTA procurement guidelines that specify, “Recipients are not allowed to divide or split the procurement to avoid additional procurement requirements that apply to the larger acquisitions.”[20]

[20] Federal Transit Administration, “Best Practices Procurement & Lessons Learned Manual” October 2016. FTA Report No. 0105. Page 54 https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/funding/procurement/8286/fta-best-practices-procurement-and-lessons-learned-manual-2016.pdf

Issuing a procurement instrument (RFP/RFQ) is the traditional way of selecting a vendor and purchasing services. Agencies should be cautious of requirements bloat because it may unhelpfully limit vendor responses and the approaches. Requirements bloat can be avoided by: (1) carefully selecting requirements, and (2) avoiding uncritical recycling (copying/pasting) of scopes of work and requirements from previous procurements, as these requirements may be out of date or not be applicable to all agencies.

Many agencies also find that it is useful to conduct a **limited-scale pilot** to "test drive" software and hardware. A limited-scale pilot makes it possible to evaluate a system and a vendor through hands-on experience rather than relying purely on a proposal response for this evaluation. A pilot that is implemented for a limited duration (e.g. for three months) and on a subset of the vehicle fleet (e.g. for one or two vehicles) can allow the transit agency to:

- Discover configuration issues or challenges.
- Test the accuracy of counts.
- Identify connectivity issues.
- Begin assessments of rider demand.
- Test any driver and dispatcher interfaces for effectiveness and ease of use.
- Evaluate reporting function usefulness and ease of use.

A limited-scale pilot could be very useful in testing an APC system but would be more difficult to implement for an AFC system.

A test pilot can be initiated by selecting vendors to provide pilot services within an agency's discretionary purchasing threshold. After the pilot, a successful pilot vendor can be directed to perform full implementation of the APC or AFC system. From vendors' perspectives, it is not reasonable to expect a pilot to be performed at no charge, especially if more than one vendor is invited. To conduct a pilot fairly and thoroughly, allocate funds for the pilot, and there must be dedicated agency staff assigned to the project to ensure it is successfully executed and that the proposed technology is well understood.

At a minimum, the scope of work and requirements in an RFP or RFQ should include:

- Key objectives and priorities (See planning and design)
- Information about relevant legacy systems in use (See planning and design)
- Requirements for modularity and interoperability, as well as requirements dictated by funding source. Core recommended requirements are:
    - Components use standard communication protocols such that they can interface with components from other vendors. This is especially important if the agency already has existing ITS components, such as AVL, that it wishes to continue using. It will be helpful for the project if existing components also support standard data protocols and formats.

    - Configuration with GTFS and/or scheduling software and compatibility with GTFS-ride

If the agency requires or strongly prefers particular specifications or features, these may also be incorporated in the procurement. These may include, for example:

- More flexible AFC system: A standard-based, account-based, open payment system provides the greatest level of flexibility and opportunities for changes and expansion in the future. An agency may wish to require some or all of those components
- Required reports, such as for:
    - Varying levels of location granularity (e.g. stop level/route level)
    - Origin-destination matching (AFC)

Non-essential specifications should be omitted from core requirements and/or listed as optional/desired features. It is recommended to specify fewer requirements to allow proposers more creativity in their responses. A less prescriptive request for proposals and qualifications (focused on objectives, rather than specifications) can yield more respondents and a range of approaches.

To choose vendors, evaluate proposals based on their responsiveness to core objectives and to the experiences of references. It is highly recommended to interview references thoroughly on their experience using the system and interacting with the vendor, and to seek out some clients of the proposing vendors who are not listed as references in their proposal. In particular, it is useful to:

- Verify claims of interoperability and open data: ask references about the success, ease, and cost of integrations with other vendors and systems, for example, using an existing AVL system to provide timestamp and geolocation data for a new APC.
- Ask about implementation and operations/maintenance costs.

Implementation

The details of implementation steps and process will depend on the vendor(s) and system(s) that are selected. In general, implementation steps will include the following:

- Schedule data preparation: If GTFS data is used as an input (as is generally recommended), the GTFS data may need to be modified for use as a configuration input:
    - block_id values need to be present.
    - stop locations, schedules, and patterns need to be accurate.
- Hardware installation: Devices need to be installed on-board the vehicles, either by the vendor, a local installation contractor, or maintenance staff. This is a good occasion to begin maintenance and operations training for hardware.
- Back end payment options (AFC only): The payment options selected need to be established and operational.
- Develop policies (AFC only): AFC offers an opportunity to transition to a proof-of-payment fare system, which offers significant efficiency advantages. It is important to carefully consider fare inspection policies to ensure equitable implementation

    - Train and deploy proof-of-payment fare inspectors for consistent inspection across routes and time of day to avoid targeting specific neighborhoods or communities.
    - Fairness and the safety of both inspectors and riders is paramount; criminalizing riders will not result in an equitable transit system.
- Testing: When the system is implemented, test the accuracy counts and/or the responsiveness of fare payment mechanisms.
- Full public rollout (AFC only): Once the agency is confident in the reliability of the system, announce the system is fully implemented and implement a large publicity campaign to encourage use of the new system. To avoid overwhelming riders, consider the following guidelines for implementation:
    - Deploy the new payment system in stages;
    - Do not deploy the new system until all problems are worked out;
    - Increase outreach and education efforts.

Operation

Once an APC or AFC system is implemented, it needs to be maintained and monitored. These are the ongoing tasks that need to be undertaken:

1. **Keep data inputs up to date:** The data used to match geolocation information in APC data to stops or routes, from the GTFS feed or other scheduling software, needs to be kepts accurate and up to date. This is necessary even during short route changes caused by temporary construction. Otherwise passenger count data during that time will be unusable.
2. **Monitor passenger usage and feedback (AFC only):**
    - Rider acceptance of a farecard system is crucial for the system to provide the desired efficiency enhancement.
    - Collect rider feedback through various survey methods to isolate unexpected challenges and provide solutions.
    - When possible, break down farecard acceptance by demographic characteristics. If a certain demographic has a low acceptance rate (e.g. seniors, people with low English proficiency), the agency can conduct targeted outreach with that community to improve acceptance through increased publicity and/or identify and rectify concerns with the new system specific to that community.
    - As farecards become more broadly accepted, consider discouraging or eliminating cash payments at the farebox to improve operating efficiency. Tracking demographic acceptance of farecards is important here to ensure underserved communities are not disproportionately harmed by this step.
3. **Monitoring APC accuracy:** The system needs continuous monitoring and data processing to ensure that:
    - APC equipment does not malfunction by becoming uncalibrated or because of technical errors.
    - On-board AVL/GPS equipment is operating and reporting locations to properly assign passenger counts to routes and stops.

- Problem spots are addresses and accounted for (e.g. stops with particularly large peak boarding).
- Data anomalies are investigated or removed to ensure data conformity.

4. **Use data for service enhancement:** Passenger count data is required for most agencies for NTD reporting. However, it can also provide agencies with valuable opportunities to improve service. This requires separate assessment and planning processes to determine the best way to apply lessons learned from the data acquired.
5. **Communicate changes effectively:** Changes to the fare system after initial roll out will have a major impact on passengers. It is crucial to offer this information widely, including on shelters, vehicles, related applications, etc.

Recommendations for ODOT & Regional Organizations

The engagement of a regional organization like ODOT in transit technology can be designed to support local priorities, enact state-level priorities, or blend local and state-level priorities. ODOT can be prescriptive or permissive in its approach to technology requirements. A prescriptive approach can help to fulfill region-level priorities. A permissive approach allows transit providers to experiment and to pursue local priorities. Overall, the prescriptive and permissive approaches are not actually mutually exclusive. ODOT can define requirements and create programs related to the most important state-level priorities, while preserving opportunities for local technology choice. For example, one approach might be setting data requirements or guidelines on a regional level (e.g. for GTFS-ride), while also allowing a choice of vendor.

Blending and balancing priorities also requires deciding which functions ODOT should take responsibility for, and which functions local organizations should be responsible for, perhaps with some level of support from the regional organization.

Below are functions and actions the consultant team suggests ODOT pursue.

Standards-setting: Recommend or require APC systems that comply with industry standards for interoperability and AFC systems that use standards-based, account-based, open payment, in order to support system modularity and compatibility with statewide and third-party applications. Education for transit agencies can help them to understand and appreciate the benefits of interoperability.

Regional organizations should be permissive of piecemeal (local) procurement of modular systems. Regional integration can be achieved through modularity and interoperability rather than a top-down or monolithic decision-making model, by pursuing the guidelines and processes outlined in this white paper. This will make it possible for organizations to choose and purchase software and hardware that will work together as an integrated system and establish collaborative systems.

Statewide contracts with standards-compliant vendors: Interviewed transit agencies stated that contracting and procurement was time-intensive. By securing contracts with standards-compliant vendors and allowing transit agencies to purchase through those agreements, ODOT could save transit agencies significant staff hours.

Knowledge sharing: Encourage transit agencies that implement APC and AFC systems to share procurement documents and notes on their experience.

Vendor Survey

Service	Description
ITS system	multiple data collection technologies (possibly APC,AFC,AVL,CAD) that integrates them into one system
APC hardware	sensors or devices used to collect APC data
APC software	software that processes the raw APC data to generate ridership counts
Reporting	software that can generate reports and visualizations from APC data
APC Analysis	software that manages and aggregates passenger data and may provide visualizations
AFC system	devices and software for automatic fare collection

Vendor	**Services offered**						
	ITS system	**APC hardware**	**APC software**	**Reporting**	**APC Analysis**	**AFC system**	**Mobile ticketing**
Avail Technologies, Inc.	□		□	□	□	□	
BEA, Inc.		□					
Bytemark							□
Clever Devices Ltd.	□	□	□	□	□		
Conduent	□				□	□	
Connexionz	□	□	□	□	□		
Delerrok						□	
DILAX Systems Inc.	□	□	□	□	□		

DoubleMap		□	□	□			
Hella Aglaia		□					
Hopthru							□
INIT Innovations in Transportation Inc.	□	□			□	□	
Iris		□					
Masabi							□
NextBus		□	□	□			
Passio	□	□	□	□			
Passport							
RouteMatch Software, Inc.						□	
Syncromatics	□	□	□	□	□		
Token							□
TransitFare & Systems Ltd.						□	
TransLoc			□				
Trapeze Group	□		□	□	□	□	
TripSpark		□	□	□		□	
TSO Mobile	□	□	□				
Urban Transportation Associates, Inc.		□	□	□	□		

Glossary

Americans with Disabilities Act (ADA) - a civil rights law that prohibits discrimination against individuals with disabilities in all areas of public life, including jobs, schools, transportation, and all public and private places that are open to the general public. For transit agencies, this most commonly means ensuring access for people with sight, hearing, or mobility impairments.

Automatic Fare Collection (AFC) - technology that gathers passenger counts and other data from ticket validation as a rider boards.

Automatic Passenger Counters (APCs) - a system of sensors that count passengers boarding and alighting transit vehicles.

Automatic Vehicle Location (AVL) - technology to automatically determine and transmit the location of a vehicle.

Central Processing Unit (CPU) - the hub that processes and combines data from other ITS components to create meaningful correlated data.

Computer-aided Dispatch (CAD) - stores and retrieves data and communicates with vehicle via a data terminal to support in dispatching transit vehicle.

Full Reporter - an NTD classification for a transit agency that receives or benefits from §5307 funding and operates more than 30 vehicles across all modes and types of service and/or fixed guideway or high intensity busway.

General Transit Feed Specification (GTFS) - defines a common format for public transportation schedules and associated geographic information. GTFS "feeds" allow public transit agencies to publish their transit data and developers to use that data to write applications.

GTFS-ride - an open, fixed-route transit ridership data standard that allows for improved ridership data collection, storing, sharing, reporting, and analysis.

Intelligent Transportation System (ITS) - an integrated network of sensors, software and technology to support transportation services. ITS may include GPS, AVL/CAD, APC, AFC, and network connections so buses can send and receive data.

Interoperability - the ability of different information technology systems and software applications to communicate, exchange data, and use the information that has been exchanged.

Limited-Scale Pilot - A limited-scale pilot makes it possible to evaluate a system and a vendor through hands-on experience rather than relying purely on a proposal response for this evaluation. A pilot that is implemented for a limited duration (for example, for three months) and on a subset of the vehicle fleet (for example, for one or two vehicles). Among other things, this can allow the transit agency to test prediction accuracy and identify connectivity issues.

National Transit Database (NTD) - records the financial, operating and asset condition of transit systems in the United States.

Passenger Miles Travelled (PMT) - the total number of miles traveled by all passengers.

Unlinked Passenger Trips (UPT) - the number of times transit vehicles were boarded.

Validation – The process for checking a ticket or fare pass to see if it is valid and authentic, and/or a customer fare account is deemed to be in good standing

List of Acronyms

ADA - Americans with Disabilities Act
AFC - Automatic Fare Collection
APCs - Automatic Passenger Counters
AVL - Automatic Vehicle Location
BRT - Bus Rapid Transit
CAD - Computer-aided Dispatch
CPU - Central Processing Unit
FTA - Federal Transit Administration
GTFS - General Transit Feed Specification
IR - Infrared
ITS - Intelligent Transportation System
LRT - Light Rail Transit
NFC - Near-field communication
NTD - National Transit Database
ODOT - Oregon Department of Transportation
PMT - Passenger Miles Travelled
UPT - Unlinked Passenger Trips