



Unified Transportation Payment Media: Options for Massachusetts

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A Better City improves the economic competitiveness and quality of life of the Boston region by advancing and providing leadership on significant transportation, land development, and environmental policies, projects, and initiatives related to the commercial real estate sector.

Project Manager: Yve Torrie, A Better City

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Executive summary

Overview

Unified payment for transportation can make a significant contribution toward creating a more livable city. A visitor's or new resident's first experience in Boston often involves the transportation system. This experience can include the confusion and time investment of trying to decide what payment medium is required to ride the system, where the medium is obtained, what options are available, and how the medium is used...or travelers can simply use their mobile phone or contactless credit or debit card to board the vehicle, with the payment system computing the best value fare for all trips. Visitors and residents alike can use MBTA, regional transportation authority (RTA), private bus, bike share and other means of urban mobility easily with unified payment: the transportation network appears to be a seamless entity to users. A unified payment system can reduce barriers to use of non-drive-alone options, increase ridership and revenues, increase cost efficiency, and support innovative fare and transportation demand management policies. It can create environmental benefits such as reduced emissions levels, and it can improve equity for lower income residents by allowing access to lower fares and better payment methods. It improves mobility and access for employees and commerce in the region.

This report outlines a possible trajectory from the current, fragmented system to a seamless system through a phased implementation. The initial phase offers partial unification while laying the groundwork for a fully integrated system. The second phase is potentially groundbreaking work, using technology that has been successfully implemented in other locations while applying it to a wider set of services. A fast-track implementation could omit phase 1 and implement phase 2 directly.

Current status

Currently, a large number of payment methods are used for publicly provided transportation services such as subway, bus, commuter rail, parking, toll highways and bridges. Additional methods are used by private carriers. These systems are not generally interoperable across modes and carriers, and often require carrier- or mode-issued media such as Charlie Cards (plastic smart cards), Charlie Tickets (paper tickets) or E-ZPass transponders (for toll payment).

The payment methods for urban passenger transportation services currently used in the Boston area include:

1. MBTA subway, gated stations: Charlie Card and Charlie Ticket. Ticket vending machines (TVMs) that accept cash and credit/debit cards.
2. MBTA subway (light rail Green Line), ungated subway stations: Charlie Card, Charlie Ticket, cash on board.
3. MBTA bus: Charlie Card, Charlie Ticket, cash on board.
4. MBTA commuter rail, downtown terminals: Charlie Ticket, mTicket mobile app, cash on board. Ticket vending machines. Charlie Card not accepted.
5. MBTA commuter rail, other stations: Charlie Ticket, mTicket mobile app, cash on board. Charlie Card not accepted.

6. MBTA boat: Charlie Ticket, mTicket mobile app, cash and credit/debit card. Charlie Card not accepted.
7. MBTA parking: Park & Pay Card (3 stations), PayByPhone mobile app (80 stations), E-ZPass (1 station), cash (all stations), credit/debit card (approximately 20 “pay on foot” stations), town-issued permits (approximately 10 stations). Parking payment varies substantially by station on each subway and commuter rail line.
8. The Ride, which is the MBTA accessible transportation service. The Ride accounts are separate from other transportation accounts and are funded online (with a two day delay), mail (five day delay), phone or in person (one hour delay). No other media are accepted.
9. Other regional transportation authorities (RTAs): Charlie Card and magnetic stripe ticket (10 RTAs); 5 others have their own passes/tickets), cash.
10. Massport Logan Express: credit/debit card, cash (all routes).
11. Massport Logan Express parking: credit/debit card, cash (all lots).
12. Massport Logan Airport parking: credit/debit card, cash. Gold Passport smart card and Exit Express smart card.
13. Private bus operators (e.g., Concord Coach Lines, Plymouth & Brockton): credit/debit card (may be online), cash (all routes; purchase ticket before travel). 7 operators are in the BusPlus mobile ticketing pilot.
14. Suburban/contracted bus systems (Lexpress, Burlington B-Line, etc.): cash, town-issued passes. Some accept Charlie Ticket passes. Charlie Card not accepted.
15. Transportation management association (TMA) and employer bus services. Each has its own payment system: passes, tickets, IDs and others.
16. Commercial urban bus services (e.g., Bridj). Bridj has recently begun operations in Brookline, Cambridge and Boston. Online/mobile ticketing.
17. Mass Pike, Tobin Bridge, tunnels: E-ZPass (backed by credit card, debit card, check or cash), cash at toll booth (moving to cashless in future). Tobin Bridge cashless (E-ZPass or pay-by-mail via license plate recognition).
18. High occupancy vehicle/toll lanes: None at present, but they should be supported by a future payment system.
19. Bike-sharing services (e.g., Hubway): credit or debit card. Charlie Card (no fee) used for MBTA bike cages for individually owned bikes.
20. Car-sharing services (Uber, Lyft and others): Company-specific mobile app linked to credit or debit card.
21. Municipal parking: cash; some cities and towns (e.g., Boston) have smart card systems that operate only within that city or town.
22. Taxi: cash, and credit/debit cards in Boston cabs and a number of other towns. Taxis are outside the scope of this report, although they could be included in the single account discussed in the report.

No single form of payment is accepted by all 22 transportation services. Different services prefer Charlie Card, Charlie Ticket, credit/debit, mobile payment, E-ZPass or cash. Multiple forms are usually accepted, but some have surcharges or reduced transfer privileges to other services. The Charlie Card is not universally the preferred medium for MBTA services (in particular, it is not accepted on commuter rail or boat), and it is not accepted outside the MBTA and some RTAs. Charlie Cards are distributed in-person at limited locations at limited times; this is the best medium for most MBTA users, but obtaining one can be difficult. After a Charlie Card is obtained, a user

must use a TVM and choose the best fare to buy, which may be challenging for new or infrequent users; some fares, such as weekly passes, are not available on Charlie Cards. Charlie Tickets are preferred or required for some services on which Charlie Cards are not accepted, including commuter rail. Multiple mobile payment applications are in use for commuter rail, parking and private bus services. Different parking lots have varying payment systems.

General payment technology

Several new technologies are currently available and are expected to see broad use in general payments in the next few years:

1. Chip-enabled (EMV) credit and debit cards. In October 2015, a major change will occur in the United States payment industry. Specifically, fraud liability rules will change and move risk to organizations if they are still using magnetic stripe cards. In response, most banks are expected to issue chip-enabled cards, and most merchants will upgrade point-of-sale terminals to handle chip-enabled cards. If these newly issued cards support contactless payment, they can be tapped at gate and farebox readers, and they become a feasible option for the MBTA. Transit open payment systems in Chicago, Salt Lake City and London currently use contactless bankcards as their preferred payment medium, with Philadelphia, PA, Washington DC, and Portland, OR, also implementing such systems. In January 2015, New York announced plans for an open payment system.
2. Smart phones with Near Field Communications (NFC), which can emulate contactless credit and debit cards. These devices offer the same advantages as EMV credit and debit cards; they are media that most users will have, so the MBTA avoids the time and expense of issuing them. Payments are secure, similar to credit and debit payments. Their operation at gates and fareboxes is fast enough for transit (half a second), and transit fare collection systems that accept them for payment already exist (e.g., London). NFC phones offer two additional benefits over EMV credit and debit cards: the phone has a user interface which allows visual inspection by transportation services personnel on ungated services such as commuter rail; and customer convenience is improved, e.g., by integrated customer schedules or real-time transit information.
3. General purpose reloadable (GPR) cards, or prepaid cards, which would be issued as EMV cards for the unified system. These cards provide equitable payment access to users without credit or debit cards or NFC phones. They can be purchased in retail outlets and reloaded with cash; they are generally branded with a payment network such as Visa, MasterCard, American Express or Discover. The GPR cards should not impose any user fees, with the possible exception of an initial purchase cost to discourage users from throwing them away. The MBTA and MassDOT would likely absorb GPR card fees, similar to the costs of Charlie retail outlets today.
4. Personal identity verification (PIV) cards. PIV is a Federal government ID card standard that can also be issued by other government units and organizations to their employees. Transit benefits and pass purchases can be tied to this card through an account linked to the employer. The card has contactless functionality, so riders tap it in the same way they would a credit/debit card or phone. This option may appeal to large employers in the MBTA pass program, such as universities or hospital systems. Salt Lake City accepts PIV cards, and Washington DC, and Philadelphia, PA, are implementing open payment systems that will accept PIV cards as well as credit/debit cards and NFC phones. Using PIV cards for

large employers is expected to be easier to administer and less expensive for the MBTA than having employees use credit/debit cards.

5. E-ZPass payment (which is in broad use currently). These transponders cannot be integrated fully with transit because E-ZPass transponders operate in a significantly different environment than Charlie Cards or contactless credit/debit cards or phones. However, E-ZPass and transit use can be funded in a unified account, and GPR cards can allow cash reloads of E-ZPass at many retail locations.

The acceptance of credit/debit, GPR and PIV cards, and NFC phones directly at gates and fareboxes is termed “open payment”. A growing set of successful implementations within the US and globally lowers the risk to the MBTA moving to open payment. The MBTA can benefit from the technologies and implementation experience of these systems. Open payment systems are governed by robust standards that have third party review and certification, another motivator for adopting open payment.

Objectives for a Massachusetts system

Specific objectives for a unified payment system in Massachusetts include:

1. Increased mobility for residents and visitors by allowing use of all transportation services via readily available payment means.
2. Increased transit ridership or revenue as a result of lowered barriers to use.
3. A single account to purchase transportation, add funds, and review and manage travel options, including better support for cash customers.
4. Simplified means to purchase travel using media that consumers already possess, and simpler means to obtain transportation-specific media that are needed, such as E-ZPass transponders.
5. Allow the MBTA and MassDOT to better provide service data, offer incentives to change travel patterns, and monitor changes in travel.
6. Allow the MBTA and MassDOT to integrate non-MBTA services such as TMAs, employer bus services and commercial bus services into a seamless transit network, cost-effectively expanding the number of services and destinations available to riders.
7. Improved management of incidents, construction, special events (such as the Olympics) and other situations in which travelers are rerouted across services or modes.
8. Reductions in the cost of fare/toll collection, with fewer systems and greater operational efficiencies.
9. Reduction in uncollected fares, missed fares and fare evasion.

Options for Massachusetts

This report recommends a two-phase approach to reduce risk and better manage an implementation over many services and carriers. A fast track implementation could omit phase 1.

1. Phase 1 implements a single account and website, but retains most existing payment methods for a limited time. It incrementally integrates payment media used to make transactions in the account by unifying mobile apps, making the Charlie Card the preferred and easily-available transit payment medium and eliminating the Charlie Ticket. Phase 1

focuses on engaging as many modes, carriers and services as possible to prepare for phase 2, even if all of them cannot be effectively unified in phase 1.

2. Phase 2 continues the single account and website, and implements open payment to compute and process fares across transportation services. NFC smart phones and EMV credit/debit cards are tapped at gates and fareboxes; an NFC phone app supports visual inspection where needed. This option is essentially the same as the successful London, Chicago and Salt Lake City implementations and the in-progress Philadelphia and Washington, DC implementations, but covers a greater number of transit services.

Phase 1: Incremental implementation of unified payment

Phase 1 creates a single transportation account and associated website in Massachusetts to allow users to purchase and manage transportation services. It also establishes inter-agency and inter-carrier relationships among all the service providers, and makes initial changes in Charlie Card and mobile ticketing. Phase 1 establishes the Charlie Card as the preferred, though interim, payment method on almost all transit services and increases its distribution and availability. It phases out magnetic stripe Charlie Tickets. It implements a single parking payment system, a single mobile payment app for parking, commuter rail and private bus, and an expanded cash reload system to increase E-ZPass use and support less cash use on transit.

Phase 1's server-based account system and website allow users to register their Charlie Card, E-ZPass, mobile payment, and credit and debit cards used to purchase other forms of transportation, such as bike sharing. Key features are:

1. Users may maintain a single balance in this account that can be used on transit, highway, parking or other transportation services that require prepayment.
2. The single account can be automatically reloaded by credit/debit cards online, over-the-air via smartphones, at ticket vending machines (TVMs), or by cash at retail outlets and TVMs.
3. The Charlie Card is implemented as the principal payment medium for all transit services. It will always be the preferred payment medium for transit services, offering the lowest fares, best transfer policy and most flexibility in use.
4. The Charlie Card's availability is increased through vending machines in stations, distribution with E-ZPass and Registry of Motor Vehicle transactions, and at other sites.
5. The Charlie Card and/or Charlie Card "Lite" (a limited-use, lower-cost transit smart card) are accepted on commuter rail, boat, suburban/contracted bus services, and Logan Express. Visual inspection is supported by Charlie Card "Lite" or by print-at-home receipts, described in the body of the report.
6. The Charlie Card is updated at gates and fareboxes, as it is now, for passes and for automatic reloads of value, from the single account; this is an interim solution. The time delay for posting reloads should be short, ideally just a few minutes.
7. A single parking payment system across MBTA subway and commuter rail stations is implemented at ungated lots, and a related system is implemented at gated lots. Monthly or daily parking is generally prepaid as in the current system, and the parking subsystem is updated from the single account.
8. A single mobile phone app to supersede mTicket, PayByPhone and BusPlus is implemented. It may be possible to include Massport Logan Express, Logan Express parking and Logan airport parking, and The Ride.

9. E-ZPass and Charlie Card usage is increased by allowing cash users to reload their account (for highway and transit) at additional retail locations.
10. The account may include other services, such as bike or car sharing, to provide users with a full picture of their transportation use and possibly to allow users to compare options for meeting their travel needs.
11. Only minimal investments in the Charlie Card system are made, to selectively improve its usability. There are no major changes in its functions.

The improved integration of payment for commuter rail, boat, suburban/contracted bus, Logan Express, private bus, The Ride, RTA, TMA and other bus services as a whole encompasses over 250,000 daily users, a substantial fraction of the transit total. Parking integration adds another 80,000 daily users.

The costs of this system are difficult to estimate because the option has not been fully specified and no discussion has occurred of how the effort might be executed. For the same reason, ridership and revenue changes are also difficult to project. A rough order-of-magnitude cost is \$30 million for phase 1, but this may be in error by a factor of 4 higher or lower.

Phase 2: Unified payment with NFC phones and EMV cards

Phase 2 implements an open payment system. Instead of Charlie Cards, users tap an NFC phone or EMV credit, debit or GPR card at gates and fareboxes. The NFC phone can be visually inspected on commuter rail, private bus, and other services if the user has a transit payment app, and EMV cards can be electronically inspected by staff equipped with NFC phones with an inspection app. Parking is paid with an NFC phone app or an EMV card.

Gate and farebox readers and software must be upgraded to accept NFC and EMV compliant contactless payment, and software changes are required to accept phones and credit/debit cards directly at gates and fareboxes. A prepaid card, which could be branded as a new Charlie Card, is used as the secondary payment means for users without NFC phones or contactless credit/debit cards; the existing Charlie Card is eliminated. The prepaid card is available at retail outlets—it is sold as a gift card—and at subway station vending machines, or online with mail fulfillment. Best value pricing can be provided for daily, weekly or monthly travel, eliminating the need for daily, weekly or monthly passes and simplifying fare choices more generally. Integration across all services is feasible for users with NFC phones or contactless credit/debit or prepaid cards.

Users designate an NFC mobile phone or an EMV card as their payment means in their single transportation account; the account associates passes, single trips, parking and other expenditures with the phone or card. The single account provides convenience (such as single reloads for transit and highway, full travel history and service information, and possible incentives). Highway tolls are still paid with E-ZPass, which can use value from the single account (including toll payment in other states). License plate tolls can be associated with the single account.

Visitors and infrequent users can tap their NFC phone or EMV cards without having an account; no registration or any other action is necessary. The central server collects all taps, constructs trips, prices them, and charges the user's NFC phone or EMV card at the end of the day.

The Charlie Card and Charlie Ticket are eliminated. Riders with an NFC phone are encouraged to download the transportation payment app but are not required to do so. The app provides a receipt for visual inspection; if a user does not have the app, his or her phone is tapped to verify that a valid pass or ticket is present. PIV cards can be accepted in this option.

Key features are:

1. NFC phones and EMV cards are the preferred media on all transit services. E-ZPass is still used for highway tolls, but is part of the single account.
2. The website and single account provide additional trip data, and provide new pass and pricing options. They are backed by an open payment server that supports a wide range of fare policies, joint fares across services, best value pricing, and other features.
3. An NFC mobile phone transit app, possibly based on the Open Mobile Ticketing Alliance app, extends the phase 1 mobile app to handle taps at gates and fareboxes as well as supporting visual inspection.
4. Upgraded readers at gates, fareboxes and validators are implemented to accept NFC and EMV payment, in an open payment system. This includes the MBTA, RTAs, Logan Express and suburban/contracted bus systems, whose payment and use are fully integrated. (A validator is a card reader, with power and communications, but without a gate; several are typically mounted on posts either along the platform or at entrances to the platform for ungated services such as commuter rail or many Green Line stops.)
5. A contactless EMV GPR is sold at a large number of retail outlets and supports flexible cash reload for transit and highway.
6. PIV cards are accepted for employer pass programs.
7. Validators at commuter rail stations and boat terminals may be implemented to more fully integrate fare collection methods across the major MBTA services. This is optional.
8. The Charlie Card is eliminated. Phase 1 server software is migrated to the open payment server.
9. TVMs are reduced and eventually eliminated. Preloaded GPR cards can be bought at the vending machines at stations that were installed in phase 1. Users can add value or passes at a large number of retail outlets.

This phase improves integration for the 250,000 users added in phase 1, allows new services to be added much more easily than in phase 1, and creates a regionally unified payment system and travel demand management platform that supports policies to add substantial additional ridership.

The rough order-of-magnitude cost of this phase is about \$30 million, which again may be in error by a factor of 4 higher or lower at this early stage of system definition. Phase 2 has the potential to decrease operating costs, through reductions in card issuance, customer service, ticket vending machine and other expenses.

Benefits

In phase 2, unified payment eliminates the payment media acquisition, fare product selection, fare product purchase, reload and management steps for multiple media and services and replaces them with a tap or display of payment media the customer already possesses. (In phase 1, these steps are

made more convenient than they currently are.) E-ZPass transponders are included in a single account, and account reload is integrated. The transponder must still be obtained by users through established channels.

The key benefits to users are:

1. Single reload/automatic renewal account for transit and highway.
2. Single website to manage account.
3. Single medium always accepted at the best fare: Charlie Card in phase 1, and mobile phones and credit/debit cards in phase 2.
4. Single mobile application for subway, bus, commuter rail, boat, private bus and parking.
5. High availability of payment medium. In phase 1, Charlie Card is available at all subway stations and many other locations. In phase 2, mobile phones, credit/debit and GPR cards are used.
6. Highway traveler ability to use transit more easily with a Charlie Card (phase 1) and a unified account and phone app (phase 2).
7. Consistent and universal transfers across services. Increased transfer privileges for commuter rail, boat and private bus users. Mobile phone users receive integrated transfers. Former Charlie Ticket (and cash) bus and subway users receive lower fares and improved transfers.
8. Improved connectivity of services, allowing many more destinations to be reached with the same payment medium, and preferably with joint fares and other innovative pricing. If unified payment is supported by increased integration of schedules across services, the effect is magnified.
9. Improved cash reload for E-ZPass (and transit), to encourage increased E-ZPass usage, especially by lower income travelers.
10. Significant quality-of-life and urban livability benefits: less time in queues at TVMs; increased access to fare types and flexible fare policies; less time managing accounts, fare purchases and reloads; a single balance in an account; and the ability to travel seamlessly over all transit and highway services by tapping or displaying a single medium.
11. Faster, more reliable bus trips.
12. Economic value of more destinations reached by transit: more employment options, etc.
13. Environmental benefits for region from increased transit use and increased transit effectiveness.

Benefits to MBTA, MassDOT and service operators include:

1. Lower customer service costs in phase 2. Users whose card or phone doesn't work contact their bank, not the MBTA.
2. Higher financial security with EMV and NFC.
3. Ability to add new agencies and transportation services to the single medium and account readily.
4. Number of TVMs reduced since users have their own media.
5. Reduced reliance on a single vendor for fare collection systems.
6. Transit open payment in mainstream of payments, providing some protection against obsolescence.
7. Faster bus boarding times with elimination of Charlie Ticket and less cash use. Possible all-door boarding on high volume bus routes and Green Line surface stops.

8. Elimination of Charlie Card and Charlie Ticket issuance costs.
9. Possible staff reassignments or reductions since most payment problems will be resolved by users with their bank, not the MBTA. Possible operational changes on commuter rail.
10. Reduced cash handling costs at TVMs and on buses and Green Line.
11. Savings by combining retail outlets for Charlie Card and E-ZPass in phase 1, and in moving to open payment reload in phase 2.
12. Potential service coordination savings among agencies operating overlapping services.

The system also provides improved travel demand management options and can increase ridership and revenue for the MBTA. Some of these options are only available in phase 2. These options may create increased ridership and revenue for public transportation services, and they may benefit users as well.

1. Encourages greater usage of public transit and other travel options that may shift users from drive alone trips. Increased convenience from using phones and credit/debit cards for payment will increase ridership on existing services. Increases transit use by casual riders and visitors, since the barrier to riding is lowered.
2. Enables joint fares with RTAs, suburban/contracted bus systems, private bus and other non-MBTA operators. The expanded set of destinations made available through unified payment will create ridership on the newly-available services.
3. Allows parking pricing to be integrated with transit fares. Pricing can be demand-based.
4. Facilitates variable fares by time of day and other factors.
5. Permits group travel discounts, such as savings on transit to two or more passengers traveling together.
6. Allows for discounts for long-term users who ride transit fewer than five days per week and are not well-served by current pass products.
7. Enables offering offpeak or weekend passes.
8. Facilitates introductory fares to attract new users through limited-time discounts.
9. Increases ability to provide incentives or apply surcharges to services. Permits best value fares, where a user's cost is capped at a daily, weekly or monthly maximum, eliminating these pass products. Users do not need to choose a pass in advance.
10. Gathers improved travel data that can be used for operations, planning and policy purposes from users of unified payment and website.
11. Elimination of Charlie Ticket and cash surcharges reduces revenues, all else equal, although a fare increase can be programmed to make this revenue-neutral
12. Fares can be collected on the Silver Line airport service and other services with many infrequent riders who would not have Charlie Cards or other specific media.

A broad range of fare policies is supported by the unified payment system; MassDOT and the MBTA will have increased leverage to meet user and system goals.

The system has positive impacts on equity and environmental quality:

1. In phase 1 a greater percentage of transit users will pay lower Charlie Card fares versus Charlie Ticket or cash fares. In phase 2 all users pay the same fare regardless of payment medium, and receive the same transfer benefits. A disproportionate number of low income users currently use Charlie Ticket or cash.

2. An expanded retail cash reload network will allow more low income travelers to use E-ZPass, gaining a discount at some toll facilities.
3. Weekly passes can be expanded to a larger range of services. These are more affordable for low income riders than monthly passes, and provide access to discounted fares.
4. Best value fares remove risk from purchasing passes. Buying a pass and then being ill or not going to work results in paying for service not used, which is a larger impact on low income users.
5. The GPR card used for transit payment in phase 2 can be enabled to allow general payment. The MBTA and MassDOT may be able to obtain low fees for this card for general use, since volume will be high and customer acquisition costs for the GPR provider will be low. This can benefit low income households by providing a relatively low cost electronic means of payment.
6. Possible implementation of tap in and tap out on subways and/or buses can benefit lower income riders, whose trip lengths are often shorter than the average rider. (Tap in and tap out are not included in the cost estimates in this report, but their introduction is feasible.)
7. Environmental impacts are not discussed in this report, but increases in transit ridership will reduce non-point source emissions. Also, the provision of a seamless transportation network, possibly including improved provisions for car sharing and bike sharing, may reduce auto ownership in some households.

Implementation

The implementation of a unified payment system can be staged, moving from initial, incremental steps, to a more fully integrated system over a period of years. Because the MBTA Charlie Card system is relatively new (2006), and the E-ZPass system must be interoperable over a large number of highway toll agencies, and the cost of this infrastructure is substantial, the core infrastructure of gates, fareboxes and toll barriers will require incremental changes and not full replacement.

Modifications to card readers, data communications networks, and server software and hardware are the major physical changes. Some physical additions are required for some options: Readers may be added to vehicles and locations that currently do not have them; open road tolling is planned to be implemented (this is largely independent of unified payment); vending machines and other devices may be installed to support changes in payment media.

In phase 1 MassDOT and the MBTA can make incremental improvements that fit within a broader framework for unified payment. Phase 1 has limited technology changes; it primarily focuses on including all relevant services, deploying additional equipment of current designs (but supporting future flexibility), and software changes. MassDOT and the MBTA may choose to manage phase 1 primarily using internal resources, supplemented by limited outside consulting and engineering. Phase 1 should produce detailed requirements, based on agreement and initial experience among all parties, for phase 2, which requires a higher level of hardware and software implementation.

Phase 2 implements the unified payment system, which requires gate and farebox reader upgrades, additional software changes, and a substantial systems integration effort to ensure that all payment system elements work together in actual operations. Phase 2 is likely to be implemented with the

services of a systems integrator; it is highly desirable that the requirements and scope be agreed among all parties before the start of phase 2.

The total rough order-of-magnitude cost across both phases is approximately \$60 million, although this estimate is extremely uncertain. (The range of costs may be a factor of 4 higher or lower.) This is approximately two-thirds of the initial cost of the Charlie Card system.

Introduction and Scope

This report discusses the benefits, costs and a possible implementation plan for unified payment media for transportation in Massachusetts. Currently, a large number of payment methods are used for publicly provided transportation services such as subway, bus, commuter rail, parking, toll highways and bridges. Massachusetts has been innovative in providing new methods of payment for transportation services, such as the Charlie Card/Charlie Ticket system at the MBTA and 10 regional transportation authorities, E-ZPass on highway facilities, and mobile ticketing¹ for commuter rail (mTicket)², parking (PayByPhone)³ and commuter bus (BusPlus)⁴. These systems have provided increased convenience to customers and operational benefits to carriers, but they are not generally interoperable across modes and carriers.

The inability to use common payment methods such as cash, credit cards and debit cards presents a barrier to customers wishing to use public transportation and highway services. Also, the need to issue transportation-specific media, such as Charlie Cards, Charlie Tickets, and E-ZPass transponders, creates capital and operating expenses for transportation providers and additional barriers or confusion for travelers. Last, the variety of payment methods makes it difficult for users and policy makers to see or manage overall travel patterns. A unified payment account will increase visibility and provide flexibility in managing combinations of services, improving the ability of individual travelers to make or adjust their travel behavior, and also allowing MassDOT and other agencies to shape and implement policies to achieve regional objectives. These factors suggest that a unified means of payment, using payment methods already in the hands of travelers to the extent possible, and a unified transportation account that shows usage and costs to individuals and agencies, may be an effective innovation to improve the convenience and effectiveness of transportation services.

Unified payment and a single account can form a platform to make the regional public transportation network a single entity as seen by travelers, and enable MassDOT and the MBTA to implement innovative fare policies that leverage that single entity. This platform provides connectivity in the network; it allows many more destinations to be served seamlessly across multiple services, removes significant friction from transfers across modes and services by providing a single payment medium and joint or innovative fare policies for these trips. The platform presents a large portfolio of services to meet varied travel needs that may better allow some households to own fewer or no automobiles. It provides much greater flexibility to users in choosing modes and services when there are changes in a user's activities. The single account and unified payment allows users to dynamically change from auto to transit, across modes and services; this is expected to increase the impact of demand management policies.

¹ In this report, mobile ticketing is defined as an application on a smart phone that supports Near Field Communications (NFC) payment.

² http://www.mbta.com/fares_and_passes/mTicketing/. This is still in pilot operation.

³ <https://paybyphone.com> . The MBTA owns this application.

⁴ <https://www.bytemark.co/news/2014/09/04/bytemark-develop-mobile-ticketing-system-massdot-busplus-program> . This pilot has been announced.

Because public transportation has economies of scale, making the transit system a single entity from a payment and account perspective may also improve efficiency: some duplicate or parallel services by carriers or modes can be consolidated, and access and distribution services can be coordinated better with those serving longer legs of trips. The MassDOT Green DOT Implementation Plan⁵ calls for tripling the mode share of bicycling, transit and walking by 2030; a unified account and payment platform will allow MassDOT and the MBTA to maximally utilize routes and capacity on existing and new services by flexible pricing of fares, passes, transfers, and incentives across all these services.

⁵ <http://www.massdot.state.ma.us/GreenDOT/GreenDOTImplementationPlan.aspx>

Current Status

Summary of transportation services and payment methods in Boston area

The payment methods for urban passenger transportation services currently used in the Boston area include:

1. MBTA subway, gated stations: Charlie Card and Charlie Ticket. Ticket vending machines (TVMs) that accept cash and credit/debit cards.
2. MBTA subway (light rail-Green Line), ungated subway stations: Charlie Card, Charlie Ticket, cash on board.
3. MBTA bus: Charlie Card, Charlie Ticket, cash on board.
4. MBTA commuter rail, downtown terminals: Charlie Ticket, mTicket mobile app, cash on board. Ticket vending machines. Charlie Card not accepted.
5. MBTA commuter rail, other stations: Charlie Ticket, mTicket mobile app, cash on board. Charlie Card not accepted.
6. MBTA boat: Charlie Ticket, mTicket mobile app, cash and credit/debit card. Charlie Card not accepted.
7. MBTA parking: Park & Pay Card (3 stations), PayByPhone mobile app (80 stations⁶), E-ZPass (1 station), cash (all stations), credit/debit card (approximately 20 “pay on foot” stations), town-issued permits (approximately 10 stations). Parking payment varies substantially by station on each subway and commuter rail line⁷.
8. The Ride, which is the MBTA accessible transportation service. The Ride accounts are separate from other transportation accounts, and are funded online (with a two day delay), mail (five day delay), phone or in person (one hour delay). No other media are accepted.
9. Other regional transportation authorities (RTAs): Charlie Card and magnetic stripe ticket (10 RTAs); others have their own passes/tickets), cash⁸.
10. Massport Logan Express: credit/debit card, cash (all routes).
11. Massport Logan Express parking: credit/debit card, cash (all lots).
12. Massport Logan Airport parking: credit/debit card, cash. Gold Passport smart card and Exit Express smart card.
13. Private bus operators (e.g., Concord Coach Lines, Plymouth & Brockton): credit/debit card (may be online), cash (all routes; purchase ticket before travel). 7 operators are in the BusPlus mobile ticketing pilot.
14. Suburban/contracted bus systems (Lexpress, Burlington B-Line, etc.): cash, town-issued passes. Some accept Charlie Ticket passes⁹. Charlie Card not accepted.

⁶ <https://paybyphone.com/mbta-locations/>

⁷ http://www.mbta.com/riding_the_t/parking/?id=16205#C

⁸ Wikipedia entry for Charlie Card, and RTA Web sites: MetroWest Regional Transit Authority (October 2010), Brockton Area Transit Authority (March 2011), Lowell Regional Transit Authority (November 2011), Merrimack Valley Regional Transit Authority (branded "Tap and Ride Card"; February 2012), Montachusett Regional Transit Authority (March 2012), Worcester Regional Transit Authority (April 2012), Cape Ann Transportation Authority, Cape Cod Regional Transit Authority (November 2012), Southeastern Regional Transit Authority (January 2013), and Berkshire Regional Transit Authority (January 2014).

15. Transportation management association (TMA) and employer bus services. Each has its own payment system: passes, tickets, IDs and others.
16. Commercial urban bus services (e.g., Bridj). Bridj has recently begun operations in Brookline, Cambridge and Boston. Online/mobile ticketing.
17. Mass Pike, Tobin Bridge, tunnels: E-ZPass (backed by credit card, debit card, check or cash), cash at toll booth (moving to cashless in future). Tobin Bridge cashless (E-ZPass or pay-by-mail via license plate recognition).
18. High occupancy vehicle/toll lanes: None at present, but they should be supported by a future payment system.
19. Bike-sharing services (e.g., Hubway¹⁰): credit or debit card. Charlie Card (no fee) used for MBTA bike cages for individually-owned bikes.
20. Car-sharing services (Uber¹¹, Lyft¹² and others): Company-specific mobile app linked to credit or debit card
21. Municipal parking: cash; some cities and towns (e.g., Boston) have smart card systems that operate only within that city or town¹³.
22. Taxi: cash, and credit/debit cards in Boston cabs and a number of other towns. Some accept contactless payments¹⁴. Taxis can be included in the single account discussed in the report.

Payment system details by transportation service

Table 1 shows a summary of the transportation services listed in section 2.1, along with the forms of payment accepted on each. There are six principal forms of payment: cash, credit/debit card, Charlie Card, Charlie Ticket, mobile payment (3 different applications) and E-ZPass. Green cells indicate that this form of payment is standard or preferred; yellow cells indicate other forms of payment that are accepted, usually with a surcharge or transfer restrictions; red cells indicate this form of payment is not accepted. Some details or variations are not included in the table, but are mentioned below. In table 1:

1. Standard: medium is preferred by the transit agency and it offers the lowest fares and best transfer privileges.
2. Accepted: more than one medium is accepted at best fare and transfer privileges; there is no preference between the multiple media. There may be some variations, as noted below.
3. Surcharge: medium is accepted at a higher fare and possibly with lower transfer privileges.

⁹ There are 14 cities or towns with contracted bus systems. Eight accept printed passes on Charlie Tickets: Canton, East Boston, Hingham, Hull, Mattapan, Medford, Milton, and Winthrop. Six do not: Bedford, Beverly, Boston (Mission Hill), Burlington, Dedham, and Lexington.

¹⁰ <http://www.thehubway.com/>

¹¹ <https://www.uber.com/>

¹² <https://www.lyft.com/>

¹³ <http://www.cityofboston.gov/parking/metercards.asp>.

<https://wmq.etimspayments.com/pbw/include/orderentry/boston/input.jsp>

or <http://www2.cambridgema.gov/traffic/luke.cfm>

¹⁴ <http://www.inc.com/hardware/articles/201101/smart-mobile-payments.html>

Table 1 : Payment media accepted by mode and carrier. Existing case.

Service	Payment medium					
	Cash	Credit/debit	Charlie Card	Charlie Ticket	Mobile payment	E-ZPass
MBTA subway-gated	TVM-> Charlie Card or Charlie Ticket	TVM-> Charlie Card or Charlie Ticket	Standard	Surcharge	Not accepted	Not accepted
MBTA subway-ungated	Surcharge	Not accepted	Standard	Surcharge	Not accepted	Not accepted
MBTA bus	Surcharge	Not accepted	Standard	Surcharge	Not accepted	Not accepted
Commuter rail-downtown	TVM-> Charlie Ticket	TVM-> Charlie Ticket	Not accepted	Standard	mTicket	Not accepted
Commuter rail-other	Accepted, surcharge (some)	Not accepted on train	Not accepted	Standard	mTicket	Not accepted
MBTA boat	Accepted	Accepted	Not accepted	Standard	mTicket	Not accepted
MBTA parking	Accepted	Pay on foot stations (20 stations)	Not accepted	Not accepted	Pay-By-Phone (80 stations)	Route 128 station only
MBTA The Ride	Not accepted	Not accepted	Not accepted	Not accepted	Call with credit/debit	Not accepted
Other RTAs	Surcharge (some)	Not accepted	Standard	Not accepted	Not accepted	Not accepted
Logan Express	Accepted	Accepted	Not accepted	Not accepted	Not accepted	Not accepted
Logan Express parking	Accepted	Accepted	Not accepted	Not accepted	Not accepted	Not accepted
Logan Airport parking	Accepted	Accepted	Not accepted	Not accepted	Not accepted	Not accepted
Private bus carriers	Accepted	Accepted	Not accepted	Not accepted	BusPlus	Not accepted
Suburban/contract bus	Accepted	Not accepted	Not accepted	Some passes accepted	Not accepted	Not accepted
Highway toll facilities	Surcharge (some)	Not accepted	Not accepted	Not accepted	Not accepted	Standard
HOV/HOT lanes(future)	Not accepted	Not accepted	Not accepted	Not accepted	Not accepted	Standard
Bike sharing	Not accepted	Standard	Not accepted	Not accepted	Not accepted	Not accepted
Car sharing	Not accepted	Standard	Not accepted	Not accepted	Not accepted	Not accepted
Municipal parking	Accepted	Accepted (some)	Not accepted	Not accepted	Future	Not accepted

The restrictions and operational issues for each service are:

1. MBTA subway-gated stations: Ticket vending machines issue only Charlie Tickets. A user must have an existing Charlie Card to obtain the lowest stored value (single trip) fares and to obtain free transfers between subway and bus. (Weekly and daily passes are issued only on Charlie Tickets and give the lowest fare and full transfers.) Charlie Cards are free, but are available only at 18 out of 60 gated subway stations, usually at only one entrance, generally from 7am to 7pm, 7 days per week from a customer service agent. Roughly half of riders use a pass, and half use single fares¹⁵. In 2007 over 60% of trips were Charlie Card¹⁶; the remainder were Charlie Ticket; the use of Charlie Card has increased since then.
2. MBTA subway (light rail)-ungated subway stations: These stations generally do not have a ticket vending machine. A user without a Charlie Card or Charlie Ticket may pay cash on board, at a surcharge. In 2007 over 60% of ungated subway trips were Charlie Card, 20% were Charlie Ticket and 20% were cash.
3. MBTA bus: Almost no bus stops have ticket vending machines. A user without a Charlie Card may pay cash on board, at a surcharge. A user may reload a Charlie Card or purchase a Charlie Ticket at the bus farebox. Riders are encouraged to obtain fare media at retail outlets or subway stations rather than on the bus. In 2007, 60% of bus trips were Charlie Card, 10% were Charlie Ticket and 30% were cash. There is a retail network selling Charlie Tickets, Charlie Cards; some outlets carry only pre-loaded cards and tickets, while others can add value or passes to Charlie Cards.
4. MBTA commuter rail-downtown terminals. Commuter rail single-ride Charlie Tickets do not provide free transfers to subway or bus. Commuter rail monthly passes on Charlie Tickets do provide free transfers to subway or bus. mTickets do not provide free transfers to subway or bus; mTicket monthly passes are discounted \$10 due to this restriction. Onboard fares are issued on paper tickets and do not provide transfers.
5. MBTA commuter rail-other stations: Few MBTA commuter rail stations have ticket vending machines. Interzone tickets or passes (for trips not including a downtown station) are not available at TVMs; interzone passes are available online; interzone tickets and passes are available on mTicket and at retail outlets (but an interzone mTicket does not provide transfers to buses). Some stations have nearby retail outlets to purchase Charlie Tickets, although any outlet not at a station platform is not fully convenient for riders. 53% of commuter rail riders drive and park, 28% walk, 12% are dropped off and 4% transfer from bus or subway¹⁷. 67% of riders use a monthly pass, 16% use multi-ride tickets, and 11% use single-ride tickets.
6. MBTA boat: Ticket offices are available for ticket purchase.

¹⁵ Impact Analysis of the 2007 MBTA Fare Increase and Restructuring, Central Transportation Planning Staff, September 2008. At http://www.ctps.org/Drupal/data/pdf/studies/transit/PostFareInclImpacts_final.pdf

¹⁶ Data from Automated Fare Collection (AFC), May 2009, TRB National Transportation Planning Applications Conference, Robert Guptill, Central Transportation Planning Staff. At trbappcon.org/2009conf/TRB2009presentations/s19/07_impact.ppt

¹⁷ MBTA Systemwide Passenger Survey Commuter Rail 2008–09, Central Transportation Planning Staff, June 2010. At http://www.ctps.org/Drupal/data/pdf/studies/transit/MBTA_Passenger_Survey/Commuter_Rail_Volume.pdf

7. MBTA parking: Payment is highly variable by station. A Park&Pay card is used at Alewife, Braintree and Wonderland subway stations. E-ZPass is used at the Route 128 station commuter rail station. Honor boxes for cash¹⁸, and the PayByPhone mobile app are used at approximately 80 stations. Many parking facilities are managed by a single vendor, LAZPark, but may support PayByPhone or not, credit/debit card payment or not, or E-ZPass (at one station). Some parking lots are owned and managed by cities and towns, which may have permits, cash or credit/debit payment. Some facilities are managed by RTAs with varying payment methods. Monthly parking passes, at a \$10 discount over daily rates, can be purchased online for many stations¹⁹.
8. The Ride, which is the MBTA accessible transportation service. There is no payment upon boarding a vehicle; funds must be available in an account and are deducted when the service is provided. The MBTA is implementing a system in which debit cards are issued to users of The Ride that cover a portion of trip cost (the first \$15) by taxi.
9. Other regional transportation authorities (RTAs): These agencies do not accept Charlie Tickets; they issue magnetic stripe tickets as change when cash is paid, which is a very limited use. Only Charlie Cards are used for passes and stored value. A rider can have an MBTA pass, an RTA pass and stored value on a single Charlie Card. There is a 24-48 hour delay in value added to Charlie Cards at bus fareboxes.
10. Massport Logan Express: There are ticket agents at the remote stops who handle all ticketing, except Back Bay, which accepts Charlie Card and Charlie Ticket passes for free rides, accepts credit/debit cards, and does not accept cash. 42% of Logan Express ridership is Logan airport employees, who receive a large discount, \$75 for a 44 ticket book, versus a regular fare of \$12 per trip.
11. Massport Logan Express parking: The ticket agents at the remote stops also handle parking payment. Logan airport employees can purchase monthly parking for \$40, versus a regular rate of \$7/day.
12. Massport Logan Airport parking: Parking is paid at kiosks in or near the parking garages. A separate Parking Passport Gold card costs \$200 for the first year, and \$100 for following years, and hourly rates are higher than the standard rates. It provides guaranteed parking even if garages are full for other users. An Exit Express card program issues a smart card to the traveler to avoid pulling a magnetic stripe ticket on entry.
13. Private bus operators: Several operators have online ticketing, in which riders can purchase and print tickets. Operators are likely to accept tickets displayed on phones instead of printed tickets in the future.
14. Suburban/contracted bus systems (Lexpress, Burlington B-Line, etc.): Several systems accept Charlie Tickets with printed pass information that can be visually inspected. They do not accept Charlie Cards or Charlie Tickets with stored value.
15. Transportation management association (TMA) and employer bus services. Services that accept general riders (e.g., Route 128 Business Council Alewife shuttles, Charles River TMA EZRide) and those that may accept them in the future (e.g., perhaps the Longwood Medical Area or Seaport employer shuttles) should be considered for integration in unified

¹⁸ A law suit has been filed about the honor box system. See <http://www.enterpriseneews.com/article/20140827/News/140826881>. The issues appear to be a lack of receipts and a claim that errors are made in issuing violation tickets.

¹⁹ http://www.mbta.com/riding_the_t/parking/default.asp?id=25316

payments. They can be included in the same way as private operators. There are currently 100 or more buses in operation that are or could be open to general ridership in the metropolitan area, and the number has been growing.

16. Commercial urban bus services. These services can be included in the same way as other private bus services.
17. Mass Pike, Tobin Bridge, tunnels: MassDOT and many other agencies are moving to all-electronic tolling (AET)²⁰; it has already done so on the Tobin Bridge. A contract with Raytheon was signed to implement AET on the entire Mass Pike in 2014²¹.
18. High occupancy vehicle/toll (HOT) lanes²²: A new payment system should support designated HOT lanes should MassDOT choose to implement them in the future.
19. Bike-sharing services (Hubway). Annual or monthly memberships are purchased online. 72-hour or 24-hour passes are purchased at Hubway kiosks.
20. Car-sharing services (Uber, Lyft and others): This is an additional mobile app; a smart phone is required.
21. Municipal parking. This area is not covered in the report; it is listed because it is another transportation service with varied payment options. Cash is still the dominant form of payment; most Massachusetts drivers appear to keep a pile of quarters in their vehicles for parking meters.
22. Taxi. Taxis are outside the scope of this report. Taxis can be included in the single account discussed in the report.

The MBTA website has a comparison of Charlie Card and Charlie Ticket. It does not address the issue that Charlie Cards cannot be used on commuter rail, daily or weekly pass issuance only on Charlie Tickets, or the use of Charlie Cards on other RTAs (but not Charlie Ticket), and other issues.²³



²⁰ <http://www.massdot.state.ma.us/main/tabid/1075/ctl/detail/mid/2937/itemid/336/MassDOT-Schedules-All-Electronic-Tolling-Public-Meetings.aspx> and <http://www.bizjournals.com/boston/blog/techflash/2014/08/massdot-awards-130m-electronic-toll-collection.html>

²¹ <http://www.bostonglobe.com/business/2014/08/13/raytheon-team-will-install-all-electronic-tolling-system-massachusetts-turpike/8JG6ROI9ekk77aaFACHuL/story.html>

²² http://en.wikipedia.org/wiki/High_occupancy_toll_and_express_toll_lanes

²³ http://www.mbta.com/fares_and_passes/charlie/?id=8720 as shown in Table 2.

Table 2: Charlie Card and Charlie Ticket comparison

Compare the Card & the Ticket		
Feature		
Reusable, Rechargeable	Yes	Yes
Fee Structure	Pay standard T fare	Pay standard T fare plus surcharge (no surcharge when using a T-Pass on a CharlieTicket)
Load 1 ride, multiple rides or store a T-Pass	Yes; Loads value for rides <u>and/or</u> a T-Pass	Yes; Loads either value for riders, <u>or</u> a T-Pass
Online Account Management	Yes	No
Auto-reload using credit/debit card	Yes	No
Free Local to Local Bus transfer	Yes	Yes
Discounted transfers between Bus and Subway	Yes	No

Charlie Cards can be obtained at Downtown Crossing, retail outlets and 17 subway stations. This provides two stations for the Silver Line, two for the Blue Line, four for the Green Line, six for the Orange Line and six for the Red Line²⁴. A Charlie Ticket can be obtained from a TVM at all gated stations at all times.

²⁴ http://www.mbta.com/fares_and_passes/charlie/?id=25666, as shown in Figure 1.

Where Can I Find A CharlieCard?

CharlieCard Distribution Locations

Need a [CharlieCard](#)? Ask a Customer Service Agent for a CharlieCard at one of the following Distribution Locations to get yours today:

	Monday - Friday	Saturday	Sunday
Alewife	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.
Arlington	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.
Ashmont	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.
Back Bay	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.
Dudley Square	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.
Forest Hills	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.
Harvard Square	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.
Haymarket	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 2:30 p.m.
Kenmore	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.	10:30 a.m. - 7:00 p.m.
Maverick	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 2:00 p.m. 4:30 p.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.
North Station	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.
Oak Grove	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.
Park Street	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.
Quincy Center	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.
Ruggles	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.
South Station	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.	7:00 a.m. - 7:00 p.m.
Wonderland	7:00 a.m. - 1:30 p.m.		

Figure 1: Charlie Card availability at subway stations

Of the 15 regional transportation authorities, 10 accept Charlie Cards. A Charlie Card can hold an MBTA pass, an RTA pass and stored value. None of the 10 accept Charlie Tickets, though most issue change for cash on the bus on a magnetic stripe ticket and some sell 1 day or 7 day passes on magnetic stripe cards. Almost all of the 10 have TVMs at a transit center, retail outlets and online reload through the MBTA website.

MetroWest RTA:	Charlie Card stored value, at a lower fare than cash. Can obtain Charlie Card from bus driver, the only RTA to do so.
Brockton Area Transit:	Charlie Card 1 day, 7 day and 31 day passes and stored value on Charlie Card.
Lowell RTA.	Charlie Card stored value, at same fare as cash.
Merrimac Valley RTA.	Charlie Card stored value, at a lower fare than cash.

Montachusett RTA.	Charlie Card 14 day and monthly passes, stored value at a lower fare than cash.
Worcester RTA.	Charlie Card monthly pass or stored value, at a lower fare than cash.
Cape Ann TA.	Charlie Card stored value.
Cape Cod TA.	Charlie Card stored value.
Southeastern RTA.	Charlie Card monthly pass or stored value, at a lower fare than cash. SRTA states that Charlie Cards can be purchased at TVMs.
Berkshire RTA.	Charlie Card monthly pass or stored value, at a lower fare than cash. Only Charlie Card providers transfers.

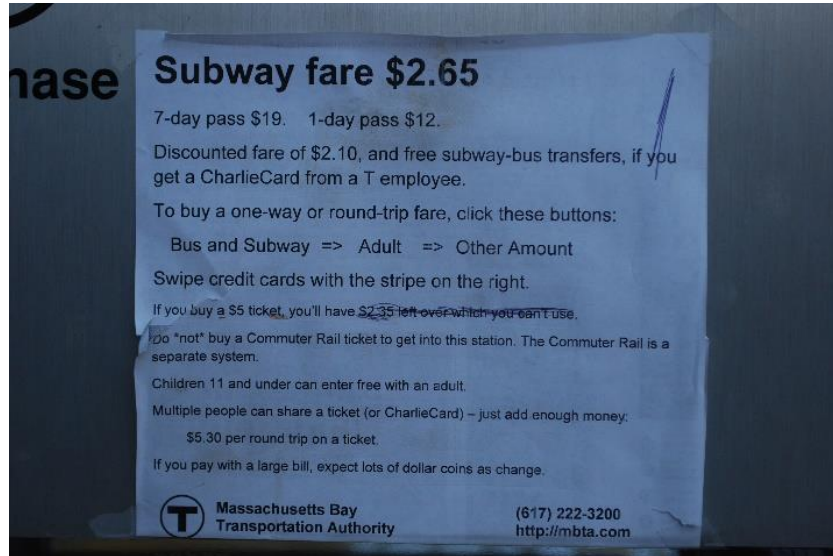
The other five, which are primarily small (Martha’s Vineyard, Nantucket) or remote from Boston (Pioneer Valley, Franklin RTA) have electronic fareboxes that accept magnetic stripe and smart cards but use non-Charlie Card media. Greater Attleboro is the only agency near Boston that does not accept Charlie Cards.

Fare payment devices

There are two types of Charlie Card ticket vending machines, which accept cash and credit/debit cards, or credit/debit cards only. They are located at all subway stations.



There are informal instructions posted at many machines to avoid some common problems:



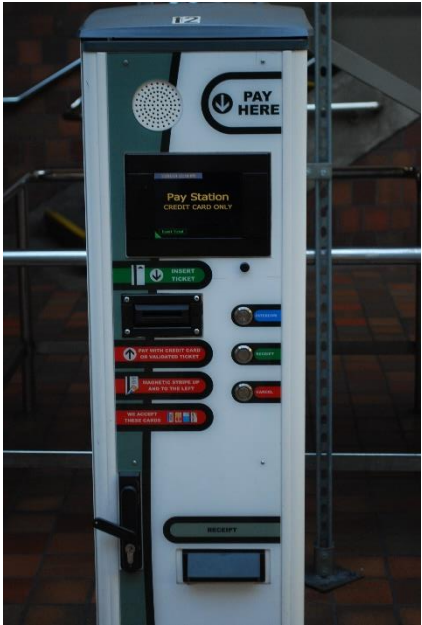
Gated subway stations have arrays of gates that accept Charlie Cards and Charlie Tickets:



Some stations have Pay on Foot parking:



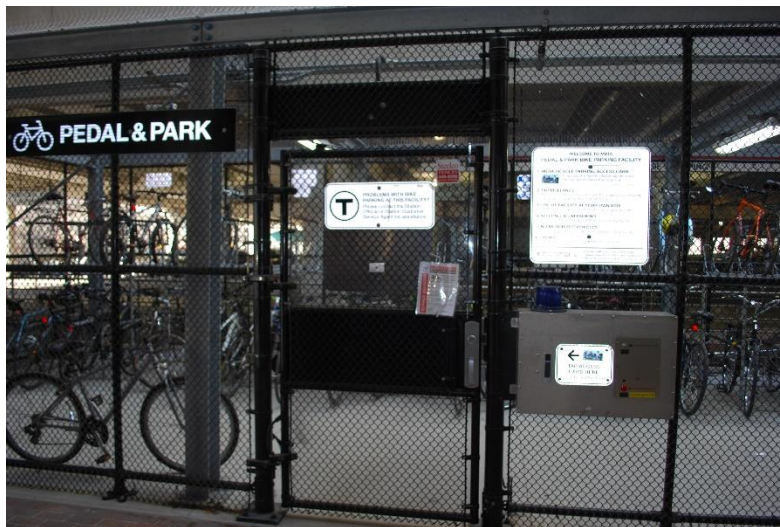
There are two types of Pay on Foot machine, for cash and credit/debit, or for credit/debit only:



Some stations have vending machines for other products; this indicates that vending machines for Charlie Cards could be placed in similar locations, which is suggested in phase 1:



Bike cages use Charlie Cards for access:



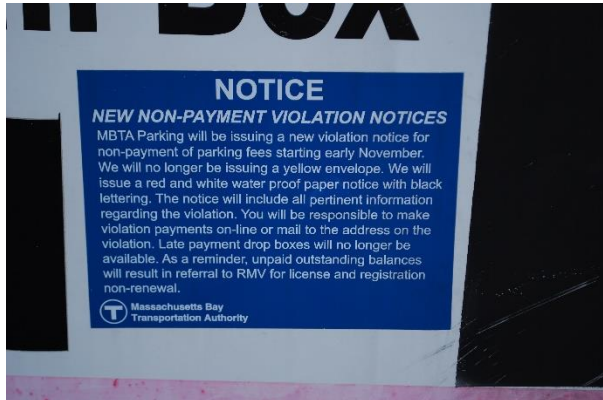
The Hubway bike share service has kiosks near many subway stations:



Most commuter rail stations have ungated parking lots, and accept cash or mobile phone (PayByPhone) payment:



There are posted instructions for common issues:



Almost all commuter rail stations have variable message signs that may be able to provide power and communications for validators, if adopted in phase 1 or phase 2:



Buses use a standard farebox:



Charlie Card retail locations that sell passes and stored value have Charlie Card equipment behind the counter:



Payment media used in Boston

No single form of payment is accepted by all 22 transportation services listed above; table 3 shows the number of services that accept each payment type.

Table 3: Payment media accepted by transportation service

	Payment medium					E-ZPass
	Cash	Credit/debit	Charlie Card	Charlie Ticket	Mobile payment	
Standard	10	9	4	3	7	2
Accepted/surcharge	7	3	0	4	1	1
Not accepted	5	10	18	15	14	19

Table 4 shows the approximate daily usage of each transportation service.²⁵ The Charlie Card and Charlie Ticket system can serve about 67% of transportation trips, and E-ZPass can serve about 28%, for a total of 95% of all daily trips. On highway toll facilities, 73% of transactions are E-ZPass and the remainder are cash, as of 2013. On the MBTA, about 70% of transactions were Charlie Card, 25% Charlie Ticket and 5% cash, as of 2007. Thus, Charlie Card and Charlie Ticket currently serve about 47% of daily trips, and E-ZPass serves about 20%. The remaining 33% are served by cash, credit/debit cards and other minor forms of payment. While many of the non-Charlie Card services have low current ridership, they have more scope to grow; giving them a “network effect” through unified payment and inclusion in a seamless transit network may increase their growth.

²⁵ Data in table 4 is drawn from multiple sources: MBTA weekday ridership from MBTA 2014 Blue Book, 14th ed. Other RTA ridership from MassDOT website. Logan and Logan Express number of parking spaces are the rough estimate of ‘daily users’; data from Massport website. Logan Express ridership from Massport. Private bus carriers from Plymouth & Brockton data in National Transit Database (<http://www.ntdprogram.gov/ntdprogram/cs?action=showRegionAgencies®ion=1>), extrapolated by number of bus trips for all private bus carriers. Suburban/contract bus ridership from MBTA 2014 Blue Book. Bike sharing based on 1,300 bikes reported on Hubway website. Highway tolls from Mass DOT ETC_MLT transactions spreadsheet 2013; vehicle trips are used, since we are focusing on number of payment transactions. Taxi, TMA buses and commercial urban bus services are excluded.

Table 4: Approximate daily usage of transportation services in Massachusetts

Service	Daily users	Percentage
MBTA subway-gated	653,000	31.8%
MBTA subway-ungated	114,000	5.6%
MBTA bus	388,000	18.9%
Commuter rail-downtown	58,000	2.8%
Commuter rail-other	71,000	3.5%
MBTA boat	4,500	0.2%
MBTA parking	60,000	2.9%
MBTA The Ride	7,000	0.3%
RTAs	87,000	4.2%
Logan Express	4,000	0.2%
Logan Express parking	4,000	0.2%
Logan Airport parking	16,000	0.8%
Private bus carriers	16,000	0.8%
Suburban bus systems	2,500	0.1%
Highway toll facilities	565,000	27.5%
Bike sharing	2,000	0.1%
Total	2,052,000	100.0%

One other payment medium is used across many services: transportation benefits cards or checks. These are issued by employers as a tax-free employee benefit. These benefits can be issued on debit cards, checks or directly as passes or stored value on Charlie Cards or Charlie Tickets. Employer-paid or subsidized passes and value are treated as a means of funding a transportation account in this report. Examples of companies that provide transportation benefits services are TransitChek, Edenred Commuter Check, RideECO, TranBen, eTRAC, WageWorks, and FlexDirect. The MBTA and most private bus carriers in Massachusetts accept most of these benefits services²⁶.

Several related services are outside the scope of this report: Bicycle and parking benefits, vanpool payments and incentives, and the Emergency Ride Home (ERH) program, which provides up to four taxi or rental car trips per year for sustainable transportation users. These services, and transit benefits, can be included in the single transportation account described in later chapters.

This report assumes that no significant changes in gated subway stations will be made, and that existing ungated stations will remain ungated. A variant of proof of payment fare collection, which uses validators, is an option for commuter rail service. Proof of payment is not otherwise considered.

²⁶ Voucher and Pass Program Directory, at <http://www.fta.dot.gov/3732.html>

As a point of comparison for the cost estimates of the options presented in this report, the original Charlie Card automated fare collection contract between the MBTA and Scheidt & Bachmann was signed in February, 2003 for \$75 million. As of June, 2011, there were an additional \$19 million in change orders, bringing the system cost to approximately \$94 million²⁷. As of 2009, the MBTA reports having 1,640 fareboxes and garage vaults (used for cash management), 520 ticket vending machines (TVMs), 200 retail sales terminals, 660 fare gates, and some number of validators and handhelds. The system also includes management computers at each station, and hardware and software on servers for system management and integration²⁸. RTA Charlie equipment is not included in these totals.

Example

The existing range of payment options can be complex for new or infrequent users to understand, and it makes it difficult to manage demand, provide incentives, and establish benchmarks. Even for frequent or experienced users of public transportation facilities, the variety of payments can be a challenge, as the example below shows:

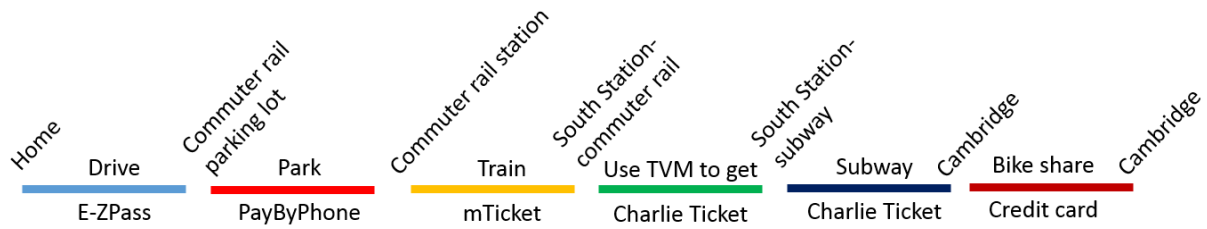
In difficult cases, a public transit user may need to have multiple payment methods to make a single trip. For example:

1. The user drives one exit on the Mass Pike to a commuter rail station. E-ZPass is used.
2. The user parks at the commuter rail station. The PayByPhone mobile app is used at the station chosen, but the user must be prepared to pay cash or use a credit card if he/she needs to go to another station to park if the chosen lot is full.
3. Commuter rail is used to go to South Station. The Masabi mTicket mobile app is used because it is more convenient than obtaining a ticket at a sales outlet and cheaper than paying cash on-board.
4. The MBTA Red Line is used to go to Cambridge. A Charlie Ticket is obtained at a ticket vending machine and used for travel.
5. A bike sharing service is used to make a short trip at noon. A credit card is used.
6. The same four payment methods used for the morning trip are then used for the return trip in the evening.
7. On a subsequent day, the user may travel to Logan Airport, paying for Massport parking possibly with a Gold Passport or Exit Express card, or Logan Express service and remote parking with cash or credit card. If the user stops along the way to the airport and parks the car for a short period, the user must have coins or a town-issued smart card for the parking space.

²⁷ Official Audit Report –Massachusetts Bay Transportation Authority's Automated Fare Collection System, Commonwealth of Massachusetts, Office of the State Auditor, September 2012. At <http://www.mass.gov/auditor/docs/audits/2012/200905833a.pdf>

²⁸ MBTA Automated Fare Collection, Electronic Payment Systems in Transit, University of Massachusetts – ITPS Workshop, February 2009, Nancy Brooks, MBTA. At http://www.ecs.umass.edu/umass_itps_workshop/slides_brooks.pdf

Figure 2 shows the five different payment media that are used. Each one is a separate account that must be managed by the rider: E-ZPass reloads, PaybyPhone daily or monthly passes, mTicket single trips or passes, Charlie Tickets and a general credit/debit card. (The colors in the figure are not related to the colors in the tables.)



Five accounts and five payment media are used

Figure 2 : Example trip, current.

Admittedly, this example is difficult. Massachusetts has implemented many improvements in the payment for transportation services, such as the Charlie Card/Ticket, E-ZPass, Masabi mTicket and PayByPhone. For most users on their daily commute, one or two payment methods are used; users become familiar with them and they pose no issues. Some complexity is due to external factors beyond local control, such as tax codes, for which transit benefit cards are issued. However, for visitors, new residents, existing residents who rarely or never use public transportation, and even frequent transit riders using a new service, the variety of payment methods, fare options and rules creates a potential barrier to usage. There are many types of passes and fares; it can be difficult to decide how to obtain the best value for trips other than a daily commute, and it can take some effort or cost to obtain the required payment media.

General Payment Technology

New types of mobile phone and credit/debit card payment are being implemented that can potentially be used for transportation payment instead of some of the transportation-specific media in current use. This chapter reviews these developments and discusses how these new technologies may be used.

Retail and transit payment

Fifty years ago, most transit fares were paid with cash or tokens, and most retail transactions were also paid in cash. People “paid with what was in their pocket.” Cash became less convenient for transit payment as fares increased and exact change was required. At the same time, retailers moved away from cash to credit card payments to increase sales. The needs of these two segments diverged: transit required fast transaction speeds but did not require a high level of security because payments were small; retail did not require fast transactions but did require a high level of security because payments could be large. Transit smart cards (and magnetic stripe cards), and bank-issued credit and debit cards met the needs of one of the segments well, but did not meet the other’s needs at all.

Credit and debit cards in the US will rapidly become electronic in the next few years, primarily to manage fraud concerns. If the cards issued by banks are contactless (similar to transit smart cards, that are tapped on a reader) or if Near Field Communication (NFC) phone payment becomes widespread (see below), and if transit systems adopt changes in readers and software to accept bankcards (and NFC mobile phones emulating bankcards), this can provide a unified payment method for transit and retail once again, in which people “pay with what’s in their pocket” instead of requiring a transit-specific payment medium.

EMV (chip-enabled) credit and debit cards

The EMV²⁹ standard for electronic credit and debit cards is being implemented world-wide, although the US is one of the last countries in the world to migrate. As of December 2013:

- 81.6% of cards and 99.9% of payment terminals in Europe are chip-enabled
- 54.2% of cards and 84.7% of payment terminals in Canada, Latin America and the Caribbean are chip-enabled
- 38.9% of cards and 86.3% of payment terminals in Africa and the Middle East are chip-enabled
- 17.4% of cards and 71.7% of payment terminals in Asia Pacific are chip-enabled

These numbers are increasing sharply each year.

²⁹ EMV stands for Europay-MasterCard-Visa, who jointly developed the initial chip card standard. EMVCo is the organization that manages the EMV standards for cards, readers and other specifications; it includes all six major payment networks: Visa, MasterCard, AmEx, Discover, JCB (Japan) and UnionPay (China)

In the US:

- 70% of credit cards and 41% of debit cards are expected to be chip-enabled by 2015 in one typical analysis³⁰. 100% EMV compliance is expected in 2018. In October 2015, a major change will occur in the United States payment industry. Specifically, fraud liability rules will change and move risk to organizations if they are still using magnetic stripe cards.
- 88% of payment terminals are expected to be chip-enabled by 2017³¹.

Most EMV cards issued in the US are expected to be contact cards that must be inserted into a terminal, rather than dual-interface cards, which are both contact and contactless. A contactless card is needed for use on public transportation systems. It is not clear if credit and debit card issuers will issue contactless cards in metro areas in which public transportation and other contactless applications are being implemented. A contact EMV card (“chip-and-pin”) costs about \$3.50 and a dual interface (contactless) EMV card costs about \$4.50. The cost difference, plus the unknown customer acceptance of contactless cards, make some banks reluctant to issue contactless EMV cards.

This is a large issue for a unified transportation medium in Massachusetts: if contactless (dual-interface) EMV cards will be issued in large numbers in Massachusetts, the acceptance of credit and debit cards directly at gates, fareboxes, parking entrances/exits and other transportation facilities becomes feasible. Otherwise, the option to use credit and debit cards more broadly either must wait until dual-interface cards are issued or until Near Field Communications (NFC), described in the next section, becomes widely used. Or, the MBTA can issue contactless EMV cards for a period of time until most consumers have either NFC phones or contactless EMV cards. Chicago is using this approach in the Ventra system.

The October, 2014 introduction of Apple Pay makes predictions difficult at this moment: if Apple Pay (which uses NFC) becomes popular, banks will have less reason to issue contactless cards, but NFC will play the same role. If Apple Pay does not become popular, banks may issue more contactless cards.

The acceptance of EMV credit/debit cards directly at transit gates and fareboxes is called “open transit payment” or “open payment”. The transit agencies implementing open payment (Utah Transit Authority, Chicago Transit Authority, Southeastern Pennsylvania Transportation Authority, Washington Metropolitan Area Transportation Authority, and Transport for London) have developed similar approaches to technical issues such as:

- Using payment networks’ global transit industry rules, such as MasterCard’s rule that transit fares can be aggregated into a single transaction of up to \$15 of spend over 14 days if the issuing bank approves an initial authorization request from a US transit merchant for a \$1 amount. Visa, AmEx and Discover have similar rules. These rules may evolve for US conditions as additional transit open payment systems are implemented.
- Using so-called offline transactions, in which the card and reader interact without the server; this speeds up the transaction and makes it not dependent on having a fast network connection. Alternatively, rapid authorization can be provided by a specialized server

³⁰ <http://www.aitegroup.com/seventy-percent-us-credit-cards-be-emv-enabled-end-2015>

³¹ <http://digitaltransactions.net/news/story/Researcher-Predicts-Almost-90-of-U-S-POS-Terminals-Will-Be-EMV-Capable-by-2017>

operated by a bankcard network, e.g., MasterCard's Transit MasterCard Interchange Processor (TMIP).³²

- Using EMV cards at gates cannot require PIN entry. These last two elements are also covered in bankcard industry rules.

The Smart Card Alliance has been the principal organization that has facilitated these discussions and agreements in the US.

NFC mobile phones for payment

The other relevant payment technology is Near Field Communications, or NFC, which allows a mobile smart phone to emulate a credit or debit card when tapped on a payment reader. Transportation already uses mobile payment applications (such as PayByPhone and Masabi mTicket) but these do not interoperate with subway gates, parking gates or bus fareboxes (though mobile apps can be used if the bus driver visually inspects the phone). NFC also allows a mobile phone to act as a card reader; this capability can be used to provide inexpensive validation points on ungated services such as commuter rail or above-ground Green Line stations, which could allow passengers to tap their phones to indicate that they have paid their fare, similar to a gated station³³. Trials and implementations in Europe and in the US (Long Island Railroad) have used this concept. Users have been positive about the technology in virtually every NFC trial³⁴. Last, NFC supports peer-to-peer communications within apps, e.g., those that implement the Open Mobile Ticketing Alliance³⁵ specification for transit payment.

NFC adoption on mobile phones in the US is projected to be between 32%³⁶ and 53%³⁷ between 2015 and 2017. The number of payment terminals in the US that will accept NFC is projected to be 87% in 2017. A non-NFC phone can be converted into an NFC phone using a sticker, an NFC SD or SIM card, or a sleeve; this option may be used as an interim measure though this has rarely been done because the experience is separate from the mobile phone. Wallets, such as Google Wallet and Softcard (formerly Isis), are currently deployed to allow a user to store credit, debit, loyalty, membership and others cards on a phone, and to select the one to be used when tapping on a reader. The introduction of Apple Pay using NFC on the iPhone 6 is likely to spur adoption. Market projections, such as the 32% to 53% numbers mentioned above, were made before the Apple Pay announcements; the projections are likely to increase.

³² Transit Risk Management Processing Solution White Paper, MasterCard, 2011.

³³ This report outlines the option of using validators with power and communications for commuter rail; these have the benefit of reading both NFC phones and EMV cards. The "NFC validator" does not require power or communications but can read only NFC phones; it could be used by the MBTA if the penetration of NFC phones is sufficiently high when validators are considered for commuter rail.

³⁴ <http://www.nfcworld.com/2013/02/23/322501/orange-releases-malaga-nfc-ticketing-trial-results/> is typical. See <http://www.nfcworld.com/list-of-nfc-trials-pilots-tests-and-commercial-services-around-the-world/> for a list.

³⁵ <http://www.open-mobile-ticketing.com/>

³⁶ <http://www.nfcworld.com/2013/06/05/324448/one-in-three-mobile-phones-to-come-with-nfc-by-2017/>

³⁷ <http://mobilemarketingmagazine.com/53-cent-phones-nfc-enabled-2015-says-frost/>

Transit agencies adopting open payments can generally accept NFC payments in the same manner as they accept EMV card payments: the NFC mobile phone emulates an EMV card. NFC stickers and other interim strategies may or may not be supported. Ticket vending machines upgraded to accept EMV cards will also accept NFC EMV payment; this is true for all transit systems, whether they are open payment or not. NFC also allows payment channels beyond bank-issued EMV credit and debit cards, such as payment through a pay-as-you-go mobile phone account; accepting these forms of NFC payment will likely require changes in software and security in transit agencies. These newer forms of NFC payment can generally be added incrementally after the core EMV and NFC capabilities are implemented.

Different approaches to NFC have different transaction times; the MBTA may favor the embedded secure element over the others.

GPR or general purpose reloadable payment cards

A significant issue with credit and debit card payments is, of course, the provision of payment services to those users who do not have or do not wish to use credit or debit cards. Transit agencies moving to open payments have arranged for a general purpose reloadable (GPR) card to be issued for low income and other users. Chicago's Ventra card is an example, and others are proposed. The Ventra GPR card has an initial purchase cost of \$5, which becomes an initial credit for transit use³⁸. If the card is used only for transit, there are no other fees. If the card is used as a retail prepaid (or gift) card, typical prepaid card fees are charged³⁹. Los Angeles Metro has a TAP ReadyCard⁴⁰ that is similar. In both cases, there has been controversy⁴¹ and misunderstanding about the fees, the role of the for-profit issuer of the card, and other issues; these elements must be carefully managed and clearly communicated if a GPR card is used as part of a unified transportation payment medium. While some of the concern has been due to misunderstandings, startup issues, and reaction to change, there are potential issues of being sufficiently clear about the different terms of use for public transit versus retail, and about the general issues of prepaid cards independent of transit use. The MBTA and MassDOT may choose to play an anchor role within the Massachusetts public sector as a high-volume issuer of GPR cards around which other state and municipal agencies can design programs.

³⁸ <https://www.ventrachicago.com/howitworks/> While Ventra is an open payment system, CTA has not emphasized this, and encourages all riders to use a Ventra card, even though they can use a contactless credit/debit card. This may be because current contactless credit/debit cards are not EMV cards, and EMV card issuance is just beginning in the US. If the MBTA moves to open payment quickly, it might use the same approach while EMV and NFC media are introduced.

³⁹ <https://www.ventrachicago.com/assets/1/7/VentraPrepaidDebitFeeSchedule.pdf> Transit agencies should be able to negotiate lower fees than are typically charged because of the large number of users and the low marketing costs to the provider. This can be a benefit to low income users if the fees are lower than those charged by check cashing, currency exchange, other prepaid cards and other alternative financial services.

⁴⁰ http://accessla.org/riding_access/riderid/rideridfaq.html

⁴¹ For example, http://articles.chicagotribune.com/2013-04-02/news/chi-cta-ventra-card_1_prepaid-debit-account-ventra-fare-payment-system

The GPR card has a fee structure determined by its program manager.⁴² Many include fees for use. Transit GPR cards can offer fairly low fees for unbanked and under-banked users but transit systems are nervous about charging even a low price for services. Without GPR cards, underbanked people often pay a cost at currency exchanges and check cashers that can be much higher than a GPR card for the same service. The cost to the consumer varies by program but the GPR industry is converging on a more consistent pricing approach. The transit agency can choose to pay the costs, which some have, or participate in a revenue share to offset fare collection costs, as CTA (Chicago) and SEPTA (Philadelphia) have chosen. A transit GPR card can be viewed as a social benefit offered by transit, not as an added cost.

GPR cards can be registered to a person or anonymous. Anonymous cards used only for transit have essentially no restrictions; if they are used for retail purchases, there are limits on reloading them, based on anti-money laundering laws and the Patriot Act.

PIV or personal identity verification cards

One additional type of card may be accepted by open payment systems: personal identity verification (PIV) cards, which are a smart card issued by the Federal government to employees and contractors, and may also be issued by other government units and other organizations to their employees (under the PIV-I or CIV standards)⁴³. The Opacity security standard is used in conjunction with PIV to protect card data as it is sent to a reader⁴⁴. The Utah Transit Authority has demonstrated the use of PIV cards for transit payment, and WMATA's and SEPTA's open payment systems will also accept PIV cards⁴⁵. The benefit of accepting PIV and similar identity cards is that low or no fees from the financial industry are incurred for pass purchases and use, and the costs of issuing a separate card are avoided. Given the MBTA's large employer pass program, it may be possible to accept employer IDs if they meet the PIV-I standard at gates and fareboxes. EMV and NFC are used only as identifiers, which an employee PIV card can also provide; none of these cards store any transit data. (Traditional transit smart cards such as the Charlie Card contain the stored value or pass, and trip data, on the card itself.) The MBTA could give a small discount to employers who issue PIV or similar cards that can be used for transit payment, since the MBTA will benefit from lower costs. The cost of issuing a PIV-I can be as high as \$25-\$30 at medical institutions, in which the card is used to define many levels of access privilege⁴⁶. Most employers would have lower costs.

Employees would choose to receive a pass or value each month through their employer, as they do in current pass and transit benefit programs. The employer sends a list of employee IDs and a check

⁴² For example, see <https://www.serve.com/>. Choose 'Why Serve' to see a comparison of fees by program. Note the low fees for AmEx Serve. (There is no endorsement of any products or services mentioned in this report.)

⁴³ http://www.smartcardalliance.org/resources/pdf/piv-i_case_studies_wp_022212.pdf and http://www.smartcardalliance.org/resources/lib/PIV-I_White_Paper_012811.pdf

⁴⁴ http://www.smartcardalliance.org/resources/pdf/OPACITY_Overview%203.8.pdf The use of Opacity with PIV cards is expected to occur in 2016.

⁴⁵ http://www.wmata.com/about_metro/news/PressReleaseDetail.cfm?ReleaseID=5637

⁴⁶ <http://www.dhs.gov/xlibrary/assets/st-credentialing-interoperability.pdf>

or electronic payment to the MBTA; the employee IDs are the PIV card numbers⁴⁷. Instead of receiving and using a Charlie Card or Charlie Ticket, they would use their contactless employee ID card at gates and fareboxes. The other terms and processes of the pass or transit benefit program are unchanged. There are no payment industry fees for trips that the employees take. Their taps are recorded and processed at the MBTA server. If an employee takes trips that are not covered by their pass, or exceeds the value placed on the account associated with the PIV card, a backup means of payment is required. Employees may be required to associate a backup credit/debit or GPR card with their account for these trips. Transit benefit providers typically allow a rider to add value to a transit benefit account to pay for a pass whose value exceeds the amount provided by an employer; policies vary on whether a rider can add value to the account for single trips.

Smaller employers, or those who do not issue an identity card suitable for transit payment, would associate the pass with a credit/debit card chosen by the employee, or issued by the employer or the MBTA, and transmit that information to the MBTA monthly.

PIV cards are an optional element of a unified payment system.

Open payment in transit⁴⁸

In open payment systems, contactless bankcards issued by banks and processed by bank card networks are accepted by transit agencies at gates and fareboxes as the primary fare payment medium. The system uses standard merchant readers⁴⁹, merchant acquirers/banks, bankcard networks, and the issuing banks process fare transactions. This is a five-party system, as shown in Figure 3:

1. The cardholder uses his or her credit, debit or prepaid (GPR) card at a gate or farebox. The cardholder can also use his or her NFC mobile phone, which can emulate an EMV card.
2. The transit agency's acquirer (a bank or a payment technology company) captures the transaction. Either the agency or its acquirer performs transit-specific processing to handle passes, prepaid value, aggregation, transfers and other features. Not every card or phone tap is passed to the bankcard network.
3. The bankcard network carries the transaction from the agency's acquirer to the bank that issued the passenger's card
4. The issuing bank bills the consumer and is responsible for many types of fraud and most non-payment.
5. The transit agency receives payment via a settlement process. The merchant (transit agency) is financially liable for some types of fraud.

⁴⁷ <https://www.orc.com/nfi/> is an example of an organization issuing PIV cards for employers

⁴⁸ This section is drawn from "Open payment for regional public transportation travel", George Kocur, prepared for Rudin Center, New York University, June 2010.

⁴⁹ These readers meet the same payment processing standards as retail point of sale (POS) terminals. Their hardware is typically hardened due to the vibration, dirt, moisture, electrical variations and other challenges of bus on-board and subway gate operating environments.

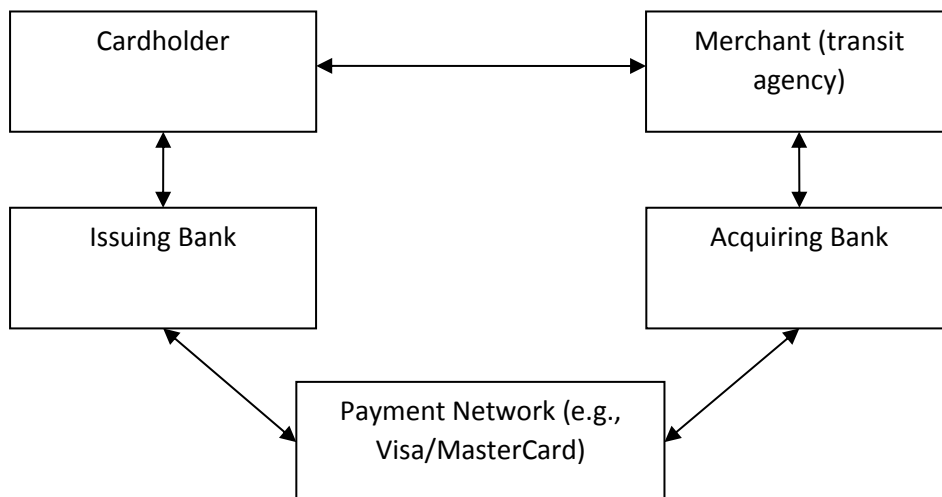


Figure 3 : Open payment system components

The use of contactless bankcards (or NFC phones) for direct payment of transit fares differs from transit smart card practice in two significant ways. First, no value or passes are stored on the bankcard. The card is used only as an identifier that ties the passenger to a payment account stored on a server. Second, the transaction to open a gate or accept payment at a farebox is authorized by a server connected to the gate or farebox via a data network. The open payment option requires a high-availability, high-performance server and network to process transactions. Bus transactions are processed online, as broadband wireless network costs and performance appear to be acceptable. At gates and fareboxes, a full authorization is not performed before the rider is allowed to enter; this takes may take several seconds and would create unacceptable delays. Instead, the card or phone is authenticated: since the card or phone has a computer chip, its identity and authenticity can be verified from the keys/secrets it has. The authorization for the purchase occurs in the back-end servers a few seconds later, after the rider has entered. If the rider’s card or phone does not have a sufficient balance or credit limit, there is a risk that the trip will not be paid for. Analysis indicates that this risk is very low, and it appears that acquirers are willing to accept this risk with little or no additional fee. Appendix A describes one possible set of processing steps in open payment. Alternatively, bank card associations may offer transit risk management products; one example is the MasterCard Transit Risk Management Processing Solution⁵⁰, which can provide near-real-time authorization for taps at gates and fareboxes.

Open payment systems are based on open standards, commodity products such as contactless bank cards and readers, and payment industry services provided to retail merchants and other industries outside transportation. Adoption of an open payment framework will fundamentally reshape the way passengers pay for public transportation services. In a number of cities in the U.S. and around the world, public transit authorities are moving in this direction.

⁵⁰ Transit Risk Management Processing Solution White Paper, MasterCard, 2011.

Contactless bank card technology is relatively mature. It relies on banking standards, unlike transit smart card technology. In an open system, the payments industry would primarily manage fare payment, possibly including nontraditional participants such as mobile carriers or social media companies. This may increase competition, which may result in better services or lower fees. Mobile phone (NFC) technology is becoming mature and widely implemented on Android and Apple handsets; this places media capable of transit payment in the hands of a large number of additional consumers.

An open payment approach provides many desired features in a transit fare payment system. We briefly note the difference between open payment and a smart card such as the Charlie Card for each feature.

1. Fare policy flexibility. In open payment, fare logic resides on servers, enabling a virtually unlimited number of fare policies. In contrast, smart card fare logic is in readers at gates and fareboxes, and is more limited in fare policies, and is not interoperable across modes and carriers. The challenge of maintaining consistent fare rules across many thousands of readers in a smart card (Charlie Card) system is costly in itself, in addition to the constraints it puts on fare policy.
2. Fare model. The open payment fare model is an account-based model that enables pre-paid (pass) and pay-as-you-go products. It enables Web purchase and other self-service channels. Smart card systems store value and passes on the card; cards must be obtained before travel, and all fares are pre-paid, placing two barriers to usage at the start for potential customers.
3. Regional interoperability. A common payment card allows interoperability and does not require (but allows) coordination, such as joint fares or passes, between transit agencies and other transit providers. Smart card systems require agreement on the data stored on the card and the fare logic on readers, which have to handle all fares for all services; this is usually not feasible for an entire region.
4. Modal interoperability. Contactless cards can be tapped at gates, fareboxes and validators across all transit modes. NFC phones are even more versatile, also allowing visual inspection. Several options for open payments in ungated regional rail systems are feasible.⁵¹ Smart card systems can generally serve only a limited number of modes because of card and reader limitations.
5. Future-proofing. By using mainstream payment technology, transit agencies benefit from new services and technologies such as NFC phones and lower-cost providers (possibly mobile phone or social media services) without the need for customization for transit. Smart card systems are provided by a vendor, and the technology is generally difficult to change.

⁵¹ <http://planphilly.com/articles/2013/05/30/septa-to-gate-regional-rail-stations-for-new-payment-technology> is an example of the approach and the issues. Gates are being installed at the five downtown SEPTA rail terminals and the fare structure is being simplified. Montreal's Opus card is used with validators on commuter rail: <http://www.amt.qc.ca/fares/rules.aspx>; this is not an open payment system, but it demonstrates the use of validators.

6. Broad availability of contactless media. Banks will issue EMV cards in 2015 and beyond. In areas with open transit payment, the banks may issue EMV contactless cards. If MassDOT and the MBTA pursue open payments, meetings with the payment networks (Visa, MasterCard, AmEx and Discover), large national card issuers (Chase, Bank of America, Wells Fargo, U.S Bank, Citibank and Capital One) and local Massachusetts issuers to determine and possibly influence their plans for cards issued in Massachusetts. Android and Apple (iPhone 6) phones support NFC; this is a large base of potential users. Smart cards must be manufactured and distributed by the transit agency.
7. Core technology. Servers, wireless data networks and fiber optic networks are proven technology, used as core components in open payments by banks, card networks and merchants. The MBTA has good network connectivity at subway stations; 4G wireless services are available for buses and commuter rail stations. By using commercial and standards-based technology, a larger set of vendors and more competition are expected for fare systems. Smart cards use readers and cards as their backbone, rather than networks and servers. Cost reductions for readers and cards have been small compared to those of networks and servers.
8. Performance. EMV card or NFC phone transactions can be completed in approximately the same time as transit smart cards (about 0.5 seconds) at gates and fareboxes.
9. Security. Payment card industry data security standards (PCI/DA DSS) and standard auditing procedures are followed. Smart cards use lower security standards.
10. Equity. Prepaid card options must be provided to serve riders without bank cards. Transit agencies may choose between closed loop (but open standard) transit-only and open loop general purpose cards. Smart cards must be obtained by riders; riders in low income communities often use cash or magnetic stripe tickets that have higher fares and lower transfer privileges.
11. Customer experience. Existing holders of bankcards and smart phones, and younger riders are likely to be early, enthusiastic adopters. Older riders and people without bankcards will be served well but are expected to use fewer innovative features of the open payment system. Smart cards are different than the mainstream payment experience; users experience unfamiliar ways of obtaining and using the media, and resolving customer service issues.
12. Minimize implementation and operation risk. A few successful open payment implementations are now in service, lowering the risk substantially. There are many more smart card implementations; their technology risks are low.
13. Lower costs. Open payment generally allows an agency to select devices, such as gates, fareboxes, TVMs and others from different vendors. Encouraging competition in devices can lower costs. Open payment can use more standard payments processing software and may be able to leverage existing enterprise resource planning (ERP) software already implemented at an agency for other financial and control purposes. Open payment reduces media issuance costs because it generally uses media owned by customers. Last, open payment back office software is newer and should be more generic, also lowering costs.

Future trends will likely make the EMV bankcard and NFC phone option more favorable over time, since it uses commodity server, network and payment technologies whose costs are decreasing. By

relying on the payments industry to issue cards which can be used to pay transit fares, a transit agency can also realize savings from avoiding the costs to produce, distribute, track and provide customer support for its own smart card or other fare media.

Developments in Other Cities

This chapter reviews developments in transit payment systems and accounts in other cities and countries.

Transit smart card systems in North America

There are currently about 300 public transit smart card systems in the world⁵²; it is believed that none of them are interoperable with any other. In the United States and Canada, there are many major public transit smart card systems⁵³ (and some smaller agencies also have smart card systems):

1. Atlanta-MARTA: Breeze Card
2. Baltimore-MTA: Charm Card
3. Boston-MBTA: Charlie Card
4. Chicago-CTA: Ventra, open payment: Accepts contactless credit and debit cards at gates and fareboxes
5. Houston-Metro: Q Card
6. Jacksonville-JTA: Star Card
7. Lindenwold-PATCO: Freedom Card
8. Los Angeles-MTA: TAP Card
9. Miami-MDT/Tri-Rail: Easy Card
10. Minneapolis-Metro: Go-To Card
11. Montreal-STM: Opus Card
12. New Jersey/New York-PATH: SmartLink Card, and NJ Transit Tap>Ride open payment on select bus routes and Newark AirTrain accepts contactless credit and debit cards.
13. Philadelphia-SEPTA: Key Card, open payment (2015): Accepts credit and debit cards at gates, fareboxes and validators
14. Phoenix-Valley Metro: Platinum Pass
15. Pittsburgh-PAT: Connect Card
16. Portland OR-Tri-Met: Planning an open payment system that accepts credit and debit at fareboxes
17. Salt Lake City-UTA: open payment: Accepts contactless credit and debit cards at validators and fareboxes
18. San Diego: Compass Card
19. San Francisco-MTC: Clipper Card
20. Seattle-Metro: Orca Card
21. Spokane-ST: Go Card
22. Toronto-Metrolinx: Presto Card
23. Tucson-SunTran: SunGO Card
24. Vancouver-Translink: Compass Card
25. Ventura County, CA-VCTC: Go Ventura Card

⁵² NFC Standards for the NFC Ecosystem, Smart Card Alliance, 2011

⁵³ Transit and Contactless Open Payments: An Emerging Approach for Fare Collection, Smart Card Alliance, 2011

26. Washington DC-WMATA: SmarTrip Card. Migrating to open payment (contract signed 2014)

Public transit smartcard characteristics

These North American cards are the core of public transportation in their areas; the majority of public transportation trips are paid by these cards (and their magnetic stripe brethren, in many cases). However, they are difficult to extend to other modes and services:

1. All are valid on gated (subway) services
2. Almost all are valid on bus services (PATCO and PATH are the only known exceptions)
3. Most are valid on light rail services, where they exist (PATH and Toronto are exceptions)
4. About half are valid on commuter rail services (Miami, Montreal, Salt Lake City, San Francisco, Seattle, Vancouver and Toronto).
5. Most cards are accepted by nearby smaller regional transportation authorities, usually all-bus systems.
6. Few cards are accepted for parking: only Miami and San Francisco (5 SFMTA garages only) do so.
7. In a few cases, smart cards are used for access (e.g., bike cages): Boston, Montreal, Salt Lake City and Washington.

Transit smart cards are difficult to extend to other services because:

1. Passes and value are stored on the card, which has limited storage and uses an agency-specific data layout that is difficult to modify. (General purpose payment media, such as credit and debit cards, store no data on the card; they function strictly as an identifier.)
2. The cost of a transit trip, or other service, must be computed by the card reader (at the gate, farebox or other access point such as a parking gate) and written to the card with agency-specific logic that must be programmed into all readers.
3. Acceptance outside a transit agency is difficult because the security standards for smart cards are less stringent than for general payments (such as credit or debit cards), and there is no general clearing and settlement mechanism by which transactions are posted and funds are credited to the account of the agency or organization providing the service.

Transit payment initiatives

While transit smart card systems perform their specific task well, they are a barrier to having a unified transportation payment method in urban areas.

To overcome these issues, in part, a set of initiatives in North America have been undertaken:

1. Chicago Ventra, Philadelphia Key Card, Salt Lake City UTA open payments. These three systems accept credit and debit cards at gates and fareboxes for payment. This allows credit and debit cards to be a single payment medium across modes and services within the area. Washington, D.C. let a contract in January 2014 for an open payment system overlay on its current system. Chicago, Washington and Philadelphia are the second, fourth and sixth largest US transit system. (New York is first, Los Angeles is third and Boston is fifth.)

2. Several systems are using mobile phones as a major component of their payment system. Portland OR Tri-Met has implemented a mobile app for almost all services and fares, and is planning to accept credit/debit cards and NFC phones in an open payment framework⁵⁴. This is a possible model for the MBTA, as Tri-Met's plan has similarities to the options laid out in this report⁵⁵. Tri-Met is starting as a proof-of-payment systems, while the MBTA is already gated on the subway system, so there are significant differences as well. The Dallas DART system has implemented Go Pass⁵⁶.
3. Los Angeles Metro ExpressLanes. The Metro ExpressLanes pilot project was conducted in 2013, in which LA Metro and Caltrans implemented a variable toll system on the I-10 and I-110 freeways. Toll charges are based on the number of passengers in a vehicle and the level of congestion. If a user links his/her public transportation and highway toll accounts, ExpressLanes provided credits and a chance to win gift cards, based on the frequency of transit or carpool use; it also provided rewards for referring users to the program. For example, if a traveler used transit 32 times at peak periods, he or she was given a \$5 toll credit. At the end of the one year demonstration, transit ridership had increased by 14% and 110 new vanpools had been created. \$10,000 in toll credits were given out, and 480 travelers received gift cards. The program is now permanent⁵⁷.
4. Los Angeles ExpressPark⁵⁸. ExpressPark varies parking fees according to demand, and provides information on prices and the locations of available parking via mobile phone applications, or variable message signs. Drivers pay with a credit card, debit card or by mobile app. This is not linked with ExpressLanes or any other transportation initiative.
5. San Francisco SFPark. This is also a variable parking fee system.
6. Montreal. Montreal offers Opus Card users discounts on Bixi (bike sharing), Communauto (short term auto rental) and Passeport Mobilite (a program aimed at real estate developers that provides public transport information, and discounted bike sharing and shared car programs). Other agencies that have established pilots with car sharing services at typically three to five stations include Portland, OR, Tri-Met⁵⁹, Toronto, ON, Metrolinx⁶⁰, NJ Transit⁶¹, Chicago, IL, CTA⁶².
7. nuRide⁶³. nuRide provides incentives for greener trips. It has operated in Massachusetts since 2010 and has about 25,000 members.

⁵⁴ Tri-Met is asking its users for input: <http://surveymonkey.com/s/efare>. This link is likely to be short-lived; Tri-Met can be contacted to obtain the survey and results.

⁵⁵ <http://trimet.org/efare/index.htm>

⁵⁶ <http://www.gopass.biz/gopass/index.html>

⁵⁷ <https://www.metroexpresslanes.net/en/about/about.shtml>

⁵⁸ <http://www.laexpresspark.org/>

⁵⁹ <http://news.trimet.org/2014/01/trimet-and-zipcar-join-together-to-increase-transportation-options/>

⁶⁰ <http://www.zipcar.com/press/releases/zipcar-and-metrolinx>

⁶¹ http://www.njtransit.com/rg/rg_servlet.srv?hdnPageAction=CarShareProgramTo

⁶² <http://www.transitchicago.com/goinggreen/multimode.aspx#carsharing>

⁶³ <http://nuride.com/>

Notable initiatives outside North America include:

1. London (Transport for London) Future Ticketing Project (FTP). This is an open payment system for subway (tube or underground), bus, light rail, national (commuter) rail, and river boats, in a complex urban area with a complex fare policy. FTP was implemented system-wide in September, 2014, and usage has grown very rapidly.⁶⁴ In the first eight weeks of operation (mid-September to mid-November, 2014), 12 million contactless EMV transactions were made.⁶⁵ As of February, 2015, over 500,000 contactless EMV transactions are made each day, and the number continues to grow. Contactless EMV passes will be introduced in the next phase in the near future. There have been essentially no operational problems, and there has been highly positive feedback from users.⁶⁶ It has been particularly effective with infrequent riders and in supporting large events, such as football games at a large stadium.
2. Singapore INSINC. The INSINC program has awarded over US\$1 million in incentives to people taking transit or driving in less congested times. In addition to incentives, they have used social media (commuters are compared to their friends) and personalized offers to influence travel behavior. INSINC uses the possibility of large prizes rather than small incentive payments.

⁶⁴ <http://www.nfcworld.com/2014/09/26/331633/tfl-reports-rapid-adoption-contactless-payments-london-transport/>

⁶⁵ <http://www.tfl.gov.uk/info-for/media/press-releases/2014/november/12-million-contactless-journeys-made-since-launch>

⁶⁶ Sample tweets include: "Contactless payment for the tube is an absolute dream", "TfL going contactless has revolutionized my life", "Something really great and time saving is being able to use contactless bank card in London underground", "Touching in and out of the tube with my contactless card, peoples, we live in a golden age of wonder", "Contactless payment on the underground is joyous. Good move TfL", "Got to say I am a bit nerdy excited about using my contactless card on the tube when I'm in London next weekend...no more queuing yay!"

Payment Media Capabilities

Current payment media must meet a wide range of requirements, as shown in Table 5. No single medium, current or future, appears to be able to meet the requirements of all transportation services. In table 5, green cells indicate the requirement is fully met; yellow cells indicate the requirement is partially met; red cells indicate the requirement is not met. Most text entries are either “yes” (the requirement is fully met) or “no” (the requirement is not met). Some are qualified if a supporting element is needed to meet the requirement. In security, the green cells are noted as excellent or good security; good security is sufficient. In customer service expense, green is low expense, yellow is medium expense and red is high expense, even though all media can be supported.

There is one variation on Charlie Card that is not in Table 5: “Charlie Card Lite”. This is a limited-use, lower-cost version of a Charlie Card. It is thinner, has less robust security and a lower lifetime. In general it has the same characteristics as a Charlie Ticket. The MBTA may replace the Charlie Ticket with Charlie Card Lite, allowing the retirement of magnetic stripe readers at gates and fareboxes, and perhaps improving the reliability of the payment means. The Charlie Card Lite must still be reissued frequently, which continues the relatively high level of mail, card stock and customer support expense of Charlie Ticket

Table 5: Requirements for payment media

Requirement	Payment medium						
	Cash	Credit/debit (EMV contactless)	Charlie Card	Charlie Ticket	Smart phone payment (non NFC)	NFC phone	E-ZPass
High volume transit gate access	No	Yes, with network/server	Yes	Yes	No	Yes, with network/server	No
Ungated transit access	Yes	Yes, with network/server	Yes	Yes	Yes	Yes, with network/server	No
High volume toll barrier access	Poor	No	No	No	No	No	Yes
Non-transit acceptance	Yes	Yes	No	No	No	Yes	No
Visual inspection	No	No	No	Yes if printed	Yes	Yes	No
Electronic inspection (with inspection device)	No	Yes	Yes	Yes	Bar code only	Yes	No
Travelers have medium already	Yes	Maybe in 2015 and beyond	No; must be issued	No; must be issued	Most	Likely in 2015 and beyond	No; must be issued
Transfers between services	No	Yes, with network/server	Yes	Limited	Very limited	Yes, with network/server	No
Supports flexible pricing, marketing	Limited	Yes	Limited	No	Limited	Yes	Yes
Security	Good	Excellent	Good	Low	Good	Excellent	Excellent
Customer support expense	Low	Low	High	High	Low	Low	Medium

High volume transit gate access

This is the major capability provided by Charlie Card, Charlie Ticket and similar transit-only payment systems. These cards have value or passes stored in their memory, and the gate readers have system-specific (MBTA-specific, in Boston) logic to read the value and passes. Charlie Card and Charlie Ticket do not work like credit or debit cards, which check an account stored on a server; all Charlie transactions are local between the reader and the card, which makes them fast and not dependent on network connections. Also, Charlie Card and Charlie Ticket are not general financial instruments, so their security can be (and is) less strict than credit or debit cards. A drawback of Charlie Card and Charlie Ticket is that they must be issued by the MBTA and other agencies, and riders must obtain them, which is a barrier to use and an added expense. An additional drawback is that the data and logic on a Charlie Card are specific to the MBTA and are not extensible to other transportation services.

In the last few years, it has become feasible to accept credit and debit cards directly at transit gates. This has required industry-specific changes in credit and debit card processing rules (which is common—hotels, rental cars, and gas stations are other industries with their own rules) and upgrades to gate readers and networks. The credit and debit cards must be contactless—they are touched or tapped on a reader rather than being inserted—to provide acceptable performance.

Smart phones with apps cannot be used at gates; this is a drawback of current MBTA and MassDOT systems such as mTicket (commuter rail), PayByPhone (parking) and BusPlus (commuter bus). NFC smart phones emulate a contactless credit or debit card and can be used at gates; these are a leading option for a unified payment system. It may be possible to place bar code readers on subway gates to allow non-NFC smart phone apps to be used; this is a variation that is briefly described in phase 2.

Ungated transit access

Transit payment at ungated light rail (Green Line, and Mattapan), commuter rail and bus stops is typically on board the transit vehicle. Off-vehicle payment is used in some cities (e.g., New York MTA Select Bus⁶⁷) by placing fare vending and validation equipment at all bus stops on high volume routes, and by having inspection on the vehicles to ensure riders have paid. This is expensive and unlikely to be effective in Boston; it is not considered in this report. A proposal to extend the use of Charlie Card to commuter rail in Boston has not been implemented, primarily due to cost concerns.⁶⁸

Charlie Card and Charlie Ticket meet the requirements of on-vehicle data collection well if there is a farebox that can read the medium. However, if the vehicle does not have a farebox, or riders do not have convenient access to obtain and load Charlie Card and Charlie Ticket, this form of payment is less effective. Private commuter buses do not have fareboxes; riders at MBTA bus stops must

⁶⁷ <http://web.mta.info/mta/planning/sbs/>

⁶⁸ <http://blog.mass.gov/transportation/mbta/mbta-mticket-named-top-10-transportation-project-in-u-s/>. An estimate of \$70 million in savings is given for not implementing Charlie Card for commuter rail.

generally find a Charlie Card retail outlet to obtain media and passes; commuter rail train staff do not have equipment that can read Charlie Cards.

Credit and debit cards can be used at fareboxes, providing the same functions as Charlie Card and Charlie Ticket; this requires farebox and fare server upgrades. Credit and debit cards do not require a rider to obtain transportation-specific media. They still require a reader, however. An NFC phone, which can both emulate a credit/debit card and show a visual ticket for inspection, offers significant promise for use on commuter rail and private commuter buses, as well as serving MBTA subway and bus travel.

A final issue is that placing cash-acceptance tasks on the bus driver and farebox (especially to reload a Charlie Card) significantly compromises bus service speed on ungated services. Transport for London went cashless on buses in August, 2014⁶⁹.

High volume toll barrier access

The other major transportation payment area is highway, bridge and tunnel tolls. E-ZPass is used in the Northeast by 26 agencies in 15 states, including all toll facilities in Massachusetts; it is governed by the E-ZPass Interagency Group (IAG), also called the E-ZPass Group. The Moving Ahead for Progress in the 21st Century Act (MAP-21) requires that all highway toll systems be interoperable across the US by 2016 although this deadline may be extended⁷⁰. Transponders are currently the dominant technology for toll payment, but automotive GPS electronics and license plate readers may eventually supplant them. This report considers transponders as the preferred medium.

E-ZPass consists of vehicle transponders and barrier-based readers. Highway travelers must obtain a transponder, establish an account, and usually provide a credit or debit card to load value into the account. Accounts are typically managed online. MassDOT has a cash reload program at retail kiosks⁷¹. This program can be extended to additional locations and merged with the transit cash reload program in phase 2. MassDOT may use an approach similar to the New York MTA's program to improve customer convenience for lower-income users, the E-ZPass Cash Reload card, which allows customers to reload their account at 2,500 stores that accept Visa ReadyLink⁷². This allows cash customers to use E-ZPass lanes and to pay the lower E-ZPass toll rate in New York. These locations agree to charge no more than \$2 for a reload; since E-ZPass tolls are lower than cash tolls, the user obtains a lower total cost even with the reload fee. The MassDOT reload rate is \$1.95, and users receive a discount at four toll barriers, which can offset the cost of the reload.

E-ZPass cannot be used for transit gate access for a number of reasons. First, the transponders are typically fixed in place in a vehicle. Second, they are designed to operate at long range (up to 100

⁶⁹ <https://www.tfl.gov.uk/info-for/media/press-releases/2014/february/london-buses-to-go-cashless-from-mid-2014>

⁷⁰ <https://www.fhwa.dot.gov/map21/summaryinfo.cfm>

⁷¹ <http://www.massdot.state.ma.us/highway/traffictravelresources/ezpassmapprogram.aspx>

⁷² https://www.e-zpassny.com/en/faq/reload_card.shtml Visa ReadyLink is used as a GPR example in the remainder of the report. There is no endorsement of Visa or any other organizations that offer similar products.

meters for open road tolling), while transit readers operate at very short ranges (1 or 2 inches) to limit fraud and interference. For technical reasons, E-ZPass operates at different radio frequencies than transit readers or merchant point of sale terminals. Third, E-ZPass has a different security model than transit readers: E-ZPass does not need to encrypt data between the transponder and reader, because it can verify that the transponder is in the correct vehicle by photographing the license plate number, checking the number of axles, and performing other checks. Thus, integrating highway tolls and transit payment with one consumer device is infeasible, at least at present.

License plate readers, and automated number recognition, may be supplant E-ZPass and other transponders in the future. If this were to happen, a traveler could associate his or her license plate number with the single account to pay tolls; there would be no need for an E-ZPass transponder, and this would create the possibility of a fully unified payment system. License plate readers are being used in all electronic toll collection for vehicles without transponders, including the Tobin Bridge. Technical issues remain before they become the preferred toll collection method. The use of license plate readers is outside the scope of the report, as are vehicle-based GPS and other new technologies. However, the phase 2 system can accommodate them.

Non-transit acceptance

Only cash, credit and debit cards are generally accepted forms of payment, which can be used at non-transit services such as bike sharing, car sharing, taxis and parking. Credit and debit cards are also required to use mTicket, PayByPhone and BusPlus mobile applications. The general availability of credit and debit, the adoption of EMV (chip-based) cards, and the emergence of payment-enabled (NFC) phones and contactless EMV cards, suggests that credit and debit cards may be suitable media for unified payment.

Visual inspection

Some transportation services without electronic processing capabilities require that the payment medium be inspected visually. For example, print-at-home tickets on bus carriers and Amtrak are examined by the driver or conductor. Since credit and debit cards have no user interface, they cannot be used where visual inspection is required without additional steps. Mobile phones can display tickets purchased by credit or debit, which makes them attractive as a unified payment medium.

Charlie Cards cannot be inspected visually. A number of services accept Charlie Tickets but not Charlie Cards because the medium must be inspected visually. These include commuter rail and suburban/contracted bus systems, and they accept only passes whose information is printed on the Charlie Ticket. They do not accept stored value on Charlie Tickets.

Electronic inspection

Media may need to be inspected on a vehicle to ensure that passengers have valid tickets or passes, especially on ungated services.

All payment media can be inspected electronically if staff have a device, usually a smart phone, which has the appropriate hardware interface (typically a bar code reader or NFC). A Charlie Card or Charlie Ticket can be inspected without a communications network being available to the inspector since all data is on the card or ticket. Credit and debit cards generally require network access to confirm that the user has touched in at a gate or farebox⁷³. Almost all untagged MBTA services that might require electronic inspection operate above ground, so that mobile access is available. (Buses in the tunnels to Logan Airport and downtown are an exception.)

Media held by travelers

About 80% of US households have a credit or debit card. None have Charlie Cards, Charlie Tickets or E-ZPass transponders unless they have obtained one from the MBTA or MassDOT (or other agency).

About 20% of US households do not have a credit or debit card.⁷⁴ General purpose reloadable (GPR) cards (also known as gift cards) can be used to provide access to transportation services for these households. There are two broad options:

1. MassDOT can issue a transportation-only card, good only at MassDOT and affiliated services (such as private commuter bus carriers). The card can be registered or not, at the traveler's option. If it is registered, it can be managed by the user, and value can be protected if it is lost and stolen. Both registered and unregistered cards can be reloaded, although registered cards can be reloaded more times and with greater value. The specific limits vary by card issuer. Transit agencies adopting open payments generally plan to charge a fee (\$5 is typical) to obtain the card. Retail outlets charge a reload fee; for example, when a rider reloads \$20, the outlet may charge a \$2 fee. The MBTA can add the \$2 to the value of the reload, giving the rider a \$22 balance. The rider gives the clerk \$22; the MBTA receives \$20 electronically and the store keeps the \$2 fee⁷⁵. There are no other fees.
2. MassDOT can issue a card that is also accepted at merchants. When issued to a traveler, the card's default setting is for transportation only. If the user goes online or contacts a call center, he or she can enable the card for more general purchases. Open payments transit agencies negotiate a fee structure in which transportation reloads and purchases have no fees; retail purchases have fees, but agencies may be able to obtain favorable terms. Such a card can offer benefits to low income users, but is likely to be controversial.

The GPR card follows the same standards as credit and debit cards (it is essentially a debit card backed by a low balance) and can be generally be accepted at transportation services like a credit

⁷³ Inspectors board a vehicle and tap their mobile phone on the farebox to download all taps in the last hour; they also have a wireless connection to download the latest list of lost, stolen and otherwise invalid cards and phones. All data and transmissions are encrypted. This system is in current use in London with contactless payment.

⁷⁴ US Federal Reserve Bank of Philadelphia has an extensive report series on payment at <http://www.phil.frb.org/consumer-credit-and-payments/payment-cards-center/>

⁷⁵ AS mentioned above, the New York MTA cash reload program includes a prepaid card with new E-ZPass transponders. See https://www.e-zpassny.com/en/faq/reload_card.shtml. A \$2 fee is paid for E-ZPass reloads; the intent had been to negotiate a \$1 fee for transit reloads for a proposed open payment transit card that has not been implemented.

or debit card. Use of GPR cards for bike share, car share or other services requiring a damage deposit may be restricted, or GPR users may be required to purchase damage insurance.

The use of credit and debit cards at gates and fareboxes is described in section 3.6, Open payment in transit.

Transfers

Transfers between services are supported by credit and debit cards, and NFC phones. These are interoperable media that will be accepted by most transportation carriers, including distant transit agencies such as Chicago, Philadelphia and Washington DC. Mobile phones offer greater capabilities than cards since they can be used in ungated services where visual inspection is used.

The Charlie Card offers support for transfers across a smaller set of services; it supports most transfers within the MBTA system, but is not accepted on commuter rail, private commuter buses, suburban/contracted bus systems, bike sharing, car sharing and similar services. Because it is an MBTA-specific payment means that requires gate or farebox readers, its scope is limited. Because data space is limited on the Charlie Card, its ability to store a large number of services and transfer types is limited.

The Charlie Ticket is also limited. It supports local bus-local bus transfers, but not subway-bus transfers. It does support commuter rail-subway and commuter rail-local bus transfers, which the Charlie Card does not. A magnetic stripe ticket such as the Charlie Ticket has more limited space to store data than a Charlie Card, and a shorter useful life, which account for its lower capabilities. (The Charlie Ticket could provide some additional capabilities beyond its current implementation, but the MBTA chose to limit it for policy reasons.)

Flexible pricing, marketing and demand management

Credit and debit cards, since they are held by most users, allow MassDOT and MBTA to market more flexibly, since media do not need to be provided for transit use. MassDOT and MBTA can organize marketing efforts for customer acquisition, targeting transit non-users, without the lack of a Charlie Card being an impediment. Incentives can be targeted to specific areas or groups through the use of discount or promotional codes, and the duration of incentives can be tailored. By tying marketing to credit and debit, richer demographic information is available; marketing information must be used carefully by a public agency. Since values and fares are computed on a server and not stored on cards (or computed by gates and fareboxes), there is much more flexibility in scope and pricing.

A second marketing focus can be customer retention, aimed at keeping existing riders (or retrieving those who have just left a transit service). A different set of incentives can be provided to this set of people. Examples of the use of these marketing capabilities are described in phase 2.

Security

Security in EMV cards and NFC phones meets payment industry standards, which are very high. The introduction of EMV cards and NFC phones allows transactions to be made without the merchant (MBTA or MassDOT) needing to have the credit or debit card number; this sharply reduces the risk of breaches of credit and debit card information, which have been a major issue in recent years. The level of attack on EMV and NFC is high because they are general payment media, but the level of fraud is generally low.

Charlie Card security is moderate. It uses encryption that has been broken, and does not offer some of the additional safeguards of general payment media. However, Charlie Cards are not a large target for criminals, since the amount of money involved is fairly limited. It is unlikely, though not impossible, that the Charlie Card weaknesses would be targeted by criminals. A possible scenario is the production of cloned Charlie Cards (with the same serial numbers as valid cards) or cards that do not decrement their stored value; both have been demonstrated.

Charlie Ticket security is modest. Magnetic stripe tickets can be copied. Again, they are not a large target because the amount of money is limited. There are informal reports from other cities of large numbers of counterfeit magnetic stripe tickets being used. The tickets are inexpensive to produce; hypothetically, if a criminal sold counterfeit 7-day passes (\$19) for \$10, he or she could generate a modest amount of illicit revenue. This scenario appears to have occurred in at least one transit system.

E-ZPass security is excellent. Data from the E-ZPass readers to the server is encrypted and managed to high standards.

Customer support

Direct acceptance at gates and fareboxes of credit and debit cards (and NFC phones) is expected to reduce customer service costs, if Charlie Card and Charlie Ticket are phased out. Customers with a problem at a gate or farebox are likely to use a second credit or debit card if the first one fails. They are also most likely to call their bank rather than the MBTA to resolve the problem. The MBTA will still handle calls about malfunctioning gates, incorrect fares or transfers, and the like. Payment with a NFC mobile phone transit app will require more support than NFC phones without the app, since customers will contact the MBTA in more cases if there is an issue.

MassDOT must continue to support E-ZPass; there are no alternative forms of payment for highway tolls at present.

Objectives for Massachusetts

Specific objectives for a unified payment system in Massachusetts include:

1. Increased mobility for residents and visitors by allowing use of all transportation services via readily available payment means.
2. Increased transit ridership or revenue as a result of lowered barriers to use.
3. A single account to purchase transportation, add funds, and review and manage travel options, including better support for cash customers.
4. Simplified means to purchase travel using media that consumers already possess, and simpler means to obtain transportation-specific media that are needed, such as E-ZPass transponders.
5. Allow the MBTA and MassDOT to better provide service data, offer incentives to change travel patterns, and monitor changes in travel.
6. Allow the MBTA and MassDOT to integrate non-MBTA services such as TMAs, employer bus services and commercial bus services into a seamless transit network, cost-effectively expanding the number of services and destinations available to riders.
7. Improved management of incidents, construction, special events (such as the Boston Marathon or a potential Olympic Games) and other situations in which travelers are rerouted across services or modes.
8. Reductions in the cost of fare/toll collection, with fewer systems and greater operational efficiencies.
9. Reduction in uncollected fares, missed fares and fare evasion.

Phase 1 and phase 2 are designed to meet these objectives, as discussed below.

Phase 1: Incremental Implementation of Unified Payment

This initial phase makes incremental improvements in the integration of transportation payments that do not require major technology changes from current systems, and it creates a single transportation account and website. In phase 1, the single account supports existing or incrementally modified payment media; it does not change the basic operation of the Charlie Card or E-ZPass systems. Because Charlie Card is a card-based system, there will be some restrictions on what is possible. This phase is a set of preparatory activities to facilitate the open payment system in phase 2. A fast-track plan would omit phase 1 and implement phase 2 directly; the planning steps in phase 1 would still need to be done within phase 2.

Single transportation account

The single account is accessed via a website that supports payment, purchase and management of transportation services:

1. The server-based account system and website allows users to create a transportation account by registering their Charlie Card, E-ZPass, mobile payment (mTicket, PayByPhone, BusPlus), and possibly credit and debit cards used to purchase other forms of transportation such as bike sharing.
2. Users may maintain a single balance in this account that can be used on transit, highway, parking or other transportation services that require prepayment. If this is not initially possible, separate highway and transit accounts may be maintained, but the user may easily transfer funds between them.
3. The single account can be automatically reloaded by credit/debit cards online, over-the-air via smartphones, cash and credit/debit cards at ticket vending machines (TVMs), or by cash at retail outlets.
4. The number of locations in the retail reload network should be expanded, and they should handle both highway and transit. Reload amounts are added to E-ZPass and/or Charlie Card value or passes using current methods to credit accounts. Charlie and E-ZPass reload locations should be integrated; it may be possible to use a system similar to the New York MTA to reload the unified account.⁷⁶ Credit and debit cards should be accepted for Charlie Card reloads at all retail locations; the commission rate may need to be raised to allow this, and agreements with the retail locations may need to be amended to require credit/debit card acceptance.⁷⁷ As an additional incentive for retail locations, the MBTA and MassDOT

⁷⁶ At the E-ZPass reload store visited, the transaction was done at the point of sale terminal using the PayXchange service from Softgate Systems, an open platform for top-ups and bill payment for cash-preferred users.

⁷⁷ At one Charlie Card retail outlet, the owner noted that the 1.8% commission is not sufficient to cover credit card fees. He noted that 2.5% would allow him to accept credit/debit, which would be more convenient for users. He noted that a moderate number of users were inconvenienced by having to pay cash for the MBTA reload part of a purchase at his store. At a store with E-ZPass retail reload, the commission is \$1.95 even though only cash is accepted. (The Charlie commission on a \$20 reload, by contrast, is \$0.36.) Having some difference in commissions between highway and transit may be effective, but the current difference is quite large.

can provide advertising for them on commuter rail variable message signs, on buses and subways on a space-available basis and elsewhere.

5. The user should be able to control the reload amount and timing; this is a benefit to low-income users, who may find uncertain reload amounts and timing difficult to budget for. Massachusetts offers a manual reload option that requires mailing a check or going to one of five customer service centers. By implementing an expanded cash reload system at retail outlets, convenience for cash customers can be improved.
6. The website may provide additional capabilities to control reload amounts and timing. If the user associates his or her mTicket and Charlie Card numbers, additional transfer privileges can be provided. The account system supports additional transfers with different payment media.
7. Having an account is not mandatory; users opt in. The account may contain personal information or it may be anonymous. If users only enter a Charlie Card number, for example, and reload with cash, no other information is needed.
8. The account records users' participation and usage of all services, to provide users with a full picture of their transportation use, and possibly to allow users to compare options for meeting their travel needs. It will display as much Charlie Card data as feasible. The app shows total expenditures; if tolls are paid, the app can estimate auto operating costs as well as direct expenditures. If a user enters his or her home address and indicates trip destinations on the Web, time and cost estimates for alternatives can be provided. Users may be eligible for incentives or discounts; they may be required to register E-ZPass and Charlie Card information to obtain some or all incentives⁷⁸.
9. Employer pass programs and transit benefit programs are linked to the single account. The MBTA or MassDOT may act as a third party for benefits used on private bus carriers to simplify program administration for employers, who would only work with one agency.
10. A third party may manage the single account, so that there is a separation from MassDOT or the MBTA, such as a Transportation Management Association (TMA)⁷⁹ or other nonprofit organization.

The account is used to pay for a large number of transportation services:

1. MBTA and RTA value and passes are bought through the account. Users must be able to indicate whether value is being added or a pass is being purchased when using cash reload at a retail location.
2. The Charlie Card is updated at gates and fareboxes, as it is now, for passes and for automatic reloads of value⁸⁰, from the single account. The time delay for posting reloads should be short, ideally just a few minutes⁸¹. Analysis is required to determine the feasibility of rapid updates.

⁷⁸ See the Los Angeles and Singapore programs as examples.

⁷⁹ <http://www.commute.com/employer-options/transportation-management-associations>

⁸⁰ The MBTA website notes that "automatic reload of value will be available soon". We assume this capability can be added as an incremental change; this must be confirmed. A flexible top-up that adds a user-selected amount when the balance reaches a trigger level should be implemented if possible.

⁸¹ Sydney, Australia's Opal Card fulfills products purchased on the Opal website to 100% of Opal gates and fareboxes within 60 minutes over an area of 40,000 km². This might be the minimum standard for phase 1.

3. Monthly or daily parking is prepaid as in the current system, and the parking subsystem is updated from the single account. Parking systems at subway and commuter rail stations should be unified. A single means of payment for all gated lots, and a related means for ungated lots, should be provided. For example, a mobile app for ungated lots and credit/debit cards for gated lots, tied to the single account and providing daily and monthly parking.
4. Interfaces should be provided to mTicket, PayByPhone and BusPlus mobile ticketing systems, so that their payment and usage are also managed and visible in one account. These services should have a single, unified mobile app if possible. The user selects commuter rail, boat, parking or private bus as the service to be purchased, and the app takes him or her to the specific screens to complete the purchase. Ideally, the unified app provides service information as well as payment.
5. The unified app should allow users to add value or passes on their Charlie Card. Again, the delay to send the update to a gate or farebox should be short. Users should be reminded to add value or passes before they run out of value. Users could be allowed to take one trip with insufficient value as a convenience if mobile top-up is widely used and has a delay in posting the added value or pass.
6. Interfaces for Massport Logan Express, Logan Express parking and Logan airport parking should be provided. These services should also be served by the single mobile payment app if possible. The user would additionally select Logan Express, Logan Express parking or Logan airport parking in the unified app, and again the app takes him or her to specific screens to complete the purchase.
7. Interfaces to The Ride and RTAs should be included if possible. The unified app gives these choices as well.
8. Interfaces to bike share, car share and other services should be included if possible. These are two or more additional choices in the unified app.

A single transportation account implies the ability to store payment card information as part of a card-on-file system, and hence also implies challenges around the secure storage and management of consumers' payment card information.

Rapid changes in the US payment industry in this field are expected over the coming twelve months that – if adopted quickly – will result in substantial reductions in the level of exposure to risk endured by merchants such as the MBTA and MassDOT. Two examples of these changes are:

1. The MasterCard MasterPass network of wallets and associated APIs⁸² opens up the possibility of the MBTA/MassDOT handing off the challenge of securely storing card details to a Digital Wallet Operator (DWO) and calling for credentials as and when required through the MasterPass APIs. Citi is the first East Coast issuer to choose to become a DWO.⁸³
2. MasterCard expects to come to market next year with a card-on-file tokenization service that will allow a merchant like the MBTA/MassDOT to replace all the card credentials held in its system with otherwise-meaningless tokens provided by MasterCard as part of a new tokenization service.

⁸² Application programming interfaces.

⁸³ <http://www.citigroup.com/citi/news/2014/140825a.htm>

These and similar offerings could reduce the degree of card-on-file risk borne by the MBTA/MassDOT in the single account.

Consolidation of payment media

Consolidation of payment media will increase clarity for consumers and is a stage toward further unification of payment. The major actions are:

1. Implement the Charlie Card as the principal payment medium for all MBTA transit services.
2. Increase Charlie Card availability and usage.
3. Accept Charlie Card on commuter rail, boat, suburban/contracted bus, and Logan Express bus.
4. Provide transfers between commuter rail, boat, suburban/contracted bus, private bus, Logan Express bus, MBTA bus and subway using the Charlie Card. As an interim strategy, use Charlie “Lite” tickets, described below.
5. Accept value in the unified account on The Ride.
6. Harmonize RTA acceptance and use of Charlie Card.
7. Phase out Charlie Tickets.
8. Implement a single parking payment system for all MBTA subway, bus and commuter rail parking facilities for both in-person and mobile payment.
9. Implement a single mobile app for commuter rail, boat, private bus, suburban/contracted bus, Logan Express, Logan Express parking, and subway/bus/commuter rail parking. Possibly include Logan airport parking.
10. Modify the E-ZPass On-The-Go and related programs to allow integrated cash replenishment for tolls and transit. Modify the Charlie Card retail outlet program as part of this change.

Only minimal investments in the Charlie Card system are made, to selectively improve its usability. There are no major changes in its functions. If any of these phase 1 actions are infeasible operationally or are too expensive to implement with current technology, they can be omitted. A plan should be developed for each deferred service for phase 2 unification.

The improved integration of payment for commuter rail, boat, suburban/contracted bus, Logan Express, private bus, The Ride, RTA, TMA and other bus services as a whole encompasses over 250,000 daily users, a substantial fraction of the transit total. Parking integration adds another 80,000 daily users. Having many more services and destinations available seamlessly to travelers is expected to increase ridership beyond these numbers, and may encourage TMAs and employers to provide additional services.

Charlie Card as principal payment medium

The Charlie Card is proposed to be the principal payment medium for all transit services. It will always (in phase 1) be the preferred payment medium for transit services, offering the lowest fares, best transfer policy and most flexibility in use. This replaces the mix of Charlie Card and Charlie Ticket media, and makes Charlie Card a universal medium for transit services. This is a staging step toward unified acceptance of open payment media in phase 2; it creates clarity for users and it

establishes payment relationships among a large number of services and carriers that are necessary for phase 2. It imposes some operational changes for an interim period on commuter rail and boat services that are discussed below.

Increase Charlie Card availability

The intent is to provide a Charlie Card to every resident and visitor who might use transit services, so that they are easily able to take transit trips when service is available. The secondary purpose is to allow Charlie Tickets to be phased out. By increasing the number of Charlie Cards held by highway users and visitors, this allows the MBTA and others to market transit and alternative services to a population of non-users more effectively. For example, based on the address of the E-ZPass user, a discount can be given for nearby subway, bus, boat or commuter rail services, or for bike share services that would make transit use easier. The value can be placed on the single account, restricted to use only on the service being marketed; the value is removed if not used in the given time.

Some options for increased distribution to transit users include:

1. Vending machines at subway stations, so that all stations (and most entrances) have availability at all operating hours. It is convenient to have a means to purchase a card in stations, even if there are nearby retail outlets. The vending machines can sell GPR cards in phase 2.
2. Vending machines at Logan Airport, Logan Express parking lots, and high volume visitor locations.
3. Bus drivers on suburban/contracted services and other low volume services where this may be operationally feasible.
4. Commuter rail staff on off-peak trains.
5. Private bus carrier ticket agencies.

The price of a Charlie Card can be set at perhaps \$5, with a \$5 credit on the card. During the transition period, Charlie Cards can be distributed to existing monthly and weekly Charlie Ticket holders at no charge. Some free distribution of Charlie Cards with no value on them is likely to be effective with some groups.

The vending machines can sell GPR cards in phase 2. It is convenient to have a means to purchase a card in stations, even if there are nearby retail outlets.

Some options for increased distribution to highway users include:

1. Including them with E-ZPass transponders.
2. Vending machines at Mass Pike service areas.
3. Registry of Motor Vehicle (RMV) offices, in person and with mail renewals.

The Charlie Card can be registered to the person obtaining a transponder, license or registration in the single account, if the person opts in. These Charlie Cards would have no cost and no value, except the vending machines could have a \$5 fee and the card could have a \$5 value.

Accept Charlie Card on more services

Acceptance on suburban/contracted bus and Logan Express bus requires installation of Charlie Card fareboxes. Since these fareboxes would transition to accepting EMV and NFC payment in phase 2, the design should support this change. A revenue settlement process would need to be established between Massport and the MBTA, and a means to provide lower fares for Logan employees must be implemented on the Charlie Card, probably through the single account.

Acceptance of Charlie Cards on boat services may require installation of Charlie Card readers at boat terminals, or it may use the same method as commuter rail, described next.

Commuter rail is the difficult case. There are several options, none entirely satisfactory:

1. Issue passes and single ride tickets on Charlie Card “Lite”. This is a limited-use contactless card that can be issued by existing Charlie TVMs. Also use Charlie Cards for some cases.
 - a. Passes must still be mailed or physically distributed each month, since printed information is used for visual inspection.
 - b. Charlie Card “Lite” can be accepted at subway gates and bus fareboxes, providing transfers to single ticket users and to pass users (who already have them).
 - c. If Charlie Card “Lite” is issued, Charlie Ticket must be discontinued. This is not a problem, since Charlie Card “Lite” provides all Charlie Card functions.
 - d. mTicket pass travelers who also have a Charlie Card will get a monthly or weekly MBTA pass on their Charlie Card. They must associate the mTicket and Charlie Card numbers in their unified account. This avoids mailing a new Charlie Card “Lite” every month.
 - e. mTicket single ticket travelers who also have a Charlie Card will get a transfer on their Charlie Card valid for three hours after activating their mTicket. This is handled as an update at the subway gate and, if feasible, at bus fareboxes. The transfer is removed after three hours if it is not used. Again, the unified account is used.
 - f. When cash is paid onboard, no transfers are given.
 - g. When single trip travel is purchased online, the user must stop at a TVM to get a Charlie Card “Lite”. If there is no TVM at the user’s station, a single ticket cannot be purchased online.
 - h. Charlie Card “Lite” will be less durable and capable than Charlie Card. The MBTA should contact other agencies that have used similar tickets to ensure that they are operationally feasible.⁸⁴
2. Issue passes and single ride tickets on Charlie Card so that transfers and integrated use of the entire transit system are the default option. The user must have a Charlie Card in all the cases below.
 - a. When commuter rail travel is purchased at a TVM, the TVM also issues a Charlie Ticket with the printed pass or ticket information, including the associated Charlie

⁸⁴ For example, Atlanta’s MARTA system ceased selling single use Breeze Tickets in 2011: http://www.breezecard.com/htm/ticket_card.html

Card number. The Charlie Ticket is coded to have no value and is used only for visual inspection on the train⁸⁵. The rider must show the Charlie Ticket and, on request, the Charlie Card on board the train.

- b. mTicket and cash users are handled in the same way as option 1 above.
 - c. When travel is purchased online, the user must either stop at a TVM to get a no-value Charlie Ticket for display, or print out a ticket at home that contains the same information. If there is no TVM at the user's station and the user does not print out a ticket, the no-value ticket is mailed to them if they have a monthly pass; they must request it on the website. Single tickets must be printed by the user if there is no TVM.
 - d. Inbound riders on the first weekday of the month may be allowed to travel on last month's pass, to allow them to obtain the new Charlie Ticket at a downtown terminal.
 - e. Commuter rail could offer a weekly pass and not offer 10 ride tickets, to be consistent with other MBTA services, and to lower outlays for low income riders. The viability of this depends strongly on reducing the number of media that must be mailed to users, which a Charlie Card-based option provides.
 - f. If Charlie Cards are issued with bar coded serial numbers, as is recommended for private commuter bus, and if on-train staff already have smart phones to scan mTicket bar codes, on-train staff could scan Charlie Card bar codes with the same phone. The staff phone would contain a list of valid Charlie Cards with their associated pass or ticket, updated using a wireless connection. This could avoid the need to use no-value tickets or printed tickets. Commuter rail single ride tickets would have to be for a specific train or time, or on-train staff would need to enter the origin and destination, and then update the Charlie Card account via the wireless connection.
3. Use validators, so that tickets are primarily inspected electronically with visual inspection as "proof of payment"⁸⁶. The MBTA has already considered similar options and chosen not to implement them, primarily due to cost. This option may be less expensive than earlier alternatives.
 - a. At all stations, validators are placed on posts along or near station platforms. Validators read Charlie Cards in the same way as a gate. Riders tap in and tap out as if gates were present. Riders may not need to tap out at downtown terminals, which can be the default destination. Monthly pass riders may only need to tap once a month, or they may be asked to tap in on each trip. This makes commuter rail a "virtual" gated service, which allows more consistent use of fare media and fare policies with the rest of the system.

⁸⁵ This is similar to New York MTA Select Bus Service, where users must swipe their Metrocard (smart card) on a device at the bus stop, obtain a receipt and show it to an inspector if asked. Some European cities have similar systems.

⁸⁶ Montreal is a nearby city that uses this system for its commuter rail. See <http://www.amt.qc.ca/fares/rules.aspx>. Commuter rail monthly pass holders tap once at the start of each month. Single trip or 10-ride holders tap a validator before boarding. There are validators, not gates, at the downtown terminal. SEPTA is gating its commuter rail downtown stations as part of its Key Card system.

- b. Because the MBTA already has variable message signs at almost all commuter rail stations, power and communications are already available; it is possible that these could be used for power and communications for the validators. Validators take little power, although heating a small area on the validator may be required during very cold temperatures. Required communications bandwidth is small; only minor changes may be needed to the network supporting the variable message signs.
- c. The validators should be designed to support EMV cards and NFC phones in phase 2 with minimal or no changes.
- d. Train crews no longer inspect 100% of Charlie Cards; random inspection is possible. Inspection staff can be used, so that train crew members do not need inspection devices. All mTickets continue to be inspected visually. Users who have not tapped in, or who are riding beyond the limits of their ticket or pass, are subject to penalties. Legislation may be required.
- e. The MBTA may defer a decision on validators until phase 2. If NFC phone penetration is high, validators that require no power or communications may be used. Users would tap their NFC phones at these passive validators; the phone provides the power and communications. Passive validators are much less expensive. Card users would need to be inspected by train staff, possibly on a random basis, if passive validators were used.

No TVMs are needed at commuter rail stations other than downtown. Most users will pay with a mobile phone app, Charlie Card or Charlie Card “Lite” with passes or tickets purchased before travel. (Recall that increased Charlie Card distribution is part of phase 1.) Users without one of these media, who should be a small minority, can also pay with a Massachusetts driver’s license or liquor ID; on-train staff can scan the bar code. If the user has associated his or her driver’s license with the single account, as well as a credit/debit card, the purchase is billed to the credit/debit card. This is analogous to license plate tolls for users without E-ZPass. Even if the user does not associate the driver’s license with a credit/debit card, the state can deny vehicle registration or license renewal until fares are paid. This could also allow trains to be cashless; riders could be expected to board with either a Charlie Card, mobile phone app or driver’s license.

Increase transfers with Charlie Card

With Charlie Card as the preferred medium, commuter rail, boat, and suburban/contracted bus users can transfer to and from MBTA bus and subway services. Users of mTicket with an associated Charlie Card have the same transfer privileges.

Transfers to and from MBTA services can also be provided for private bus and Logan Express users. In this phase Logan Express buses are equipped with Charlie fareboxes and are treated as integral parts of the transit network. Massport may change employee pricing for passes with MBTA transfer privileges. Charlie Card vending machines and TVMs can be located at Logan Express lots, or Logan Express staff can issue cards.

Private commuter bus BusPlus or regular ticket users can be given the same transfer privileges as commuter rail, Logan Express, suburban/contracted bus and boat users. They must have a Charlie Card (bus agencies can distribute them); riders receive discounted transfers for the number of trips

purchased (single, 10 ride, 20 ride). Revenue settlement must be implemented with the private carriers for the transfer funds. This will improve bus rider convenience, since they receive a discount and do not need to go to TVMs at downtown terminals. This reduces lines at TVMs, and it is expected to increase private bus ridership.

Charlie Cards are not used for payment for private commuter trips; the BusPlus mobile app (or a unified app) or printed tickets are used. Charlie Cards are distributed by agents for the bus carriers to allow passengers to transfer to MBTA services. Charlie Cards distributed by non-MBTA services must have a bar code with the card number on the back; this should be a minor change.

The bus agent must have an app running on the payment terminal used to issue tickets (which may be a web-based or hybrid point of sale terminal); the agent scans the bar code on the Charlie Card, indicates the transfer to be given, and hits “accept”. This information is sent via an Internet connection to the MBTA server; the information can be sent perhaps every 30 minutes (or in real time) so that the transfer value is available to be written to the card at a gate when the rider arrives. It is possible that the information would only need to be sent to gates at South Station and a limited number of other transfer points. Transfers to MBTA bus services can be provided if fareboxes can be updated quickly enough; this is the same issue as with cash reloads at retail locations.

Similar options are available for other private services such as TMA services, Bridj and others. This could expand the number of destinations reached by private services, while relieving peak period congestion or avoiding additional peak period expenditures by the MBTA, since many of these services operate principally in peak periods. For example, EZRide charges a \$2 single fare; it could charge \$3 for a transfer trip. The MBTA would receive \$1.50, and EZRide would also receive \$1.50, since there are two (shorter) legs to the trip over the two services. This type of integration can be used with other providers to provide more seamless travel.

The Ride

The Ride can accept value in the single account. The Charlie Card itself does not need to be accepted on the vehicle, but a rider can use the same stored value account as for other transit trips. Eligibility is managed on the single account server when a trip request is made. The Ride’s debit card program for taxi use, in which the first \$15 is subsidized, should be integrated into the single account. A rider must use a personal credit, debit or GPR card to pay the balance of the trip cost; while it would be ideal for the rider to store the personal card in the personal account, use it to pay the balance automatically, and see the full cost of trips, this is not feasible in phase 1.

RTA use of Charlie Card

In phase 1, RTA acceptance and use of the Charlie Card should be standardized to the extent possible. MassDOT may request the Massachusetts RTA association (MARTA) to develop a single, model fare policy and to harmonize RTA websites so that fares and policies are displayed consistently. The use of separate RTA and MBTA passes continues, since the Charlie Card can hold both. RTA-commuter rail transfers are more convenient since commuter rail uses Charlie Cards in phase 1. Common use between the MBTA and RTAs of the value stored on the Charlie Card also continues. Reloads of value from online purchases should be made faster if possible.

Phase out Charlie Ticket

Charlie Tickets are eliminated during phase 1. Subway and bus service operations are unchanged. Users pay with Charlie Card, or cash on bus or ungated stops.

Commuter rail passengers either use Charlie Card “Lite”, or Charlie Cards at validators, or they carry a no-value Charlie Ticket or printout associated with their Charlie Card number to allow visual inspection. Boat passengers use either validators or printed media, the same as commuter rail.

Weekly passes must be offered on Charlie Cards; they are only offered on Charlie Tickets at present. The rider should be able to choose the start date of the weekly pass. If the rider has both value and a pass on a Charlie Card, he or she may wish to use value for some trips before activating the pass.

Single parking system

The MBTA should implement a single parking payment system across MBTA subway and commuter rail stations. It can possibly use the existing operator’s mobile and in-person payment applications at all lots, even if not managed by that operator. The payment method may vary between gated and ungated lots: a credit/debit card tied to the single account can be used at gated lots, while a mobile app can be used at ungated lots. The mobile app and the credit/debit card can both be tied to the single account. When the parking concessions are renewed, the MBTA, Massport and RTAs should require a single application for all lots. Cities and towns that manage commuter rail parking lots should be contacted and encouraged to also participate in the single system.

Phase 1 also offers an opportunity to upgrade the cash payment “honor boxes” at many parking lots. They can be replaced with credit/debit card machines or Charlie Card validators. If Charlie Card validators are used, the rider must have a single account to associate the Charlie Card with the license plate of the vehicle in the parking lot. A limited cash payment option should be retained, either with a bill acceptor at the kiosk or an envelope and lockbox system.

Even though E-ZPass works well at Route 128 station, the MBTA should replace it with the single application for consistency.

Single mobile app

The MBTA and MassDOT should implement a single mobile phone app to supersede mTicket, PayByPhone and BusPlus. This offers additional convenience in phase 1, and begins the process of having a single mobile app for payment on most or all transit services in phase 2. In phase 1, the mobile app is not accepted on MBTA bus or subway services.

Massport Logan Express, Logan Express parking and Logan airport parking may be included, as can mobile payment for suburban/contracted bus services. This mobile app becomes a central element of the next stage of unified payment.

The mobile phone app could also be accepted on TMA (e.g., Route 128 Business Council, Charles River EZRide) and other services (e.g., Bridj). A standard MBTA interface to these services can be implemented within the app.

The mobile app should display route and schedule information for planning future trips and real-time information for current or near-term trips, as well as providing a payment means. By making the payment medium the source of service information as well, convenience is maximized.

Cash reload for EZ Pass and transit

There are two general types of Charlie Card retail outlets currently: those that sell Charlie Cards and have equipment to update them with passes and value, and those that sell only fixed media such as pre-coded Charlie Tickets with commuter rail tickets and passes. There is a different set of retail outlets that have kiosks for cash reload of E-ZPass accounts. In phase 1, MassDOT and the MBTA should explore ways to merge and expand these networks. While phase 2 supports this integration, it may be difficult to implement a good solution in phase 1.

Options include:

1. Even if different reload systems for E-ZPass and Charlie Card continue to be used, attempt to have retail outlets serve both systems.
2. Allow travelers to reload value at Charlie Card outlets to their single account and, if necessary, designate that these funds are to be used for tolls.
3. Extend the capabilities of the Charlie outlets that only sell fixed media to also update the single account using their point of sale terminal, similar to how private bus carrier agents can add transfers to Charlie accounts. The pass or value is sent via the Internet to the Charlie server, and the value is then written to the card at a gate or, if possible, farebox.
4. Modify the E-ZPass reload kiosks to allow users to add value to the single account, and possibly to designate that it be used for transit, if necessary.
5. MassDOT and MBTA could issue a GPR card that could be used at a wide network of stores that support a branded network (e.g., Visa or MasterCard) for cash reload, as described below. The bankcard reload network may result in lower overall costs and a large number of retail locations, as in the New York MTA system.

A user must have a GPR card associated with his or her single account. In the short term, there may be separate accounts for tolls and transit. The user presents the card and cash to the clerk, states the 4 digit code for the account in which to place value and the funds are placed in the account immediately.

The 4 digit codes are printed on the card: there may be one for value and one for passes. If the pass code is chosen, the exact pass amount must be loaded. It may be necessary in phase 1 for the use to choose between highway and transit value, so there may be a total of three codes (highway value, transit value and transit pass).

The merchant also collects a reload fee, which is expected to be \$1 or \$2, and this value is added to the single account; the MBTA or MassDOT absorb the cost. A minimum reload amount of perhaps \$15 can be set to limit transaction costs.

This GPR-based reload network could supplant or extend some or all of the Charlie Card and E-ZPass reload locations during phase 1; the GPR network provides the unified reload method in phase 2.

Summary

Table 6 shows the transportation services and payment methods that each accepts. While there is still significant variability, a basic pattern is established of accepting Charlie Card on all public transit services, a unified mobile app on visually inspected public transit services and parking services, E-ZPass on highway facilities, and credit/debit and cash at TVMs and staffed facilities. This phase is transitional, limiting the technology changes required, while taking key operational and policy steps toward a unified system that can be more fully implemented in phase 2.

In table 6, green cells indicate that this form of payment is standard or preferred; yellow cells indicate other forms of payment that are accepted, usually with transfer restrictions; red cells indicate this form of payment is not accepted. Other terms that are used include:

1. Standard: medium is preferred by the transit agency and it offers the lowest fares and best transfer privileges.
2. Accepted: medium is accepted at the same fare and possibly with lower transfer privileges as the standard medium, and it is less convenient because it is not the unified medium:
 - a. Cash is not preferred because of the high costs of handling it.
 - b. Debit/credit or cash do not provide transfer privileges in phase 1, and users of these media may be encouraged to have a Charlie Card and place value or passes on it with cash or credit/debit.
 - c. For parking, transfers are not an issue (although parking discounts for those who use transit would require a Charlie Card). For boat, Logan Express, private and suburban bus, transfer privileges require a Charlie Card or unified mobile app (to transfer to services that accept the mobile app).
3. Surcharge: medium is accepted at a higher fare and possibly with lower transfer privileges

These are the same definitions used in table 1, which describes current services; the details of transfer privileges and transfers are defined below.

Table 6 details include:

1. The single account is used for The Ride. The Charlie Card is not presented.
2. Commuter rail payment has three options: Charlie Card, Charlie Card “Lite” and Charlie Card with validators. The table shows the Charlie Card option.
3. All entries in this table depend on whether a service is integrated into the unified account and payment or not in phase 1. This depends on detailed choices made by the MBTA, MassDOT, RTAs, Massport, and other carriers and agencies.

Table 6: Payment media accepted by mode and carrier. Phase 1

Service	Cash	Credit/debit	Charlie Card	Charlie Ticket	Mobile payment	E-ZPass
MBTA subway-gated	TVM-> Charlie Card	TVM-> Charlie Card	Standard	Not accepted	Not accepted	Not accepted
MBTA subway-ungated	Surcharge	Not accepted on car	Standard	Not accepted	Not accepted	Not accepted
MBTA bus	Surcharge	Not accepted on bus	Standard	Not accepted	Not accepted	Not accepted
Commuter rail-downtown	TVM-> Charlie Card	TVM-> Charlie Card	Standard	Must also have Charlie Card	Unified app/standard	Not accepted
Commuter rail-other	Accepted, surcharge	Not accepted on train	Standard	Must also have Charlie Card	Unified app/standard	Not accepted
MBTA boat	Accepted	Accepted	Standard	Must also have Charlie Card	Unified app/standard	Not accepted
MBTA parking	Accepted	Pay on foot stations (approx. 20 stations)	Not accepted	Not accepted	Unified app/standard	Not accepted
MBTA The Ride	Not accepted	Not accepted on car	Standard	Not accepted	Unified app/standard	Not accepted
Other RTAs	Surcharge (some)	Not accepted on bus	Standard	Not accepted	Not accepted	Not accepted
Logan Express	Accepted	Accepted	Standard	Not accepted	Unified app/standard	Not accepted
Logan Express parking	Accepted	Accepted	Not accepted	Not accepted	Unified app/standard	Not accepted
Logan Airport parking	Accepted	Accepted	Not accepted	Not accepted	Unified app/standard	Not accepted
Private bus carriers	Accepted	Accepted	Not accepted	Not accepted	Unified app/standard	Not accepted
Suburban/contract bus	Accepted	Not accepted on bus	Standard	Not accepted	Unified app/standard	Not accepted
Highway toll facilities	Surcharge (some)	Not accepted	Not accepted	Not accepted	Not accepted	Standard
HOV/HOT lanes(future)	Not accepted	Not accepted	Not accepted	Not accepted	Not accepted	Standard
Bike sharing	Not accepted	Standard	Not accepted	Not accepted	Not accepted	Not accepted
Car sharing	Not accepted	Standard	Not accepted	Not accepted	Not accepted	Not accepted
Municipal parking	Accepted	Accepted (some)	Not accepted	Not accepted	Future	Not accepted

Technology changes and costs

The technology changes required are:

1. Implement a website and single account software to display transportation service usage to travelers, and to allow them to purchase services, reload (with cash or credit/debit cards) and manage the account.
 - a. Functions. The website shows the use of all transportation services, including total expenditures. It may be integrated with journey planning to support the display of alternatives to driving alone. It can handle incentives and discounts. It handles purchases of passes and value, including replenishing The Ride accounts. It allows users to print no-value tickets for commuter rail. It handles registration of Charlie Cards distributed with E-ZPass transponders or RMV transactions.
 - b. Interfaces. Interfaces are required to the E-ZPass account system, the MBTA AFC system, RTAs, mobile payment applications (mTicket, PayByPhone, BusPlus) or to a consolidated mobile payment app (preferred). Interfaces to The Ride account and its debit card program, employer pass programs and transit benefits are required. Interfaces to RTAs and The Ride (and its debit card program) are required. Interfaces to bike/car share providers are desirable for completeness.
 - c. This element includes the minor changes to harmonize RTA websites to show fare information in a consistent form.
2. Implement an app that private bus carrier agents can use to issue Charlie Card transfers from a point of sale terminal. This may be a modification of their existing point of sale software
3. Implement a single mobile application superseding mTicket, PayByPhone and BusPlus, to increase customer convenience and flexibility, and to simplify management. The app should be integrated with the single account, and should have a single form of customer support, security, updates and other features, rather than the duplicate functions from separate apps.
4. Acquire mobile phones and an inspection app for commuter rail inspection.
5. Implement single in-person and mobile parking payment applications across all parking lots, integrated with commuter rail and private bus mobile payment. The payment method may vary by gated and ungated lots. Integrate Logan Express parking and possibly Logan airport parking in the app. Possibly replace cash “honor boxes” with credit/debit kiosks or Charlie Card validators. (Platform validators could be used for parking payment if the user has registered their vehicle’s license plate. No data would be collected on the parking space number.)
6. Develop a settlement interface between the MBTA Charlie automated fare collection (AFC) server and E-ZPass account server, similar to interfaces between IAG members. The MBTA reports usage daily, settlement occurs daily, and reloads are initiated to replenish the account. Modified logic to set the replenishment amount when monthly pass purchases occur may be required, so that the replenishment amount is not based on projecting the monthly pass cost as a daily usage rate for the traveler.
7. Implement settlement with Massport, private bus carriers and others for transfers and other joint fares.
8. Install (simple) vending machines to sell Charlie Cards at subway stations.

9. Install electronic fareboxes on suburban/contracted bus services and Logan Express buses. It may be possible to install only a reader, without cash or Charlie Ticket features, as an add-on component to any existing fare collection devices on vehicles. The reader, whether it is a full electronic farebox or an add-on device such as a smart phone in a fixed mount, should support reconfiguration to read EMV cards in phase 2, or be able to read EMV cards from the start.
10. Implement possible changes to bus wireless network connections and the AFC server to improve the speed of value and pass transmissions to bus fareboxes.
11. Optionally install validators at commuter rail stations.
12. Make programming changes to TVMs to issue no-value Charlie Tickets with commuter rail and boat passes, and to display a prompt to obtain a Charlie Card from an adjacent vending machine if necessary. Changes to support the single account, select weekly pass start dates, and other items must be made.
13. Make programming changes to MBTA server software to put value on Charlie Cards for transfers from commuter rail, boat and possibly private bus, and to remove the value if not used in three hours. Improve the ability to upload value and passes more quickly when reloaded from retail or other non-MBTA locations. Handle Logan Express employee fares, and other service-specific requirements. (E-ZPass kiosk reloads in Massachusetts are available for use in 30 minutes within Massachusetts, and within 3 days outside Massachusetts. Charlie Card reloads should ideally be available in 30 minutes; this will require analysis and system changes.)
14. Implement the expanded cash reload program for the transportation account, including changes in retail agreements, E-ZPass kiosks and Charlie Card retail equipment.
15. Change Charlie Card production to place a bar coded Charlie Card number on the card.

These technology changes are generally independent of each other, but most or all of them should be implemented to achieve a significant first step toward unified payment and single account. If individual elements are not operationally feasible or have high implementation costs relative to their benefits, they may be deferred to phase 2, when the costs and implementation effort are likely to be lower.

A set of technical activities must be conducted to prepare for phase 2:

1. Determine the specifications for reader modifications for phase 2. A consultant can be retained to develop detailed requirements and specifications to modify or replace existing readers to meet phase 2 requirements. This consultant may also assist the MBTA in making changes in TVMs and existing software, given the introduction of EMV in the US; this might be an early task.
2. Write a concept of operations document for phase 1 and phase 2. Establish operations and payments agreements with carriers and services to be included in unified payment. Establish project management approach and funding.

The principal costs are:

1. Development of website and single account software.
2. Development of app for private bus carrier agents.
3. Development of a single mobile payment application.
4. Development or acquisition of mobile phones and inspection app for commuter rail.

5. Development and implementation of single parking payment system at all lots. Possible installation of kiosks at lots.
6. Development of MBTA automated fare collection (AFC) and E-ZPass server interfaces.
7. Development of settlement software with Massport and private carriers.
8. Charlie Card vending machines at approximately 200 entrances to 60 subway stations.
9. Electronic fareboxes on contracted/suburban and Logan Express buses. The estimated number of buses is approximately 125.
10. Possible bus wireless network upgrades for faster loading of Charlie Card updates.
11. Optional installation of gates and/or validators at commuter rail stations.
12. TVM programming changes for no-value Charlie Tickets, account updates and other issues.
13. Charlie Card server/back end programming changes, for Charlie Tickets, transfers, accounts, Logan Express and other services, and other issues.
14. Extended and integrated cash reload program.
15. Additional Charlie Cards issued. The cost is dependent on the number of cards issued, which is a policy decision. The net cost will depend on what amount, if any, is charged for the cards. Place bar codes on new Charlie Cards. Possibly reissue Charlie Cards to existing users to ensure all cards have bar codes.
16. Project management, training, and implementation costs.

There may be cost savings from:

1. Reduced Charlie Tickets issued.
2. Taking Charlie Ticket readers out of service after Charlie Tickets are phased out.
3. Negotiated changes in commuter rail on-train staff, if 100% ticket inspection is not required.
4. Faster bus boarding due to the elimination of Charlie Tickets and perhaps lower cash use.

More substantial savings may be possible in phase 2; many of the phase 1 activities are conducted to prepare for phase 2.

It is difficult to provide a credible cost estimate at this point because many issues are yet to be determined in phase 1. A rough order-of-magnitude estimate is:

- Software development: \$14 million
- Hardware (vending machines, fareboxes, parking kiosks, etc.): \$ 8 million
- Project management and systems integration: \$ 8 million
- Total capital costs: \$30 million

- Increased annual operating costs: \$ 2 million

Some of these costs include items that also support phase 2, such as the single account and website. The increased operating costs may be offset by increased revenues and possible other cost savings; these are primarily discussed in phase 2 since there is flexibility in what is done in each phase.

MassDOT and the MBTA will have more detailed cost data that can be used in planning and implementation. These costs vary widely from agency to agency and are affected by legal and regulatory issues that vary by locality. These cost estimates also assume that the current vendor, Scheidt & Bachmann, can make changes in its existing software, and that its existing software can support these elements as incremental changes rather than a major rewrite of the software.

Alternatively, Scheidt & Bachmann can give a third party access to its software to make these changes. Mobile app changes will be strongly dependent on existing contract and intellectual property issues⁸⁷. If validators are installed for commuter rail, and existing power and communications can be leveraged, the cost may be as low as indicated above.

Since stakeholder input, requirements, and design are not yet known⁸⁸, this estimate may be off by a factor of 4. Once MassDOT and the MBTA create a concept of operations that meets the needs of all stakeholders, and a requirements document that specifies the phase 1 system, more accurate cost estimates can be prepared.

This option can be implemented before EMV credit/debit and NFC phones are expected to be widely available in 2017 or 2018, although this is a best-case estimate, given the number of potential tasks in phase 1. A project and funding schedule must be developed, which may well require a longer time period. If many tasks are moved from phase 1 to phase 2, after developing requirements for them in phase 1, the phase 1 schedule may be shortened.

Transportation policy issues, benefits and ridership changes.

Examples of policy changes that may increase transit ridership in phase 1 are:

1. Improved transfers and lower fares for bus and ungated subway users by increased use of Charlie Card.
2. Transfer fares between suburban/contracted systems, RTA routes and MBTA routes, especially if services are coordinated to provide low transfer times.
3. Transfer discounts for private bus users.
4. Acceptance of MBTA passes and value on Logan Express.
5. Ability to use bike share and car share services more easily as part of a transit trip.
6. Ability to use more parking options with the same means of payment.
7. Improved coordination between services that accept the unified account and mobile payment app.
8. Incentives for new users, and possible loyalty awards for existing transit users.
9. Marketing and information on simplified and improved payment, so that the public transportation system appears as a more unified service.
10. Shorter lead times for pass purchases in employer or automatic programs for commuter rail if validators are used, since no media must be mailed or distributed each month. Ability to offer weekly passes across all MBTA and possibly some other services, to increase consistency of fare policy.

A change that may increase revenue is to implement a surcharge on late night subway service.

Possible increases or decreases in revenue may result. All of these estimates are highly uncertain:

⁸⁷ The MBTA owns the PayByPhone software, and mTicket and BusPlus are pilot programs. This provides some flexibility in moving to a unified mobile app.

⁸⁸ <https://www.fhwa.dot.gov/cadiv/segb/files/segbversion3.pdf> Figure 3-12, page 78.

1. Increased simplicity and ease of payment: \$6 million increase per year, assuming a 1% increase in annual MBTA revenues of \$600 million. This also includes increased ridership from integrating other services and increasing available destinations.
2. Switch from higher Charlie Ticket and cash fares to lower Charlie Card fares, and from discounted transfers for commuter rail, boat and private bus: \$6 million decrease per year⁸⁹.
3. Switch from cash to E-ZPass tolls that are lower at some barriers: \$1 million decrease per year⁹⁰.

MBTA fares can be adjusted to offset the changes in payment method and transfer policy to make them revenue-neutral. If that is done, revenues might increase by about \$6 million per year, more than offsetting the increased operating costs of phase 1. In most fare system projects, about half the benefits are customer convenience, and the other half are revenue increases, cost savings, and decreases in uncollected fares. It is likely that the economics of phase 1 are typical.

Ridership changes are uncertain. MBTA annual ridership is about 400 million. Using the same assumptions as the revenue estimates, we expect a 2% increase in ridership⁹¹. (As a comparison, in London, acceptance of the Oystercard smart card was extended to National Rail, which is commuter rail, and this change alone increased National Rail ridership by 3%.)⁹² It is possible that this increase may increase operating costs if it occurs on services at peak times.

⁸⁹ MBTA annual fare revenues are approximately \$600 million; 55% of ridership is on passes where there is no cash or Charlie Ticket surcharge. Of the remaining 45% of riders, 40% pay with cash or Charlie Ticket. These customers would receive about a 20% reduction in fares if they used Charlie Card. If 100% of Charlie Ticket and cash single ride customers switched to Charlie Card, MBTA revenues would decrease by about \$20 million. If we assume a fare elasticity of -0.3 for the customers receiving the 20% fare reduction, their ridership would increase by about 6% and offset about one-third of the revenue decrease, for a net decrease of perhaps \$13 million. This is an upper bound on the revenue change due to the displacement of Charlie Tickets and cash, and it is unlikely to occur in phase 1. We assume a \$6.5 million revenue decrease, half the maximum, as a rough order of magnitude estimate.

⁹⁰ MassDOT plans to implement all electronic tolling on the Mass Pike in 2017. This report assumes that the impacts of a single account and other modifications to E-ZPass will be minor compared to the AET impacts, less than \$1 million per year. About 75 million annual transactions for \$130 million in revenue are made at the Tobin, Sumner, Ted Williams and Allston/Brighton toll facilities where E-ZPass discounts are provided for Massachusetts residents. The discount is \$0.25 (20%) at Allston/Brighton and \$0.50 (14%) at the others. If cash customers are about 20% of total users, and 80% of cash customers are Massachusetts residents, the revenue decrease if all Massachusetts cash customers switched to E-ZPass would be about \$3 million. The likely impact would be less than \$1 million. A minor volume increase may occur with the lower toll rates.

⁹¹ We expect a 6% increase in the single trip users (45%) who pay with cash or Charlie Ticket (40%) due to the lower fare with those media; this is an increase of 4 million riders, or 1% of the total. We additionally assume that ridership would increase by 1% due to the improvements in the fare system.

⁹² Nihit Jain, "Assessing the Impact of recent fare policy changes on public transport demand in London", MST thesis, M.I.T., 2011: "The results show that, within 9 months of the implementation, Oystercard Pay-as-you-Go journeys on National Rail tripled, while single or return journeys on paper tickets halved. Further, after controlling for other changes, the electronic ticketing system increased travel on National Rail by around 3%. This increase resulted from growth in public transport travel and possibly from switching from other public transport modes."

The equity impacts of phase 1 appear to be positive. In phase 1, a greater percentage of transit users will pay lower Charlie Card fares, versus Charlie Ticket and cash fares. Since Charlie Tickets and cash are used disproportionately by bus riders, who have lower incomes than riders of other services, these riders will benefit from the greater use of Charlie Card. Cash users may find it easier to use E-ZPass, which will lower their tolls at Allston, the Sumner and Ted Williams Tunnels and the Tobin Bridge. Some cash users are lower income travelers who do not have credit/debit cards or who find the current E-ZPass reload system financially difficult. If weekly passes are offered across all or most services, this benefits lower income users by allowing them to benefit from pass fares without paying for a monthly pass up front.

Public information and user issues

A substantial public information program will be required to communicate the single account and website, and the changes in payment media across services, before and during implementation.

Key elements include:

1. Meet with advocacy groups, city/town governments, employers, schools and others.
2. Modify the MBTA map to show all transit services as an integrated network. Include Logan Express, private bus carriers, TMA services and others. Give each route or service a route number similar to other MBTA routes, to increase the perception of a single network. The current MBTA map is excellent in showing most services; this is an incremental change.
3. Create a related MassDOT/MBTA map showing payment media accepted on transportation services. Distribute maps and associated materials; publicize the consolidation/simplification of payment. Create maps of all parking lots showing payment methods accepted, since this is an area that is currently highly variable.
4. Place printed schedules of all services, including non-MBTA services, in the standard MBTA format, at subway stations and transfer points, extending current practice.
5. Use variable message signs (VMS) on highway facilities. Encourage E-ZPass holders to obtain a Charlie Card linked to the E-ZPass transponder in the single account. Display transit options when there is major congestion, including a reminder to use the Charlie Card. Possibly provide a holder for the Charlie Card so it can be kept with the E-ZPass transponder for such occasions, if the traveler is not a regular transit user.
6. Use social media (YouTube, Twitter, Facebook, others) to communicate changes.
7. Use posters in subway and other stations, signs on buses, brochures, community meetings, and other means.
8. Partner with transportation management associations to reach out to and educate commuters.
9. Provide incentives to sign up for the unified account. For example, for E-ZPass users who sign up for a Charlie Card and the Website, provide a free transit round trip so they are aware of how to use the service. For transit users who sign up, provide a one-time discount on passes, or a one-time bonus on stored value.

The privacy policy of the single account and website must be clearly stated, and may require additional information to be provided to the public during initial implementation. The website administrator, which may be MassDOT, a TMA or other organization, must develop a policy that defines the options users have to allow or restrict sharing of their travel and payment data among agencies and services. Payment data must be shared among services that are used for transfer or

joint trips. Travel data without personal identifiers should be shared among services to support planning and operations. Data retention should be limited to a short time period, perhaps two months unless a payment dispute or other issue is unresolved. Aggregate data, and data without personal identifiers, should be retained for a longer period for planning and analysis.

Users who wish to remain anonymous in phase 1 can continue to use unregistered Charlie Cards and cash on public transit; they can use cash in some locations on highway toll facilities. As all-electronic tolling is implemented, users must use E-ZPass, which must be registered, or pay license plate tolls, which identify the vehicle. The highway toll changes are driven by all electronic tolling, and not by the recommendations of this report, but the privacy and anonymity policies should be harmonized and stated clearly.

There may be other legal and regulatory issues that must be addressed in implementing the single account and in accepting joint payment across carriers. A review is required.

Changes in agency operations and relationships

Increased integration between MassDOT E-ZPass, MBTA and RTAs to manage a single transportation account, the reload program, joint public information and marketing, and related policy changes is required. Incorporation of contracted/suburban and Massport bus operations into the payment system is required. Non-MBTA vehicles accepting unified payment (mobile and Charlie Card) should display an indication on their headsign or on the front of the vehicle so users know it is part of the unified service.

A payments relationship with private bus carriers is used to implement the issuance of transfers for private bus riders. Massport, MassDOT and MBTA must extend their relationship to cover the new payment features in this phase. Relationships with Charlie Card and E-ZPass retail outlets must be modified as part of the expanded cash reload program.

The MBTA must close out remaining contract issues with Scheidt & Bachmann to allow even the limited modifications to the Charlie Card system in this phase. It may be possible for vendors other than Scheidt & Bachmann to make the phase 1 changes to the Charlie Card system. Phase 2 implements transit open payment, on which multiple vendors have bid in other cities.⁹³

The MBTA and MassDOT either need additional in-house project management and technical capabilities to oversee a unified payment program, or they must contract with and manage a systems integrator to perform this role. Lease versus buy decisions must be made; some systems providers may offer to implement the system for an ongoing stream of payments.⁹⁴

⁹³ For example Scheidt & Bachmann bid on the Transport for London (TfL) gate and farebox operations contract in 2014. TfL uses Cubic equipment.

⁹⁴ The Chicago Ventra system used this model.

The impact of fare integration will be substantially larger if it is accompanied by service integration with the new services included in unified payment. Some possible examples are listed below; these are illustrative only and there has been no analysis of their effectiveness:

1. Add Logan Express stops at South Station for Framingham and Braintree routes, or Airport Blue Line station stops for Peabody and Woburn routes. These would provide remote parking for intercity bus and rail services from South Station, and allow use of these routes for additional destinations such as downtown.
2. Experiment with increased Fairmount commuter rail frequencies, together with integrated transfers to MBTA bus routes and the Red Line at South Station, to increase ridership.
3. Additional MBTA, RTA and private/TMA bus service connections with commuter rail to serve employment destinations such as route 128 office parks.
4. Coordinate commuter rail/Logan Express schedules to support transfers at Woburn (Anderson RTC).
5. Improve suburban/contract bus connections with MBTA routes, such as Lexpress and routes 62 and 76.
6. Improve RTA connections to outlying commuter rail stations.

A coordinating committee for service changes may be established to promote the objective of a unified transit network across multiple modes and carriers. The committee could meet regularly to encourage greater coordination of services, and to discuss fare and transfer policy changes.

A governance process that includes fare payment, service changes and other coordination tasks must be established. Agreements among affected parties that specify business rules and processes must be established. This process may be easier in Massachusetts than in many locations because of the integration of highway and transit within MassDOT, the shared use of Charlie Card technology by most regional transportation authorities, and the integration of commuter rail services within the MBTA, for example. Many of these factors are more difficult in other metropolitan areas.

Example

For the difficult example presented in section 2.4, we assume that the user has obtained a Charlie Card from the expanded distribution program.

1. The user drives one exit on the Mass Pike to a commuter rail station. E-ZPass is used. Improved E-ZPass cash reload and a single account shared with transit are available, so more users will have and use E-ZPass.
2. The user parks at the commuter rail station. The unified mobile app is used if the lot is ungated, and the user can use the same app if he or she needs to go to another station to park if the chosen lot is full. He or she may use credit/debit or stored value from the single account. The user pays with credit/debit card at gated lots.
3. Commuter rail is used to go to South Station. The unified mobile app is again used; it only needs to be opened once to pay for parking and activate the rail ticket.
4. The MBTA Red Line is used to go to Cambridge. Since the user has a Charlie Card and a single account, his or her Charlie Card has stored value for the transfer. The user does not have to go to a TVM or make an additional payment.
5. A bike sharing service is used to make a short trip at noon. A credit card is used. The trip will be displayed on the user's account on the website, so the user can see this trip along with all the other services used. A discount or incentive might be offered.

6. The same single payment method used for the morning trip is then used for the return trip in the evening: a mobile commuter rail ticket is bought, which also places stored value on the Charlie Card for the subway trip. Parking has already been paid, and E-ZPass is used for the last leg.
7. On a subsequent day, the user may travel to Logan Airport, paying for Massport parking with the same mobile app, or Logan Express service and remote parking with the same mobile app. If the user stops along the way to the airport and parks the car for a short period, the user must still have coins or a town-issued smart card for the parking space.

Figure 4 shows the four payment media used for this trip, one less than the current case, but they can be managed through the unified account. Only one account is reloaded, or charged at the end of the day for non-prepaid services, and only one account needs to be managed by the user (when credit card numbers change, for example). The traveler uses E-ZPass, the unified mobile app and a Charlie Card, all of which are reloaded through the unified account. (The user can choose to make unified mobile app payments directly to a credit/debit card as well.) The bike share service uses a general credit/debit card, as in the current case, but these trips can be viewed on the single website, and credit card updates can be handled through the single website and account; they are passed through to the bike share service (assuming that an agreement to do so is reached). Phase 2 will improve on this substantially.

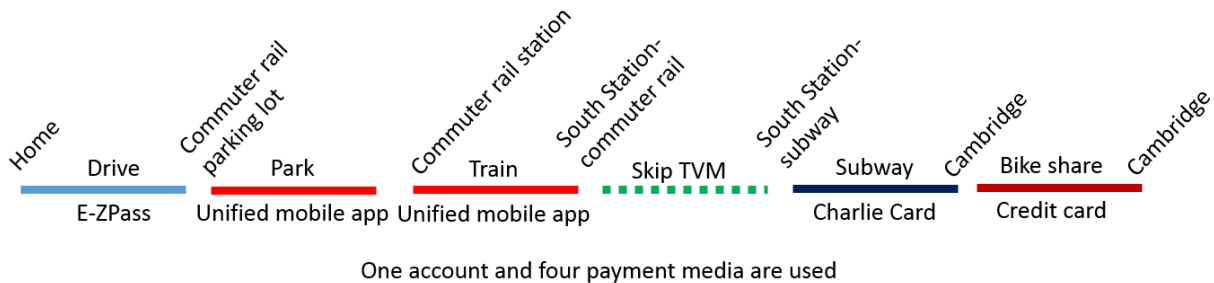


Figure 4: Example trip, phase 1.

Phase 2: Regionally Unified Payment with NFC Phones and EMV Cards

Phase 2 implements open payment across almost all transportation services. Users tap their NFC phone or EMV credit card at gates and fareboxes. The NFC phone is visually inspected on some services, and EMV cards (and sometimes NFC phones) are electronically inspected in some cases. All fares and values are stored on a central server in an account for each user, giving high flexibility in setting and modifying fare policies.

Single transportation account

The single account for highway and transit travel is enhanced to provide additional features in phase 2. In phase 2, the single account offers additional convenience in purchasing and managing pre-paid and ad hoc travel, viewing overall expenditures, obtaining travel information, and receiving incentives and discounts. The account can show all trips by almost all services for NFC phone or contactless EMV card users, who will tap their phones at gates, fareboxes and validators. Only trips on visually inspected services may not be shown; single ticket activations can be shown but pass use is generally not recorded.

This phase uses a central server to compute fares for all transit travel; no value or passes are stored on cards and there is no fare logic on readers. This allows much more flexible interoperability across services. It is essentially the same as the open payment systems implemented or in progress in London, Salt Lake City, Chicago, Philadelphia and Washington, DC.

The new or changed features for payment, purchase and management of transportation services include:

1. Users designate an NFC mobile phone (preferred) or an EMV credit, debit or GPR card in the single account. For pre-purchased travel, such as passes or E-ZPass reloads, the NFC phone or EMV card is used for payment.
2. The account can be reloaded with cash at retail locations using a GPR card for transit or highway use.
3. For ad hoc travel, the user can tap his or her NFC phone or EMV card on any gate or farebox and travel; the fares will be computed and charged to the NFC phone or EMV card at the end of the day, as described in the discussion of open payments. There is no need to have stored value for per-trip payment. Cash users must have enough value on their GPR card account to pay for the trips they take.
4. Users are no longer required to have a single account to obtain transfer and other privileges.
5. The fare engine on the central server can compute best value⁹⁵ fares for almost all trips. Fare policy can be simplified: no daily, weekly or monthly passes need to be sold, since users can be given the best fare option over the trips they have made. All services covered

⁹⁵ A unified payment system can have a “best value” feature that guarantees the lowest fare over a day or a week. <http://www.tfl.gov.uk/fares-and-payments/contactless/is-contactless-for-me?intcmp=8282>

by best value must have electronic inspection. Monthly passes can still be sold for long-term daily use⁹⁶ if preferred. The price charged for the day's or week's travel is shown on the website associated with the account, along with any other incentives, surcharges or other fare variations.

6. Best value can be applied across highway and transit travel. For example, if a regular transit rider uses a toll facility to access transit, he or she can be given a discount. (This may or may not be a desirable policy; it is given as an example of the capability.)

The account and its associated NFC phone or EMV card is used to pay for all transportation services. This includes all services covered in phase 1, plus all MBTA services.

The account can provide additional travel demand management features:

1. The fare engine can compute dynamic pricing, altering fares and highway tolls in response to changes in congestion or other factors. High occupancy and toll (HOT) lanes can be supported. A congestion zone or congestion charge for the Boston downtown or other area can be supported with E-ZPass and/or credit/debit cards and the single account for payment. This is a cutting-edge option and would require significant effort.
2. Incentives can be offered in a focused manner, given the nearly complete travel record of users. Highway users whose trips could potentially be made by transit can be given limited-time incentives to switch. The incentives can be sharply focused: they can be valid only on the small set of services that substitute for the highway trip. Transit users could be given incentives to shift among modes, services or routes to improve their convenience and MBTA operating efficiency. If a short segment of a subway line is a bottleneck or is at capacity, bus services could relieve the need for expansion: short bus routes using dedicated peak-only bus lanes to distribute commuter rail riders around downtown could free up subway capacity for longer trips, as an example.
3. The single account can continue to show bike sharing, car sharing, and parking uses and costs. The user can opt into these other services. The website may show travel options that include these additional services as portions of trips, using a shared bicycle to complete a transit trip, for example, if it is the most convenient path. Incentives can be provided for these trips if desired.

Consolidation of payment media

NFC phone as preferred medium for all services

The preferred payment medium is NFC phones. EMV credit/debit cards are also accepted at the same fares and transfer privileges. Accepting EMV is identical to NFC except on services with visual inspection; on those services, the EMV card is tapped against an NFC mobile phone used by the train crew or private bus driver, while the NFC phone can be visually inspected if the user has

⁹⁶ The computation of best value over a month requires significant server resources and was not cost-effective in London due to its complex fare policy. At least an approximate monthly best value based on comparing weekly passes, plus the fractional week at the end of the month, to a monthly pass appears possible in Massachusetts, and an exact best value calculation may in fact be possible.

downloaded the Massachusetts payment app. Massachusetts may adopt an Open Mobile Ticketing Alliance⁹⁷ app which is interoperable on other transit systems. NFC phone users without a transit app can still pay for transportation with the NFC phone; the only difference is that their NFC phones must be tapped by an inspector because the phone won't show the required ticket or pass information on its display.

A backup payment method for users whose phone batteries are dead or have otherwise failed is necessary. Users can be reminded to carry an EMV credit/debit or GPR card; they can buy a GPR card at a vending machine at subway stations and at retail outlets. Cards should be available in small denominations (one or two rides) for customers in this situation.

Contactless EMV medium for riders without NFC phones

A payment means for users without NFC phones must be provided. All such users can be assumed to have contactless EMV cards, since they can obtain EMV GPR cards at retail outlets or at MBTA/MassDOT facilities. The only services on which an EMV card by itself is not sufficient are those that still use visual inspection. It may be possible to move to validators on commuter rail and boat services, and for private bus carrier drivers and commuter rail staff to have NFC mobile phones to read the expected small number of EMV cards⁹⁸. With only a small number of EMV cards, the overall time to inspect commuter rail tickets should not increase over current times with visual inspection. It is slower to tap a card on an NFC phone than to visually inspect a phone or paper ticket, so the number of EMV cards to be inspected must be small.

The Charlie Card is eliminated. Users without an NFC phone or EMV credit/debit card obtain a MassDOT/MBTA GPR card and load it at retail locations, or buy a preloaded GPR card at a vending machine at an MBTA station. GPR users can manage their account through the website, and may be able to transfer funds via ACH⁹⁹ to their account as well as through cash reload at retail outlets.

Media for visual inspection on MBTA services

Riders may make purchases on their mobile phone ("over the air") for services that use visual inspection; in this case there is no NFC or EMV tap. The transit app must handle these cases, which are expected to be a small percentage of ridership. If there is a transfer to or from a service that is not visually inspected, the NFC phone is tapped at a reader on the other service. The fare engine has the purchase, activation and tap data, and ensures that the trip is properly paid for.¹⁰⁰

⁹⁷ <http://www.open-mobile-ticketing.com/>. Its founding members are HERE/Nokia, Scheidt & Bachmann, Thales and Verifone Mobile Money.

⁹⁸ An NFC phone can read EMV cards.

⁹⁹ ACH is the Automated Clearinghouse, a low cost means to transfer funds between bank accounts. It would be used to transfer funds from a user's checking account to the single transportation account, for users with checking accounts but without credit or debit cards.

¹⁰⁰ If a rider bought a commuter rail fare, which is visually inspected, but then taps his or her phone at a subway gate, the transfer will be free. The server knows that this phone is associated with a rail trip that includes the transfer.

Riders on visually inspected services can also use EMV credit/debit cards, without a mobile phone. There are options on how they would use services that require visual inspection:

1. Staff could have NFC phones that could read the EMV card and check for valid taps or tickets, or
2. Users would have to pay and receive a receipt at kiosks before traveling.

If commuter rail has validators at stations, the number of services with visual inspection will be low. If NFC penetration is high, passive validators, with no power or communications, can be placed at surface stops. Users tap NFC phones on them; the phone provides the power and communications. The validators function essentially as a gate on which to tap in or tap out. If NFC penetration is high, this could be an inexpensive option. (This technology worked well in a Long Island Railroad pilot in 2012, and it is used in Europe.)

It may be possible to allow all-door boarding on high volume bus routes and at surface Green Line stops. Vehicles would have readers at all doors, tied to the farebox at the front. Random inspection would be required to enforce payment, as described in section 5.6. All-door boarding would have significant operational benefits. Costs for additional readers for all-door boarding are not included in this study.

On the Green Line, there is a second option: for all-door boarding, passive validators could be placed at surface stops, similar to commuter rail.¹⁰¹

PIV cards

PIV cards can be accepted in this phase. These can be employer-issued identification cards, social service agency-issued cards and other government IDs. University IDs may also be accepted. Accepting these cards with pay-in-advance stored value or passes avoids paying most bank fees on these transactions. With the MBTA's large employer pass program, this can be a major savings. Transit benefit programs will issue EMV debit cards, which is a continuation of current practice; these debit cards can be accepted directly at gates and fareboxes¹⁰².

PIV cards can be issued for the use of MBTA/MassDOT staff, contractors, emergency personnel and others requiring access to gated or otherwise restricted areas. This may bring operational improvements.

Media for non-MBTA services

Private bus carriers and other non-MBTA and non-MassDOT services can accept NFC phone and EMV card payment in the same manner as the MBTA. They can accept the NFC phone for visual inspection if it has the transit app. Alternatively, users will tap their NFC phone or EMV card to pay for services and receive a ticket, either printed or on their phone. A user with an EMV GPR card that has been reloaded with cash can use it for these non-MBTA and non-MassDOT services as long

¹⁰¹ Validators are used in the Transport for London open payment system for the Croydon Tram, which is similar to the Green Line, and they work well.

¹⁰² https://www.ventrarchicago.com/assets/1/7/CUB-B111_InstructionSheet_FINAL_NoCrops.pdf

as the balance on the card is sufficient to pay for the service being purchased, and there is an agreement between the carrier and MassDOT to do so.

Bike share, car share and other services may be included within the unified mobile app for customer convenience; the transactions from the mobile app would be passed through to the actual service provider. Travelers can use bike share and car share services without the mobile app, but will not see an integrated account summary.

Media risk management

This phase depends on users having NFC phones or contactless EMV cards. Almost all smart phones are expected to have NFC at the time that phase 2 is implemented. If this does not occur, or travelers do not wish to use NFC phones, contactless EMV cards are likely to be in use. If that does not occur, the MBTA and MassDOT can issue EMV cards as the payment medium. This is similar to the Chicago CTA open payment system in which the Ventra card is currently issued as the primary medium until EMV and NFC become widespread.

Another option, should the risk of using NFC phones and contactless EMV cards appear to be large, is to use mobile phone payment as the preferred medium but without using NFC. Phones would be visually inspected on most services. Such a non-NFC phone payment system has significant shortcomings: revenue control on services is diminished with only visual inspection; the amount of data on ridership is significantly reduced; bar code readers are probably required at gates, which will be lower performance and lower convenience; and other issues exist.

Summary

Table 7 shows the services and media accepted in this option. A unified NFC app is the preferred payment medium for all non-highway toll facilities. The phone can be tapped or visually inspected, as required by each service. EMV cards can also be used on all non-highway facilities; they can be tapped at readers, and they can be inspected by staff with NFC phones otherwise. EMV cards must be a small percentage of the payment media being used, so that additional staff on trains and other visually inspected services are not required. GPR cards are used by those without credit/debit cards, either directly or as the payment medium backing up an NFC phone.

In table 7, as in earlier summary tables, green cells indicate that this form of payment is standard or preferred; yellow cells indicate other forms of payment that are accepted, usually with transfer restrictions; red cells indicate this form of payment is not accepted. Other terms that are used include:

1. Unified NFC app: this is the preferred or standard payment medium for all transit services.
2. Standard: as in previous tables, this medium is accepted at the lowest fare and best transfer privileges. In this table, this is E-ZPass for highway and credit/debit for sharing services.
3. EMV card, and "load on GPR card": these are accepted for transit travel at the same fares and transfer privileges as the unified NFC app; the operator prefers the unified NFC app on visually inspected services because it is faster.

Table 7: Payment media accepted by mode and carrier. Phase 2

Service	Cash	Credit/debit	Charlie Card	Charlie Ticket	Mobile payment	E-ZPass
MBTA subway-gated	Load on GPR card	EMV card	Not accepted	Not accepted	Unified NFC app	Not accepted
MBTA subway-ungated	Load on GPR card	EMV card	Not accepted	Not accepted	Unified NFC app	Not accepted
MBTA bus	Load on GPR card	EMV card	Not accepted	Not accepted	Unified NFC app	Not accepted
Commuter rail-downtown	Load on GPR card	EMV card	Not accepted	Not accepted	Unified NFC app	Not accepted
Commuter rail-other	Load on GPR card	EMV card	Not accepted	Not accepted	Unified NFC app	Not accepted
MBTA boat	Load on GPR card	EMV card	Not accepted	Not accepted	Unified NFC app	Not accepted
MBTA parking	Load on GPR card	EMV card	Not accepted	Not accepted	Unified NFC app	Not accepted
MBTA The Ride	Load on GPR card	Not accepted on car	Not accepted	Not accepted	Unified NFC app	Not accepted
Other RTAs	Load on GPR card	EMV card	Not accepted	Not accepted	Unified NFC app	Not accepted
Logan Express	Load on GPR card	EMV card	Not accepted	Not accepted	Unified NFC app	Not accepted
Logan Express parking	Load on GPR card	EMV card	Not accepted	Not accepted	Unified NFC app	Not accepted
Logan Airport parking	Load on GPR card	EMV card	Not accepted	Not accepted	Unified NFC app	Not accepted
Private bus carriers	Load on GPR card	EMV card	Not accepted	Not accepted	Unified NFC app	Not accepted
Suburban/contract bus	Load on GPR card	EMV card	Not accepted	Not accepted	Unified NFC app	Not accepted
Highway toll facilities	Not accepted	Not accepted	Not accepted	Not accepted	Not accepted	Standard
HOV/HOT lanes(future)	Not accepted	Not accepted	Not accepted	Not accepted	Not accepted	Standard
Bike sharing	Not accepted	Standard	Not accepted	Not accepted	May include in app	Not accepted
Car sharing	Not accepted	Standard	Not accepted	Not accepted	May include in app	Not accepted
Municipal parking	Accepted	Accepted (some)	Not accepted	Not accepted	Future	Not accepted

Technology changes and costs

The technology changes required are:

1. The website and single account require modification. Modification of account/payment server is required to handle EMV and NFC data fields. Website extensions to handle additional trip data, new pass or pricing options and incentives are required.
2. Development of NFC mobile phone transit app, or adoption and modification (as needed) of Open Mobile Ticketing Alliance app. This extends the work done in the phase 1 mobile app. Inspection, receipts, selection of services and other features are required.
3. Upgrading all gates, fareboxes and validators to accept NFC and EMV payment, in an open payment system. This requires changing the reader logic and the reader security access module. This may require replacement of reader hardware, or it may be possible to reprogram the readers. This includes RTAs, Logan Express and suburban/contracted bus systems, whose payment and use are fully integrated.
4. Wireless data connections to all buses are required to manage risks in payment. These data connections probably can be shared with bus automated vehicle location (AVL) and other systems¹⁰³. Some improvements in bus wireless may have already been made in phase 1.
5. Development or acquisition of an open payment server with a fare engine and back-end payment server to process taps from services, and to pass EMV data to the payments processor. Open payment server software has already been developed in several cities, and it may be possible for the MBTA to license it. Best value pricing is included in some servers.
6. The GPR card must be issued as a contactless EMV card, and sold at retail outlets. The retail network to reload it must be modified from phase 1.
7. Open payment must be coordinated with the MBTA's acquiring bank. Bankcard fees may increase due to increased use; they can be minimized by use of aggregation, pre-authorization, use of PIV cards and other means. Many current TVM and online transactions use credit/debit cards, so the MBTA already has substantial bankcard fees. Some of the fee increase will be offset by customer service savings, since users with card issues will contact their bank and not the MBTA to resolve them. The MBTA Corporate Pass program accounts for 27% of revenue¹⁰⁴. If credit/debit and cash represent roughly equal portions of the remainder, and assuming a 1% bankcard fee, the MBTA's current bankcard costs may be approximately \$2 million. The elimination of cash would increase them by a maximum of \$2 million, but aggregation and the possibility of negotiating a lower fee may reduce this impact.
8. If PIV cards are accepted, readers and the back-end payment server must be modified to accept them. Interfaces to employers must be provided so that passes, value and the associated PIV card numbers are sent to the MBTA. This is an extension to the current employer pass program software. Some open payment server software already handles PIV cards.

¹⁰³ This can improve AVL information: the number of fares paid on a bus are a good indicator of how full it is, which in turn improve the predictions of its running time along the route. Even if running times are not predicted, an indicator on mobile phone apps that shows the relative load on buses on a route can be helpful to users

¹⁰⁴ <http://dspace.mit.edu/handle/1721.1/82837> "Quantifying the current and future impacts of the MBTA Corporate Pass Program", Dianne Kamfonik, SM thesis, MIT, 2013.

9. Validators on commuter rail may be implemented if that was not done in phase 1.
10. The Charlie Card is eliminated. Phase 1 server software is migrated to the open payment server. Some gate, network and farebox monitoring functions may remain from the phase 1 software.
11. TVMs are eliminated. Preloaded GPR cards can be bought at the vending machines at stations that were installed in phase 1.

The nine items above are also the principal cost elements in phase 2. It is again difficult to provide a good cost estimate because many issues have not been determined. A rough order-of-magnitude estimate is:

- | | |
|---|--------------|
| • Software development: | \$17 million |
| • Hardware (primarily 3,000 readers): | \$ 6 million |
| • Project management and systems integration: | \$ 7 million |
| • Total capital costs | \$30 million |
-
- | | |
|---------------------------------|--------------------------------|
| • Annual operating cost changes | Expected to be lower; see text |
|---------------------------------|--------------------------------|

As in phase 1, this estimate may be off by a factor of 4.

Cost comparisons with other open payment systems are difficult, because they involve different levels of gate and farebox equipment, capital construction at stations, and different arrangements for operating costs. The contract costs of other US open payment systems are:

- Chicago Ventra.¹⁰⁵ The contract amount is \$454 million and covers all capital and operating costs for a 12 year period. This is approximately \$38 million per year, and is expected to save \$5 million per year compared to current costs, as well as serving the suburban PACE bus system. A NFC mobile app with visual inspection to cover subway, bus and commuter rail is being developed at a cost of approximately \$5 million.¹⁰⁶
- Philadelphia Key Card.¹⁰⁷ The contract amount is \$129.5 million for the installation of gates on commuter rail, replacement of gates on the subway system, and replacement of readers on buses, in addition to all software.
- Washington, DC.¹⁰⁸ The contract amount is \$184 million for gate and reader replacement at subway stations, reader replacement on buses, in addition to all software.
- Salt Lake City.¹⁰⁹ A 2012 audit report places the cost of the open payment system at \$10 million. Some internal costs are not included.

The MBTA/MassDOT project is not expected to include gate replacement; only readers would be replaced or upgraded. Bus farebox replacement is assumed to be a separate effort; the phase 2 open payment effort would require reader upgrades on buses. Server software and mobile apps are the other major cost elements in a Massachusetts project. Since the MBTA is comparable to WMATA and SEPTA in scale, these estimates are taken as upper bounds on project cost. Actual

¹⁰⁵ <http://en.wikipedia.org/wiki/Ventra>

¹⁰⁶ <http://www.railwayage.com/index.php/news/chicago-taps-cubic-for-regional-transit-mobile-app.html?channel=00>

¹⁰⁷ <http://planphilly.com/articles/2011/11/17/septa-awards-1295-million-contract-build-new-fare-system>

¹⁰⁸ <http://www.washingtoncitypaper.com/blogs/housingcomplex/2014/01/08/metro-awards-184-million-contract-for-futuristic-fare-collection-system/>

¹⁰⁹ http://le.utah.gov/audit/12_01rpt.pdf , page 48.

project cost in Massachusetts may be significantly less if, as expected, there is less gate replacement and other physical construction.

A long-run reduction in operating costs is expected, although more detailed analysis is required to confirm this. Cost reductions are possible in:

1. Card issuance costs. Riders use their own NFC phone or EMV card. The MBTA and MassDOT issue a GPR card for the expected small number of users without NFC phones or EMV cards. No Charlie Cards or Charlie Tickets are issued. On balance, these costs are expected to decrease substantially.
2. Customer service costs. Riders contact their bank, not the MBTA, when their card or phone doesn't work. Riders typically have a second card available, which allows them to ride. The single account can provide self-service correction of trip charges; a user can log in and refund or change a fare, within strict limits. (Transport for London allows this.)
3. Ticket vending machines. Charlie Card machines are no longer needed. A vending machine with pre-loaded GPR cards can be substituted. The vending machine simply dispenses cards with various amounts of value; there are no fare selection functions.
4. Staff. Subject to labor negotiations, staff can be reassigned. Customer service staff at stations may be able to perform additional customer service duties as the number of fare inquiries and problems declines. Commuter rail and Green Line staff requirements due to ticket collection may change.
5. Servers. Server hardware costs continue to decline, and open payments software is more standard across systems, potentially lowering its costs.
6. Cost-effectiveness of service. Unified payment may allow some consolidation of services between the MBTA, TMAs, private carriers and others. If users can ride any service with their fare media, it may be possible to coordinate or consolidate in some cases.
7. Cashless buses. While this is a broader issue, phase 2's acceptance of NFC phones and contactless EMV cards that most riders will have, plus an expanded GPR card program and retail network, may allow the MBTA to move to cashless buses. Equity issues appear to be positive in phase 2, as described in the next section. Eliminating cash handling on buses and at bus garages will reduce operating costs. Faster bus operations on routes will directly reduce operating costs. The reduction of cash handling from fewer TVMs will have an additional but small impact.
8. Retail reload savings. Cost reductions in moving to a GPR card reload from existing Charlie Card terminals are possible.

Planning, budgeting and requirements for this phase can begin in parallel with phase 1.

Implementation times for other open payment systems have ranged from two years (CTA Ventra) to seven years (Transport for London). The MBTA effort might be planned for 3 or 4 years from inception. It benefits from past experience in open payments, but its scope and integration of many services will add time and effort.

The software and hardware changes can probably be made in parallel. Software modification and configuration may take 12 to 24 months; reader installation may take approximately the same time. The software and readers will almost certainly accept legacy cards like the Charlie Card as part of their existing capabilities, so the new software and hardware can be implemented during phase 1

or phase 2. This level of flexibility eases the migration problems from the current to the future system.

To summarize, in phase 1 MassDOT and the MBTA can make incremental improvements that fit within a broader framework for unified payment. Phase 1 has limited technology changes; it primarily focuses on including all relevant services, deploying additional equipment of current designs, and software changes.

The costs of additional readers for all-door boarding at Green Line surface stops (and possibly on buses on high volume routes) have not been included. If this option were chosen, inspection devices would also be required.

On additional technology change can be considered when reader replacement or modification is being planned: Tap in and tap out can be used on subway and bus for pricing flexibility and equity for users making shorter trips.¹¹⁰ Tap out on subway gates requires hardware modifications: readers must be placed on the inside of gates and must have mechanisms to control the gate on their left. Emergency egress must be provided even if users do not have media to tap out at gates. The costs of this change are not included in the estimate above.

This option can be implemented in 2019 or beyond. EMV card and NFC phone adoption, PIV card evolution and, most important, system development are expected to take 3 years or more.

Transportation policy issues, benefits and ridership changes

The major fare policy and marketing changes that are possible in this phase are listed below. Many of these are possible due to the flexibility of computing fares on a server, not bound by the limitations of storing data on cards and having fare logic on readers.

1. Joint fares with private bus and other non-MBTA operators.
2. Joint fares with RTAs and suburban/contracted bus systems.
3. Parking pricing can be integrated with transit fares: parkers who use transit pay a lower fee than those who don't use transit. Pricing can be demand-based.
4. Variable fares by time of day and other factors.
5. Group travel, giving discounts on transit to two or more passengers traveling together. This is possible because the mobile phone user interface allows a user to specify more than one fare to be paid. This is useful for families and other groups. This is generally not supported in card-based systems because a user interface is required to indicate the number and type of fares to be paid, and a card does not have a user interface.
6. Offpeak or weekend passes can be offered.
7. Introductory fares to attract new users through limited-time discounts are possible.
8. Best value fares can be offered, as noted above. This allows a major simplification of fare policies. Users no longer need to understand, compare and choose a fare plan in advance. Visitors and infrequent users do not need to use TVMs or make decisions on fare plans.

¹¹⁰ <http://www.sltrib.com/news/1735517-155/uta-distance-2015-fares-based-budget>

9. Customer acquisition program. With almost all users paying with NFC/EMV credit/debit/GPR or PIV cards, this provides a single repository of travel data. MBTA/MassDOT can analyze the data and identify underutilized or new services, for example, and target marketing to residents or employees in only those areas, such as introductory discounts or rewards. The single repository allows MassDOT/MBTA to group users by area (such as census tract) and identify areas that have lower-than-expected usage. This also supports a service planning function; service adjustments as well as pricing changes can be considered.
10. Customer retention program. MBTA/MassDOT can initiate programs for long-term users who are not well-served by current pass programs. Pass programs are a form of loyalty program, and can be more flexible. For example, three day a week users get no price break even if they use transit for years. Other trip patterns that are not well served by current pass definitions and pricing can be identified, and changes made.
11. Agencies, carriers and services can be added to the single payment medium readily. They must accept NFC and EMV cards; their services must be added to the single account and fare server. A revenue settlement agreement must be made if joint fares are offered, but this is not mandatory: trips can be made seamlessly across the services but riders will pay the sum of the fares across the services.
12. In open payment, retailers can “validate transit”, similar to how they validate parking. The retailer can place a transit credit on the credit/debit/GPR card used by the customer to pay for part or all of the transit trip. This policy would be novel.

This phase allows a broad set of transportation demand policies to be implemented. In addition to best value and others listed above, examples include:

1. Any fare policy that can be defined by mode, agency, time, rider group, frequency of use, sales channel, and type. There can be group fares, route-specific fares (for new, changed or underutilized services or for other policy reasons), regional fare caps, automatic refunds if there are service disruptions, automatic issuance of payment media for alternate routes if there are service disruptions or construction changes, parking refunds if service is not running, and others. Users can be encouraged to switch from congested services or time periods to uncongested ones.
2. A flexible, easy-to-use means to quickly define, configure and implement new fare products offered at readers or the website.
3. Accessible, convenient self-service support for customers. They can correct missing taps, change future product purchases, review travel history, and receive suggestions (and incentives) for changes in travel choices. Limits are placed on the number of self-service corrections.
4. Policies that span transit and highway use can be set.

Possible increases or decreases in revenue may result. All of these estimates are highly uncertain:

1. Increased simplicity and ease of payment: An additional \$6 million increase per year beyond phase 1, assuming a 1% increase in annual MBTA revenues of \$600 million.¹¹¹

¹¹¹ In

<https://www.bostonfed.org/economic/cprc/conferences/2007/contactless/presentations/Korczak.pdf>: The open payment pilot “had a positive impact on MTA ridership”.

2. Increased destinations available through a seamless transit system. This may result in further increases in ridership from phase 1 if all transit services can be used under a single payment system and fare plan, and if car share, bike share and other innovative services are integrated.
3. Feasibility of additional revenue collection. For example, it becomes feasible to charge fares on the SL1 service from Logan Airport, which is currently free, in part due to fare collection difficulties, which cause operational delays and customer inconvenience. There are about 3,000 daily boardings on the SL1 at Logan Airport¹¹², or about 1 million annual trips. At a typical fare of \$1.50 (assuming some pass users) and assuming little ridership loss, this is \$1.5 million per year in additional revenue.
4. Best value fares. There may be a revenue decrease with best value fares, if implemented. Daily and weekly fares will be capped at the pass prices; no user will spend more. This is not expected to be a large effect. More significantly, users who currently purchase weekly passes but do not obtain full value from them will pay less, lowering MBTA revenue. Weekly passes are a relatively small fraction of MBTA revenues. Monthly passes will continue to be offered, and are likely to constitute the large majority of MBTA pass revenue; these are not affected.
5. Impacts of new fare policies. The implementation of new pass types, fare plans, incentives and other innovations is expected to increase ridership further.
6. Operating costs may increase to handle new ridership.

It is possible that phase 2 will increase revenues significantly.

The equity effects of phase 2 appear to be positive. With best value pricing, there is an equity benefit to users who purchase passes but do not currently receive full value that offsets the revenue loss to the MBTA. This equity benefit may be of significant value to low income users: a low income traveler who purchases a weekly or monthly pass and does not use it due to illness, emergency, or changes in or loss of work may have lost a sum of money that is important in meeting other necessary expenses. The combination of lower NFC and EMV card fares than previous Charlie Ticket or cash fares, best value pricing, possible tap in/tap out so shorter trips pay a lower fare, and other fare policies possible with a fare server may provide substantial equity benefits.

Phase 2 allows a broad re-examination of fare and transportation policies. The Transport for London implementation has triggered such a discussion.¹¹³

http://www.firstdata.com/downloads/thought-leadership/transit-payment-systems_wp.pdf: "NYCT average fares on the subway lines involved in the pilot were up 17 percent, while revenues were up 8 percent to 13 percent. The increase was attributed to the convenience factor of using the contactless cards." (Average fares increased because users bought single rides without discounts.)

¹¹² MBTA Blue Book, 14th ed. Massport currently pays the cost of this service.

¹¹³ See <http://www.londonreconnections.com/2014/fares-2015-continuing-social-evolution/> and <http://www.londonreconnections.com/> in general as interesting examples.

Public information and user issues

The same set of public information activities listed for phase 1 will be necessary in phase 2.

A substantial amount of public information must be provided as part of the transition to phone-based payment. New fare options, activation of mobile tickets for visually inspected services, the use of phones at gates and validators, and other changes in usage must be widely disseminated. The ability to travel on all services with just a phone, and without a Charlie Card, is a major increase in convenience for most users. The phone should be tied to the single account, although this is not a requirement.

The privacy and anonymity policies for public transit change from phase 1. Users wishing to remain anonymous in this option can continue to use unregistered GPR cards and cash. Riders using the mobile app can tie it to a GPR card. The GPR card may be unregistered, though this will limit the number and size of reloads. There are no changes from phase 1 for highway toll payment.

Changes in agency operations and relationships

Changes in agency relationships from the previous phase are a continuation of the changes made in phase 1, since unified fare payment has already been implemented in phase 1 or, if not feasible, it has been planned for phase 2. In phase 2, tap data should be exchanged between agencies, along with the trips, transfers, revenue shares and other data both within a single system and crossing more than one system. Some private carriers may not wish to share certain data with others; the open payment server must allow this to be configured.

Operations may change significantly on commuter rail if validators are implemented: most revenue collection will essentially be done off-train as riders tap in and tap out.

Service integration and coordination of schedule changes between agencies and carriers continues, possibly through the same committee established in phase 1.

Example

For the difficult example presented at the start of the report in section 2.4, we assume the user has an NFC phone or a contactless EMV card to make general payments. No prearrangement with the MBTA or any agency is necessary, although it is operationally easier if the user has the transit app on his or her mobile phone. The user is not required to have a single account.

1. The user drives one exit on the Mass Pike to a commuter rail station. E-ZPass is used if the user has it. If not, license plate video payment is used.
2. The user parks at the commuter rail station. The user taps the phone or card at the entrance gate, and will tap at the exit when leaving. If the station parking lot is ungated, the user activates parking using the transit mobile app.
3. Commuter rail is used to go to South Station. The user taps his/her NFC phone or contactless card on a validator on the station platform before boarding. Upon arriving at

South Station, the user taps out with his/her phone or card at the exit gate on the South Station platform. (Tapping out at South Station may be optional.)

4. The MBTA Red Line is used to go to Cambridge. The user taps in at the Red Line gate with the phone or card.
5. A bike sharing service is used to make a short trip at noon. The phone or card is used.
6. The same single payment method used for the morning trip is then used for the return trip in the evening.
7. On a subsequent day, the user may travel to Logan Airport, paying for Massport parking with the phone or card; if a Gold Passport member, the phone or card number is tied to the Gold Passport membership, allowing restricted gates to open. The Exit Express program is no longer needed for many travelers: since it ties a credit/debit card to the Exit Express card, the credit/debit card can be used directly. If Logan Express service and remote parking are used, the phone or card are used for payment. If the user stops along the way to the airport and parks the car for a short period, the user must have coins or a town-issued smart card for the parking space—this is unlikely to change from the base case.

Figure 5 shows the two payment media used for this trip, two less than phase 1 and three less than the current case. The traveler can now use the unified NFC mobile app to travel on almost all non-highway services.

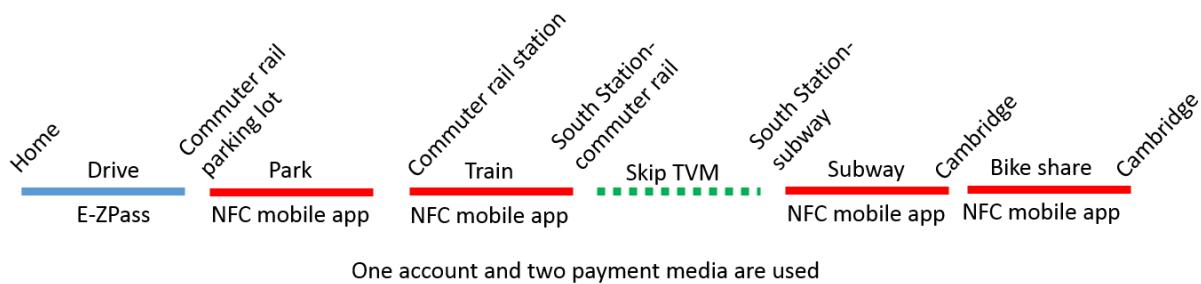


Figure 5: Example trip, phase 2

Summary of Phases

Media accepted by phase

Figure 6 shows the payment media, the devices used to purchase transportation services, the devices used to control access to transportation services, and the payment/accounting systems that are in current use. All of these figures show the principal usage patterns; less-used variations are not shown.

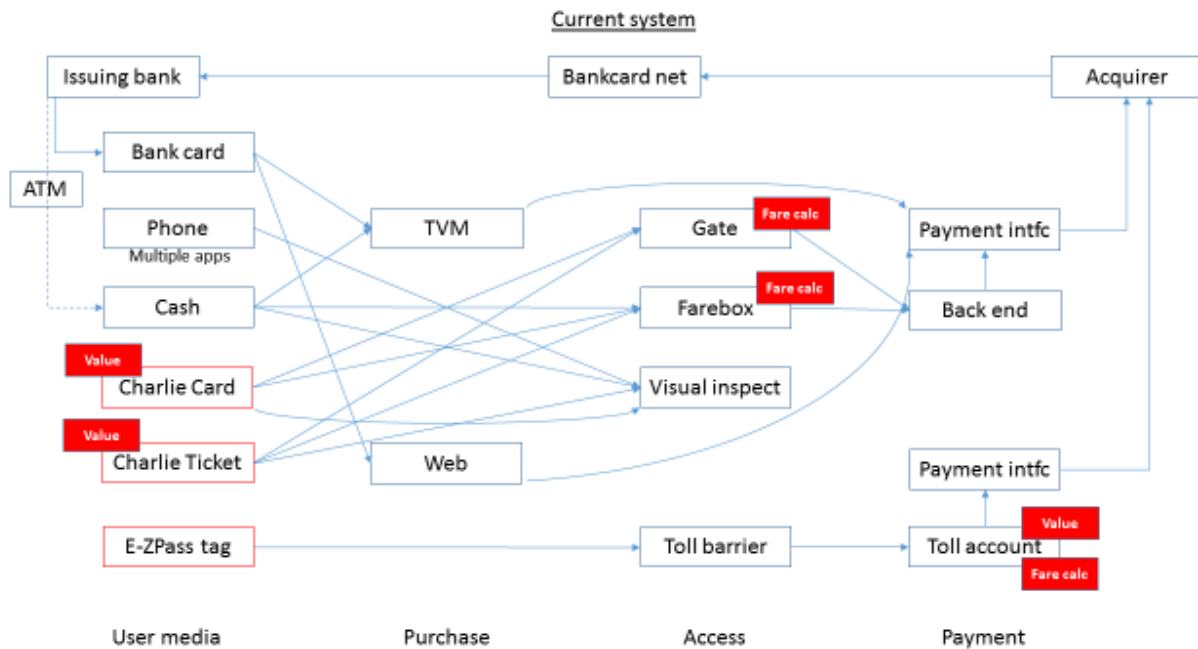


Figure 6 : Current system architecture

The key elements are:

1. Travelers use six different media types. They typically have three of them (bank card, smart phone and cash) and obtain the other three from the MBTA or MassDOT (Charlie Card, Charlie Ticket and E-ZPass tag).
2. The majority of purchase transactions are made at ticket vending machines (TVMs) or through web-based means (MBTA website, E-ZPass website, and employer pass programs).
3. Once the user has the appropriate media and has purchased a travel product, he or she can present the payment medium, typically with the travel product loaded on it, at an access device (gate, farebox, toll barrier or visual inspection). The access devices report usage to a payment or back-end system.
4. For transit, TVMs and websites use a payment interface to obtain funds for bankcard transactions; this links the MBTA to an acquirer, bankcard network and the issuing bank for the customers' credit and debit cards, from which payment is made. A back end system counts gate and farebox transactions, reconciles cash, and produces data summaries.

- Highway tolls are account-based; a bankcard is typically associated with the account and is replenished based on toll usage; a second payment interface is used to obtain payment via the banking system, in parallel to transit payment.

In the current system, there is a complex pattern that defines which payment media can be used on which transportation services. In general, media that users possess (bank cards, phones, cash) must be converted to other media (Charlie Card, Charlie Ticket, E-ZPass tag) before they can be used at access control points.

Figure 7 shows the incremental changes that occur in phase 1.

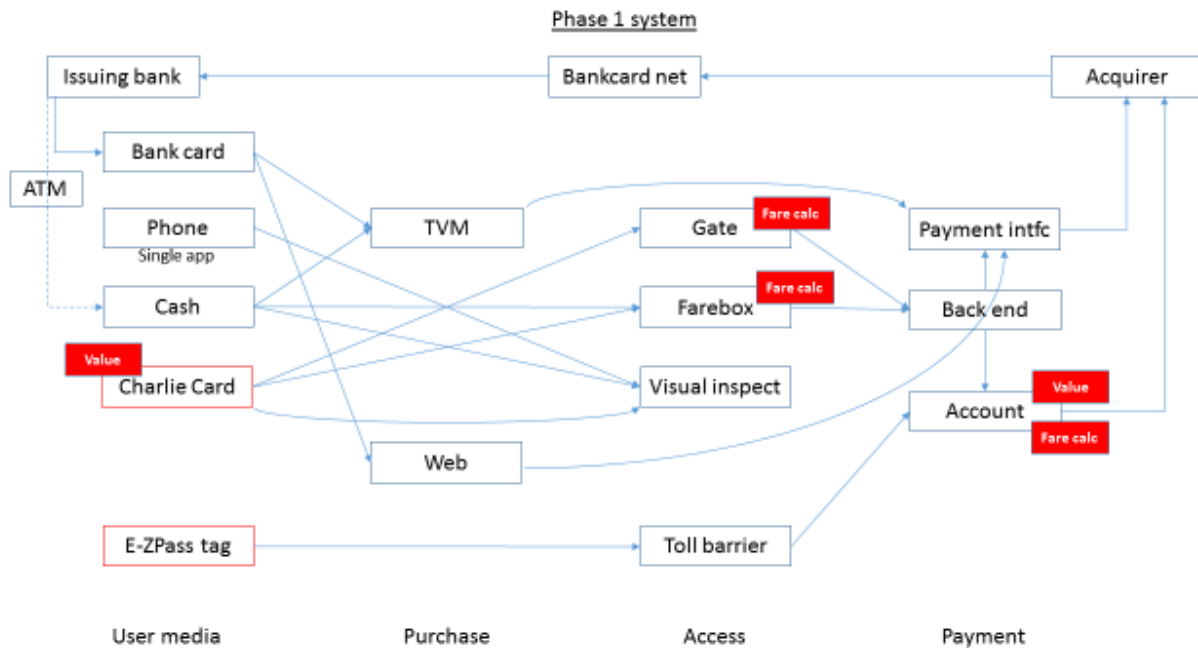


Figure 7: Phase 1 architecture

The key elements are:

- Travelers use fewer media types. The Charlie Ticket is eliminated, and there is a single phone app, simplifying the media choice for users.
- Most purchase transactions are still made at TVMs or web means.
- Access is similar to the current system in principle, but Charlie Card is accepted on all services, and a single mobile app is accepted across visually inspected services.
- A single transit and highway account shows transportation purchases and usage to travelers. Transit media and access continue to principally be card-based; the Charlie Card still stores passes and value, and Charlie Card readers continue to hold all fare logic.

Figure 8 shows the open payment architecture of phase 2.

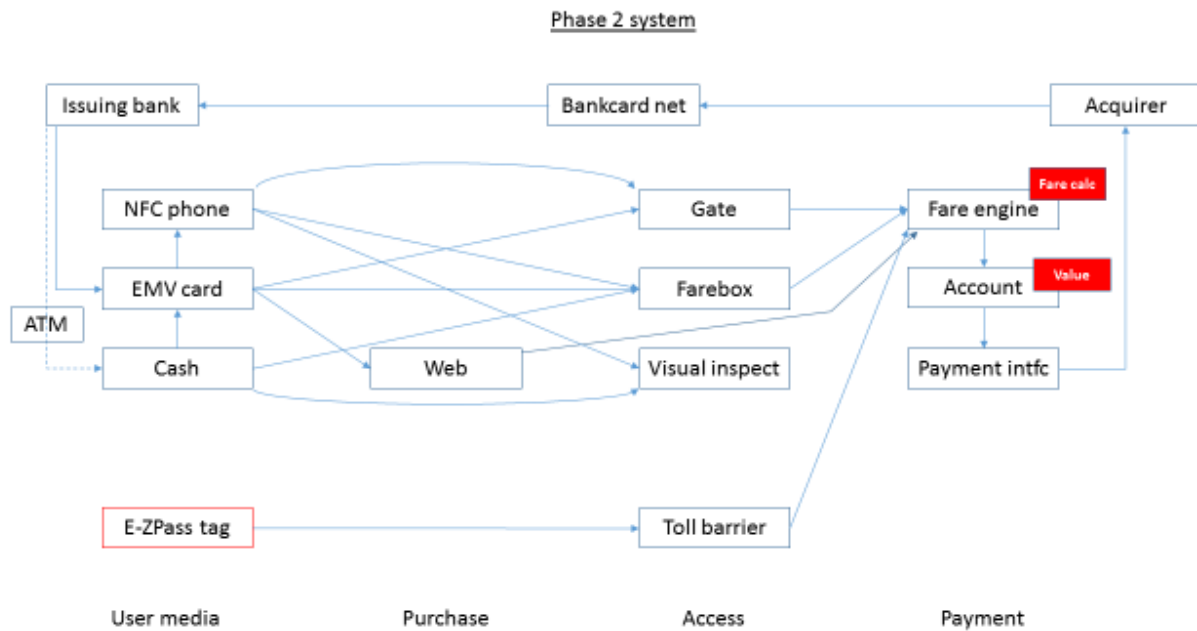


Figure 8: Phase 2 architecture

The key elements are:

1. Transit is paid for by media that users already possess. Cash users load an EMV card in most cases. EMV cards and phones are used only as identifiers in phase 2; no passes or value are held on them.
2. TVM usage drops significantly or may be eliminated; non-pass travelers will tap their own media. Pass users may purchase them at TVMs but will typically buy online or over-the-air. Web use also drops since travelers can “tap and go”.
3. Users can bypass TVMs and websites if desired, and use their EMV and NFC media directly to access services.
4. All passes, value, travel history and purchases are held in a single account (as is E-ZPass). A fare engine computes all fares and tolls based on gate and farebox taps, and on E-ZPass tag reads. A single payment interface is used for highway and transit.

Costs and benefits by phase

The implementation of unified transportation payment in Massachusetts can be structured as a two phase project. Within each phase, there are policy and operational choices. This chapter summarizes the phases analyzed in this report, as a starting point for the overall effort.

Phase 1 implements a set of incremental changes to current systems that do not require major technical changes. It establishes the Charlie Card as the preferred payment method on almost all transit services and increases its distribution and availability; it phases out Charlie Tickets and

attempts to lessen cash payment; it implements a single parking payment system; it implements a single mobile payment app for parking, commuter rail, private bus, Logan Express and perhaps other services; and it implements an expanded cash reload system to increase E-ZPass use and to support less cash use on transit. This phase creates a single transportation account and associated website for users to simplify management and reloading of value for transportation services, and to see all travel and purchases in one place. Charlie Card acceptance is extended to commuter rail, suburban/contracted bus services, and Logan Express; Charlie Card vending machines are placed in subway stations; Charlie Cards are distributed in many additional locations. The rough order-of-magnitude costs for this phase is \$30 million, with a possible annual increase in operating costs. A \$5 million annual revenue change might occur, and there may be a small (2%) ridership increase from the change to lower Charlie Card fares from cash and Charlie Ticket fares.

Phase 2 implements NFC mobile phone and contactless EMV card payment for transit services. The phone can be tapped at gates and fareboxes, and it can be visually inspected on commuter rail or private bus services if a transit app is installed. Readers at gates and fareboxes must be upgraded to accept NFC and EMV (credit/debit card) payment, and software changes are required to accept phones and credit/debit cards directly at gates and fareboxes. A GPR card is used as the secondary payment means for users without NFC phones or EMV credit/debit cards; the Charlie Card and TVMs are eliminated. Significant simplifications and increased flexibility in fare policy are possible: Best value pricing can be provided for daily, weekly and monthly travel, eliminating the need for daily, weekly or monthly passes. The rough order-of-magnitude costs for this phase are \$30 million, with a potentially significant decrease in operating costs from elimination of Charlie Card/Ticket issuance; reduction of TVMs, server costs, cash handling costs; and customer service and other staff costs. A significant annual revenue change is possible. Commuter rail validator implementation, bus tap in and tap out¹¹⁴, and subway gate modifications to allow tap in and tap out are possible in this phase.

The total rough order-of-magnitude cost across both phases is approximately \$60 million. This is less than half the initial cost of the Charlie Card system. The existing gates and fareboxes continue to be used, with modified readers on gates and fareboxes in phase 2. Software changes are focused on mobile apps and web/account server software in both phases, incremental changes in phase 1 and then an open payments system in phase 2. The cost estimates in this report are highly uncertain, since the scope, requirements, design, contract issues with the current system are not known; they are only indicative of the range of costs that might be expected.

The benefits of the unified payment system are in having a platform that supports a broad set of transportation demand options, and in eliminating fare and toll payment media as barriers to use of transportation services by consumers. With unified payment, travelers can be offered transit and highway service alternatives that they can use with media they already possess: either more broadly-available Charlie Cards in phase 1, or mobile phones and credit/debit cards in phase 2. If people can “pay with what’s in their pocket”, they are able to switch between transportation services more readily; there is much less friction or stickiness in their choices, which eliminates a major barrier to adoption of new, green services. With this core capability in pricing and offering

¹¹⁴ Utah Transit Authority has implemented bus tap in and tap out as part of its open payment system. MBTA subway and bus tap in and tap out are not included in the costs for this project.

service, MassDOT and the MBTA can expect new service offerings to be accepted more readily and have a greater chance of success. A unified payment system will add 250,000 current daily riders to a more connected transit system, and provides connectivity and additional destinations that should attract additional ridership, especially if schedules as well as fares are coordinated across some of the newly included systems.

Examples of innovative fare policies include a single account to reload for highway and transit (allowing highway travelers to use transit more easily and dynamically), a single website to manage all travel (on which transit and highway options can be displayed to provide options to users), a clearer and simpler transit fare policy (not dependent on Charlie Card versus Charlie Ticket versus cash, each offering different advantages on different services), consistent transfers across services (making the transit system appear as a seamless, regionally integrated service), a single mobile application for all services (for convenient payment and service information), a simplification of passes in phase 2 with best value (further improving the convenience and transparency of transit use), the ability to market and price services for customer acquisition and retention (with discounts, promotions and targeting for specific services), and the ability to add new services from other private and public providers easily.

Table 8 summarizes the phases and their features and costs. Annual operating cost changes are about \$5 million in phase 1, with no change or a decrease in phase 2. Annual revenue changes are in the \$5 million range and moderate ridership increases, perhaps 1 or 2%, may occur. Additional, potentially large revenue and ridership changes will occur due to fare and transportation demand management policies implemented using the unified payment platform.

Table 8: Summary of features and costs

Phase	Components/features	Time period	ROM Cost
1	Charlie Card as preferred payment, all services	2017	\$30 million
	Charlie fareboxes on suburban/contract bus, Logan Express		
	Phase out Charlie Ticket		
	Single mobile app: commuter rail, parking, private bus		
	Single transportation account, website		
	Single payment system for all parking		
	Unified cash reload system for transit, highway		
2	Unified NFC mobile and EMV payment for all transit services	2019	\$30 million
	Mobile phone or EMV card tapped on almost all services		
	NFC visual inspection		
	General purpose reloadable (GPR) card as secondary medium		
	Open payment server with best value, additional policies		
ROM Total			\$60 million

Objectives met by phase

Table 9 evaluates the phase 1 and phase 2 systems against the objectives listed in chapter 6.

Table 9: Objectives by phase

Objective	Phase 1	Phase 2
Increased mobility for residents and visitors by allowing use of all transportation services via readily available payment means.	Charlie Card is more widely accepted, and unified mobile app is used on multiple services, but differences remain	Connectivity of regional transit is seamless on gated and ungated services. All destinations accessible.
Increased transit ridership or revenue as a result of lowered barriers to use.	Website supports transit demand management	Website supports extensive transit demand management
A single account to purchase transportation, add funds, and review and manage travel options, including better support for cash customers.	Single account for most services. Improved cash reload.	Single account for all services. Extended cash reload.
Simplified means to purchase travel using media that consumers already possess, and simpler means to obtain transportation-specific media that are needed, such as E-ZPass transponders.	Charlie Card is more available, and mobile phone payment is expanded. Not all services accept Charlie Card or mobile app.	NFC phone and EMV cards, which all users have, are used as universal media on all services
Allow the MBTA and MassDOT to better provide service data, offer incentives to change travel patterns, and monitor changes in travel.	Single account has travel payment information and partial travel history.	Single account has full travel information on trips and payment.
Integrate non-MBTA services...	Initial integration, limited by Charlie Card.	Easy to add new carriers and services.
Improved management of incidents... in which travelers are rerouted across services or modes.	Some ability to use media on multiple services in case of reroutes.	Full acceptance of same media on all services. Customers can make corrections via online self-service.
Reductions in the cost of fare/toll collection, with fewer systems and greater operational efficiencies.	Unification of mobile apps, and initial consolidation of cards may have some benefit.	Acceptance of NFC and EMV reduces card, customer service, TVM, and staff costs
Reduction in uncollected fares, missed fares and fare evasion.	Reduced cash use, and possible commuter rail validator use may reduce missed fares.	Reduced cash use, and possible commuter rail validator use may reduce missed fares.

Yellow indicates partial achievement of the objective, and green indicates full or nearly full achievement of the objective. Neither phase 1 nor phase 2 eliminates the need to obtain E-ZPass transponders, and neither fully eliminates missed fares and fare evasion, but they appear to meet

these objectives as well as any system can at present. While not in the list of objectives, both phases improve equity for lower income travelers through fare reductions, improvements in connectivity and, in phase 2, best value fares. Only limited cost reductions are projected in this report, primarily due to uncertainty in the many details of policy and implementation choices.

Cost reduction may be possible beyond these initial estimates. When the options are better defined, and internal MBTA and other cost data is available, more precise estimates can be made as part of a business case. The potential cost reductions and benefits in phase 2 include:

1. Elimination of or major reduction in Charlie Card media production, distribution and support costs. Charlie Ticket media production, distribution and support costs are eliminated in phase 1. Possible reductions in fraud from eliminating ticket media.
2. Reduction in Charlie Card and E-ZPass retail reload costs, through elimination of Charlie Card equipment and use of GPR cards. Improvements in collecting revenues from retail outlets. Commission costs may decrease if overall cash use decreases.
3. Replacement of Charlie Card back end software. There may be cost avoidance in moving to a new platform that provides desired features, and not needing to make software modifications to the existing system. Fewer accounts to support, with a single account.
4. Lower maintenance costs of new readers.
5. Fewer TVMs.
6. Consolidation of multiple mobile applications, avoiding separate back office, support and other costs.
7. Consolidation of financial transactions into one system. Possible reductions in fees and chargebacks. Risk reduction from EMV and NFC.
8. Operating cost reductions due to lower bus and Green Line dwell times at stops with less cash handling and possibly all-door boarding. Travel time and reliability benefits for bus riders.
9. Possible savings in station and commuter rail staff cost through reassignment to non-fare collection duties. Since commuter rail staff also must open and close doors manually, it is more difficult to reduce staff than in systems with high level platforms and automatic doors. A reduction in lost commuter rail revenues is also possible with fewer paper and cash transactions, and a more convenient payment means.
10. Call center cost reductions. Many calls are fare media related, which are expected to decrease significantly.
11. Lower cash handling costs.
12. Increased revenues and lower costs from parking operations.
13. Improved revenue control and lower accounting costs on commuter rail from electronic fare inspection. Reduced over-riding fare zones and uncollected tickets.
14. Cost savings from service coordination made possible by unified media. The MBTA may be able to reduce service costs by using other providers' services to form part of the network. Reduced costs to add new providers, including bike share, car share and other innovative services.
15. Ridership increases from increased ease of payment, new fare policies, and service coordination made possible by unified payment.
16. Ability to charge for Logan Airport Silver Line services.
17. Reduction in travel survey costs, with more data available in single account. Added value of customer data in travel demand management and analysis.

18. Reductions in passenger time purchasing and managing fare media. Queues at TVMs will be shorter, decisions on fare products will be simplified, reloads will be lessened, acquiring media will be simpler or not necessary, etc. In most fare systems, the passenger benefits are about half the benefits present in the business care.

Next Steps

System lifecycle and developments in other cities

Most transit agencies are on their first generation of smart card payment systems, typically implemented in the last 10 or 15 years. One agency, Transport for London, is replacing many elements of its 10 year old system to improve customer convenience and operating efficiency to leading-edge levels with an open payment system. Few other agencies are in a position to make such investments, and will generally retain (and modify) a system until it reaches its end of life, which may be 20 or 30 years, or more. The other reasons that agencies replace systems are when operating practices change (for example, Los Angeles has moved from a gateless to a gated subway system), significant flaws exist in the fare system (for example, Sydney, Australia), or when regional interoperability becomes necessary (for example, the Bay Area Clipper Card).

Some payment changes, such as acceptance of EMV cards, will essentially be mandated by the payments industry. Others, such as the increased use of smart phones and smart phone payment, are likely to be demanded by customers. A final set will be driven by MassDOT's and MBTA's desires for a demand management platform, improved convenience for customers, and possible operational improvements and cost savings.

The MBTA can benefit from the early experience and lessons learned by other transit systems before considering its own implementation. The MBTA should participate in the informal group of transit CFOs and CTOs that meets on open payment and other fare system issues, if it does not already do so. The experience of the Transport for London (TfL), CTA, UTA, SEPTA and WMATA implementations should be included in the requirements process that MassDOT and the MBTA should conduct during phase 1 of the unified payment system.

Implementation framework

MassDOT and the MBTA should review this report, as well as internal reports and plans, to decide whether to proceed with planning and engineering activities for unified payment. A decision to implement a unified payments system at a policy and planning level is a first step.

The ITS Systems Engineering Guidebook¹¹⁵ provides a structured methodology for systems planning, requirements, design, implementation and operations. The framework shown in Figure 9 is recommended for management of the unified payment system. MassDOT and the MBTA may modify (simplify, in general) the framework to best fit the needs of this project.

¹¹⁵ <https://www.fhwa.dot.gov/cadiv/segb/files/segbversion3.pdf>

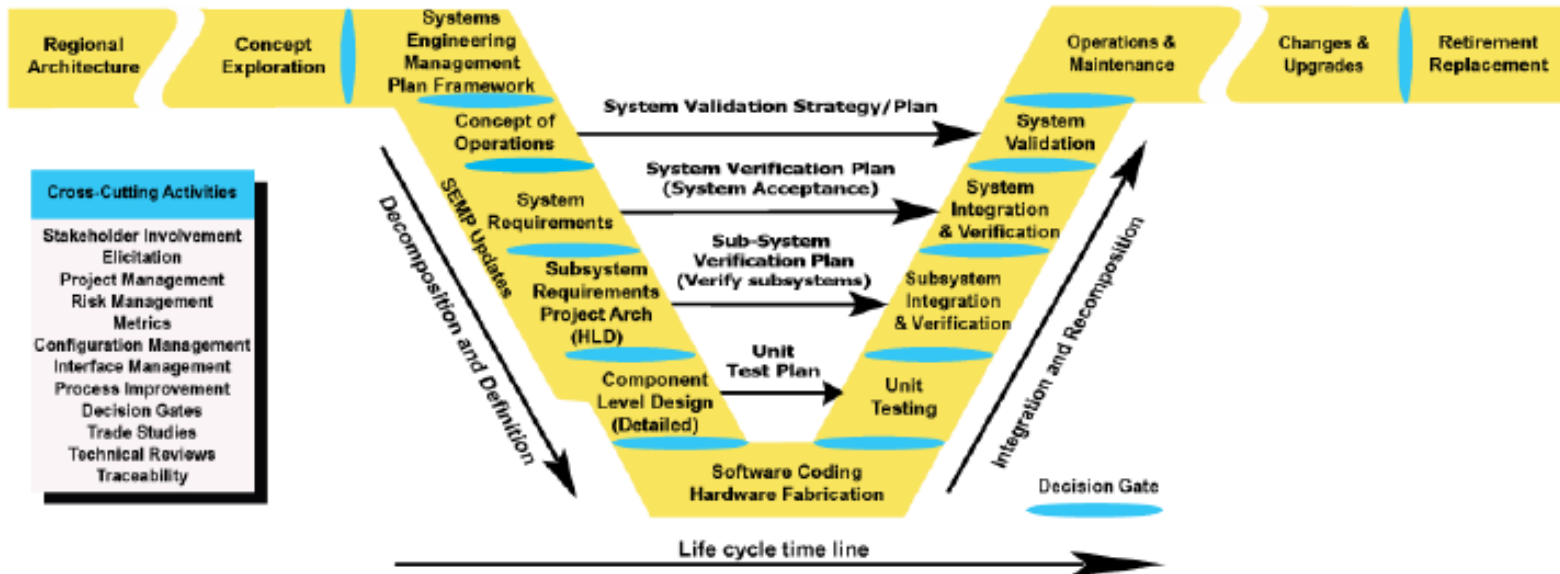


Figure 9: Systems engineering framework¹¹⁶

¹¹⁶ Ibid., Figure 3-13, page 19

The three most important steps are described below, which cover the process of deciding what the system will do. Other steps are listed in the Systems Engineering Guidebook, which should be consulted.

1. Concept of operations. This determines the services and carriers covered, the payment media to be accepted, the set of fare policies to be supported, and operating needs. A concept document defines what the system must do (but does not specify technical details), and typically contains the following key sections:
 - a. Purpose and scope of project
 - b. Background: current systems
 - c. Concept for proposed system: alternatives considered, selected alternative, customer/fare types, fare purchase options, accounts, customer service, cards and phones, readers, servers, risk management, funding, etc.
 - d. User scenarios: how the system works from a user perspective
 - e. Operational scenarios: how the system works for operators, carriers, modes, management, stations, buses, depots, external organizations

This effort is headed by MassDOT and the MBTA; concurrence of all included carriers and services is obtained. The analysis and recommendations are prepared by agency staffs, typically with limited external consulting and engineering. Separate documents for phase 1 and phase 2 are recommended. An initial draft of the phase 2 document should be prepared at the start of the effort; it will be modified and completed based on the experience of phase 1. Portions of this report can be used as starting points for the concept of operations document.

2. Business case. The concept document can form the basis for initial estimates of capital and operating cost changes, and user benefits, as a basis for an initial business case.
3. Requirements. This document defines what the unified system must do at a detailed level. The specific payment media, reader features, account and website functions, inspection processes, supported fare policies, funds management and other system elements are defined. This document is used as a guide for MassDOT and MBTA staff for phase 1, and may be the basis for a request for proposal (RFP) for systems integrators for phase 2. This is prepared by agency staffs.
4. Design. This document defines how the unified system operates at a detailed level. This may be done with external consulting or engineering in phase 1, working closely with agency staff. In phase 2, this would be done by a systems integrator, under overall supervision of agency staff.

The major steps to be taken at the start of the concept of operations process include:

1. A decision on whether to use a systems integrator in phase 1 and/or in phase 2 should be made. It may be possible to manage phase 1 internally, with external software development; an integrator is likely to be required for phase 2.
2. The interface that any integrator or software developers would have with Scheidt & Bachmann hardware, software and management must be established during the concept of operations process.
3. Other agencies such as SEPTA, CTA, TFL, UTA and others have significant experience in transit open payment that should be tapped in a substantial way before any Massachusetts effort is begun. The MBTA and other agencies also have significant experience in non-NFC

mobile apps; again, these experiences should be shared. The experiences of Tfl, CTA and SEPTA in particular should be used to guide MassDOT and MBTA choices.

4. There are a number of vendors who are implementing transit open payment systems. A request for information (RFI) or vendor meeting is likely to be helpful, to obtain feedback from likely implementers on the risks, options and requirements for successful implementation.
5. MassDOT, the MBTA, Massport, RTAs, private carriers and other transportation providers will be more tightly integrated under a unified payment system. Discussions among these parties before and during the concept of operations process and possible vendor meetings or RFI processes must be held.
6. If MassDOT and the MBTA can tightly define the phase 1 and phase 2 programs at the start, this will result in fewer changes and a shorter implementation time and lower cost. However, key risks must be assessed and resolved, and key choices must be made during the concept of operations and requirements steps of the project. These risks are:
 - a. Implementation risks. There are few project elements that have not been implemented elsewhere. The use of open payments is new, and there are still lessons to be learned, but the large agencies that are implementing open payments, and their vendors, can bring their experience to bear.
 - b. Operations risks. The system components are broadly consistent with standard transit and highway practice. Agency relationships in determining and implementing new fare and pricing policies within a unified platform, and in resolving operational issues, will require decision processes and interactions on a regular basis.
 - c. A risk-averse concept of operations appears to be feasible, which may allow a project definition with limited change orders.
7. A budget must be established for the project, and its funding over a period of years must be established. The budget will have some uncertainty, principally in the software development and systems integration costs proposed by a systems integrator.

Phased implementation in Massachusetts

The implementation of a unified payment system can be staged, moving from initial, incremental steps, to a more fully integrated system over a period of years. Because the MBTA Charlie Card system is relatively new (2006), the E-ZPass system must be interoperable over a large number of highway toll agencies, and the cost of this infrastructure is substantial, the core infrastructure of gates, fareboxes and toll barriers will require incremental changes and not full replacement.

Modifications to card readers, data communications networks, and server software and hardware are the major physical changes. Some physical additions are required for some options: Readers may be added to vehicles and locations that currently do not have them; open road tolling is planned to be implemented (this is largely independent of unified payment); vending machines, validators and other devices may be installed to support changes in payment media.

Phase 2 implements the unified payment system, which requires gate and farebox upgrades, additional software changes, and a substantial systems integration effort to ensure that all payment system elements work together in actual operations.

Appendix A. Open Payment Risk Model

The two figures below show the modifications to phone and credit/debit card acceptance that have been used in some previous transit open payment implementations. This information is presented to illustrate the issues that must be handled; there are several options available, some of which are newer and may be more effective for the MBTA and MassDOT.

The treatment of phones and cards is identical; we use phones in this description. When a rider first presents his or her NFC phone at a transit gate or farebox, a deny list (which can be either on the gate/farebox or the transit agency server) is checked to see if the card has been lost, stolen or has not been valid for payment before. If this check is passed, the phone's key/secret is verified to ensure it is valid (not counterfeit or altered), and the gate is opened. If the phone has not been seen before, a pre-authorization for a nominal amount (perhaps \$1 or \$5) is made. This amount is kept low because low income transit riders may have low debit card balances that the agency should encumber as little as possible. The gate has opened at this point; if the pre-authorization fails, the phone is put on the deny list (typically in a few minutes) and future taps will fail. The payments provider may take this first payment risk; it is small.

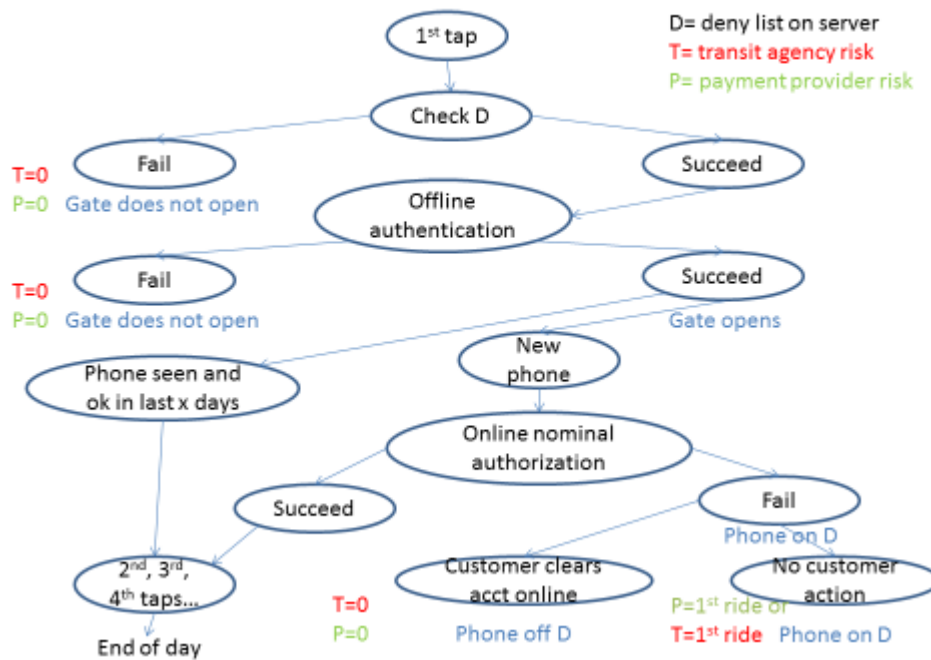


Figure 10: Open payment risk model, part 1

The user continues to use his or her phone during the day. At the end of the day, spending is computed, including daily or weekly maximums or other flexible fare policies such as discounts or promotions. If the total spending for the period (which can be a day or as long as two weeks if a rider is traveling infrequently) is below an agreed limit (often \$20), the agency receives payment automatically. The payment provider takes all the risk of non-payment. If the spending is above the limit, it must be authorized. An agency can submit an authorization before the end of the day if large

purchases are made. If authorization fails, it is resubmitted and is usually paid in the next few days; since the rider is likely to be using this card for other purchases, he or she will clear the problem with the bank. The phone is placed on the deny list until the problem is cleared.

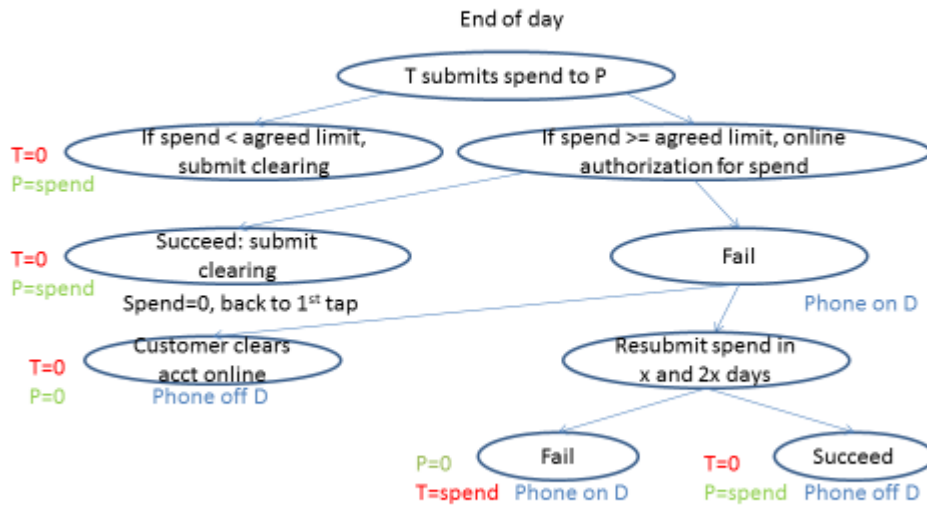


Figure 11: Open payment risk model, part 2

As mentioned in the main report, payment networks may offer systems that perform risk management and authorization in near real time for a transit agency. Similar logic is implemented, although the payment network has substantial additional information available to make the decision on whether to grant or deny access.

Unified Transportation Payment Media: Options for Massachusetts

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A Better City

33 Broad Street, Suite 300, Boston, MA 02109

Tel: 617-502-6240 Fax: 617-502-6236

www.abettercity.org

www.challengeforsustainability.org