POLICY BRIEF

Seamless and Integrated Transit

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Program Description

This project reviews and summarizes empirical evidence for a selection of transportation and land use policies, infrastructure investments, demand management programs, and pricing policies for reducing vehicle miles traveled (VMT) and greenhouse gas (GHG) emissions. The project explicitly considers social equity (fairness that accounts for differences in opportunity) and justice (equity of social systems) for the strategies and their outcomes. Each brief identifies the best available evidence in the peer-reviewed academic literature and has detailed discussions of study selection and methodological issues.

VMT and GHG emissions reduction is shown by effect size, defined as the amount of change in VMT (or other measures of travel behavior) per unit of the strategy, e.g., a unit increase in density. Effect sizes can be used to predict the outcome of a proposed policy or strategy. They can be in absolute terms (e.g., VMT reduced), but are more commonly in relative terms (e.g., percent VMT reduced). Relative effect sizes are often reported as the percent change in the outcome divided by the percent change in the strategy, also called an elasticity.

Summary

Seamless transit strategies allow for easier and more efficient transit trip planning and payment. These strategies improve the passenger experience and have the potential to increase transit ridership.

Strategy Description

Examples of seamless transit include standardized fare structures ("fare integration") and payment processes ("payment integration") as well as standardized and/or real time schedule and vehicle location information. These strategies can reduce passenger stress, improve efficiency, and may reduce fares (e.g. free transfers), make transit more user-friendly, and increase ridership.

Behavioral Effect Size

Behavioral effects are measured as increased ridership or individual transit use. Increases due to fare integration range from 2.19% in the short term up to as high as 12% in the longer term (Abrate et al, 2009). Sharaby and Shiftan (2012) found increases of 7.7% additional passenger trips and 45% of travelers switching to or increasing bus use for the current trip. About half of those (23% of the sample) would have used a different mode, while the remainder would have used bus in connection with walking and now report only bus.

Strategy Extent

Research on this topic evaluates ridership or individual transit use. No studies have been identified that assess impacts on traffic counts, VMT, mode share, or other auto-use measures.

Strategy Synergy

The effects of fare integration may be bolstered by fare media such as smart cards and mobile applications. Service extensions or improvements may extend the impact of integration and real-time information.

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Equity Effects

Seamless transit generally benefits transit-reliant, low income and racial minority groups. Use of some features though, such as real-time information, relies on phone-based data access. Fare payment system equity depends on access to bank or credit card accounts, payment locations outside of large/central rail stations, and access to digital financial tools (i.e., mobile wallets or applications). Equity for discounted monthly or multi-trip passes may be improved with practices such as fare-capping (Brakewood et al. 2023)

Strategy Description

Practices that reduce friction and improve ease-of-use and passenger experience are elements of seamless transit travel. Examples include standardized fare structures and payment processes as well as improved schedule and real time vehicle location information.

These practices can reduce passenger stress, improve efficiency, reduce fares in some cases (e.g., with free transfers), and make transit more user-friendly, thereby having the potential to increase transit use and reduce auto dependence. Elements of seamless travel include but are not limited to the following:

Integrated Fares can be among modes of transit such as bus and rail, or among transit agencies. One fare structure and any associated rules, zones, or transfer rates applies to the different modes and participating agencies.

Free Transfers allow travelers to switch from one vehicle, mode, service, or agency to another without an added fare. Typically, free transfers have set durations, e.g., 2 hours.

Integrated Payment allows a passenger to use one means of payment across different modes of service and/or agencies. This may or may not include fare integration or free transfers. One example is the Clipper Card in the Bay Area.

Contactless Payment or tap-to-pay uses near field or radio communication for payment transactions and does not require inserting or swiping a card. This can be used in combination with many other payment media; i.e., closed- or open-loop systems, bank cards, phones, etc.

Smart Cards or transit fare cards are closed-loop, reloadable payment cards that can be used for the services of one (Boston's MBTA, pre-open loop payments) or multiple agencies (Bay Area Clipper Card). Value may be added at kiosks, through online accounts, and/or at other points of sale (such as drug stores or convenience stores). Mobile wallets such as Apple Wallet and Google Wallet also support closed-loop transit cards.

Open-loop Payment for transit refers to payment made at the fare gate or at boarding (as opposed to at a payment kiosk) and does not require the use of special fare media. These systems accept payment from debit and credit cards, reloadable debit cards (and sometimes smart cards) and typically accept payment through phone- or device-based mobile wallets (Apple Pay, Google Pay, etc.)

Mobile Ticketing allows passengers to buy and display tickets and passes on their smartphone. Passengers can either display their ticket/pass when boarding a transit vehicle, validate their ticket with a contactless reader, or present it to a ticket agent.

GTFS or Global Transit Feed Specification is a standardized format to present data on transit stops, schedules, routes, and base fares. This format enables third party applications to present transit information in commonly used travel planning and mapping software or applications. GTFS is an open specification that is continuously being refined. There are several GTFS extensions that have been developed—or are in the process of being developed—to enable new capabilities. One such extension is

GTFS Realtime, which includes vehicle location information, arrival times, and service alerts. Another is **GTFS Fares v2**, which expands the fare related functionality of GTFS. (Cal-ITP n.d.)

Real Time Information includes vehicle location and arrival times as well as additional service alerts. Information may be provided on station platforms and through computer or phone-based applications by the transit agency and/or through third-party transit-specific, travel planning, or mapping software or applications.

A particular agency may employ one or more of these (or other) seamless transit strategies. Due to the availability of existing research, this brief centers on integrated fares and payment, including free transfers, and where possible, smart cards. In addition, real time information is covered here as there is relevant literature on this topic. Open-loop/ contactless payment is relatively new and there is limited work on the ridership impacts of open-loop payments, though where information is available it is included.

Strategy Effects

Behavioral Effect Size

Strategy effects are presented in terms of changes in ridership, at the station or agency level and individual transit use frequency, typically in terms of trips per week. No studies have been identified that assess impacts on traffic counts, VMT, mode share, or other auto-use measures. The key findings presented here are included in Table 1.

Beginning with fare integration, Sharaby and Shiftan (2012) examine the integration of fares and introduction of free transfers and find increases of 7.7% and 18.6% for linked passenger trips and boardings (unlinked passenger trips), respectively. Similarly, through on-board traveler surveys collected from 14,341 passenger trips, 45% of the respondents reported the trip would have been made by some other mode (or bus in combination with walking). About half of those (23% of the sample) would have used a different mode, while the remainder would have used bus in connection with walking and now report only bus.

Matas (2004) finds a 3.4% increase the annual number of trips[1] by bus and 5.3% increase for the subway system over a period within which a travel card was introduced. The authors estimate that a 7% increase can be attributed to the card for bus trips and 15% for subway trips; with other factors pushing annual trips down to arrive at the total changes over the study period.

Abrate et al. (2009) evaluate integrated tariff systems (which include coordinated rider information provision, schedules, and fares). The systems were associated with an increase in total passengers—approximately 2.2% per year in the short term and up to 12% in the long term—based on data from 69 Italian cities. These figures likely reflect ticket purchases, not individual riders (nor unlinked trips directly) and are defined as "transported passengers per year" (Abrate et al. 2009 p.122). Estimated ridership increases are greater, up to 25-34% increases in annual passengers for some specific features. For example, they found that urban locations with integration and the availability of single integrated tickets had increases in passengers of 7% in the short term and 26% in the long term. Single tickets were available in 15% of the locales in the study.

The impacts of real time information range from no effect to as much as 25% in terms of increasing the number of trips made by an individual. Some studies found little or no impact of providing real time information, including a panel study conducted before and after the implementation of real time

[1] In this study all trips are unlinked trips except for trips that are transfers between subway lines, presumably because travelers do not present a ticket when transferring between lines once they have passed through fare gates to board the first line.

information in a university shuttle bus system (Zhang et al. 2008) and a small sample experiment evaluating changes in self-reported transit use (Brakewood et al. 2016).

Though overall ridership may decrease during the timeframe within which real time information is introduced due to other factors, the impact of real-time information may be teased out. In one study, the number of boardings at specific stations on specific routes decreased by 3.9% overall. The decline is attributed to fare increases, but in the same model, a 1.7% increase is the estimated effect of real-time information provided on station platforms (Chow et al. 2014).

Ferris et al. (2010) found moderate effects; approximately 30% of respondents would increase non-commute trips and 10% would increase commute trips. In a follow up study, this number remained quite stable for non-commute trips with about 30-35% reporting they would increase, but just about doubled for commute trips, with about 25-30% reporting they would increase commute trips.[2]

Tang and Thakuriah (2011) find that 76% of participants reported they would increase transit use with real-time information.

Extent

Scale of Application: Most seamless transit features are deployed agency- or city-wide and may also be implemented regionally. Some features, such as real-time information, may be provided only on specific routes or modes. In this case it is likely to be scaled up over time to cover all routes and/or eventual system-wide implementation.

For any of the seamless transit strategies, unless a new system completely replaces an old one, such as smart cards replacing magnetic stripe tickets, there is no guarantee that they are used by travelers, as pointed out in many studies on real-time information (e.g., Brakewood et al. 2015, Tang and Thakuriah 2012). Thus, the impact of the strategy is limited to those who are using it and may not be experienced by all transit passengers. Agencies may improve uptake through marketing and outreach.

Efficiency or Cost: Some evidence shows that the reductions in fares that result from integration are made up for in terms of the increased ridership. In other cases, the integration may increase fares such that ridership decreases (Chow et al. 2014). Iseki and co-authors (2008) interviewed transit agencies who attributed ridership increases in part to smartcards and noted that reduced costs from handling cash was part of the benefit. This is also a benefit thought to occur with open-loop payment implementation. There may also be safety benefits to vehicle operators; when there is little or no cash on board transit vehicles the risk of (potentially violent) theft is reduced.

Time / Speed of Change: Dydkowski and Urbanek (2023) point out that change likely takes a few months in the case of integrated fares, but can be long lasting once it begins. As noted above, the rollout of seamless travel features may occur system wide all at once, or in a piecemeal way as each route or mode is brought into the new system. The rollout process also intersects with the adoption by travelers and depends on whether implementation is a wholesale replacement of a previous method (e.g., free transfers), or a new option made available in addition to existing systems (e.g., real-time information).

Location within the Region: Much of the research on seamless transit features deals with a region, an agency or a service area, or in some cases a particular city. There are noted differences when it comes to the extent of the

[2] These two resources include only a bar chart representing these values, so the estimates are based on the author's interpretation of the charts. One of the paper's authors was contacted but was not able to provide more detailed information.

area covered by fare integration or the area within which a single smart card may be used.

Real time information may be less relevant to commuters using rail than it is for bus travelers or others (Brakewood et al. 2015). This is likely because rail tends to be more reliable and also because commute travel is more consistent/less variable.

Differences between Regions: The potential for any smart application to be incorporated into transit operations depends on GPS enabled vehicles or at least Wi-Fi or other communication potential on vehicles – which is easier in urban areas and harder in rural areas. For example, Trinity County, California, in partnership with Cal-ITP, recently ran a pilot to assess the use of satellite internet for real time vehicle location information and found that Starlink Satellites can provide the necessary connectivity, though there are some challenges such as staff capacity (Cal-ITP 2024).

Equity

Equity has been covered fairly extensively as it relates to seamless transit. Seamless transit can make transit service more convenient, but the availability of some seamless travel features themselves, and/or the resulting benefits may vary across the population or different types of transit users.

A potential solution to some of these challenges is to make transit fare-free, though this policy brings challenges as well. Fare-free transit is covered in another brief in this series and is not the focus here. Similarly, mobility wallets that provide subsidies for qualifying transportation services and the payment media to use the funds can alleviate some of these challenges. This is also not the focus of this brief. Lastly, the availability of various payment tools is evolving and things like prepaid debit cards (i.e., reloadable debit cards issued by banks, credit companies, or peer-to-peer suppliers) may improve equity in terms of ease of payment in some (i.e., open-loop payment) systems (Brakewood and Kocur 2013).

A comprehensive literature review on the equity implications of seamless transit strategies was outside the scope of this project, but the key equity considerations are highlighted below.

Integrated Fares - One study evaluates the effects of different fare scenarios and finds integrated fares are likely to benefit all travelers, though other fare structures may result in higher per passenger benefits (or subsidies) for higher income groups. Matas and coauthors (2020) estimate the distribution of subsidies under different scenarios and by income and trip. This accounts for the phenomena that lower income travelers tend to use transit more. When flat fares are introduced, there is a "mild" regressive impact compared to the base case with fare zones. In contrast, the results of this study suggest that distance-based fares are expected to have a positive impact on the lowest income groups. Removing fare integration between modes has a regressive effect, i.e., integrated fares across modes provides higher per passenger benefits for all groups (Matas et al. 2020).

Free Transfers may result in varied per passenger monetary savings. Time savings efficiency may also result, since free transfers can offer travel and wait time reductions if the free transfer allows rail use for longer portions of a trip. Sharaby and Shiftan (2012) find that the greater the savings experienced by travelers in the free transfer context, the more likely they are to shift towards greater transit use and away from bus and walk (i.e., now they transfer), not making the trip at all (now they use the bus and make the trip). Travelers also make shifts away from driving, taxi, and walking, though to a smaller degree.

Integrated Payment can benefit all travelers but if passengers must obtain agency- or region-specific fare media and there are only limited locations and/or times to do this, it can place an added burden on those (typically more transit-reliant, more centrally located, and lower income) travelers who do not travel long distances and who are more reliant on bus service than rail service – and thus not frequently visiting stations.

Smart Cards have the same potential challenges as integrated payment.

Open-loop Payment poses equity challenges for those who are un- and underbanked or lack access to digital financial tools such as a smart phone and mobile wallets. Equity may be improved when cash is offered alongside open-loop payments and when financial tools are made available to those who are un- and underbanked. In addition, automated discounted eligibility verification may be transferred across agencies who have implemented open-loop payments, benefiting those who receive discounted fares. When open-loop payments implement fare capping (for example, once $20 is spent in one week, all additional rides are free) individuals of all backgrounds can take advantage of discounts for frequent transit use. This is in contrast to discounted transit passes that require a larger up-front investment that may be too high for lower-income travelers.

GTFS has similar equity concerns as the other or technology based seamless travel features. That is, those without smartphones or data plans may not have access to the tools that use these standardized transit data formats.

Real Time Information and **GTFS Realtime** are potentially inequitable when those with lower income or other disadvantages do not have access to the technological tools to use them. For real time information this means that those without smartphones or data plans may not be able to benefit from the resource. In one study the researchers could not evaluate the impact of the real time information among 27 participants (10% of the study sample) because they did not have a smartphone (Brakewood et al. 2014). The 2023 FDIC National Survey of Unbanked and Underbanked Households found that while 87.8% of all households have a smartphone, only 72.1% of unbanked households have a smartphone (FDIC 2024). They also report that 82.9% of non-metropolitan area households have a smartphone.

Matas et al. (2020) find that the distributional effects of subsidies are greater for lower income travelers, who make up a larger portion of transit users in general, and that this does not change substantially (nor significantly) with the type of fare structure.

In addition to the inequities faced by passengers among the seamless transit strategies, there are also inequities stemming from the vast differences among the transit agencies themselves. Large, well-funded, well-staffed transit agencies are able to nimbly make changes or experiment with pilot programs to identify the best ways to meet the needs of their passengers. Smaller transit agencies often lack the funding and the capacity to implement changes, even those that will benefit passengers.

Synergy

An overarching area of synergy occurs among all of the seamless travel features, when they reduce traveler stress and/or improve comfort, convenience, and perceptions of transit service. While this is measured in a few studies (e.g., Tang and Thakuriah 2012), it is noted as a mechanism through which seamless travel impacts ridership in a number of articles on these topics. Many seamless travel features are also likely to improve transit efficiencies, for example, by speeding up boarding, reducing idling times, and simplification of some backend systems.

Lastly, Iseki et al. (2008) conducted a meta-cost-benefit analysis and found that the introduction of smart cards improved efficiency, reduced transit agency costs and allowed data collection. This study was not centered on ridership effects, but rather covered the benefits of smart cards.

Table 1. Seamless Travel Impacts on Ridership and Passenger Behavior

Study	Study Location or Agency	Study Year	Data and Sample	Seamless Transit Feature	Outcome Variable(s)	Estimated Impact
Sharaby and Shiftan (2012)	Haifa, Israel	2008 to 2009	14,341 on-board surveys; farebox data	Integrated fares and free transfers	Passenger trips (linked trips), boardings (unlinked trips)	7.7% increase, 18.6% increase
Matas (2004)	Madrid, Spain	1991 to 2002	Ridership, service info, demographic and economic data	Travel card, integrated fares and zones	Short term change in unlinked trips (except subway to subway transfers)	1. 3.4% increase on bus, 5.3% on subway
					Long term increase attributed to card when other factors are controlled for	7.1% for bus, 15% for underground
Abrate et al. (2009)	Varies across 69 agencies in Italy	1991 to 2002	Ridership, service info, demographic and economic data	Integrated fares (additional integration and ticket features are accounted for in the models)	Ridership in short term and longer term	2.19% in short run and 12.04% in long run
Chow et al. (2014)	MBTA - Boston	Not known for the fare card data	Passenger boardings at specific station and route	Real time information – displayed on platform	Change in boardings attributed to real time information on platform	1.7% estimated increase (due to real time information
Tang and Thakuriah (2011)	Chicago Transit Authority	2008	In-person workshops with 92 participants	Real time information	Stated preference – increase transit use	76% would increase use; 0.89 1-way commute trips per week (approximate 17.1% increase based on current average 1-way commute trips of 5.16)

Table 1 (continued). Seamless Travel Impacts on Ridership and Passenger Behavior

Study	Study Location or Agency	Study Year	Data and Sample	Seamless Transit Feature	Outcome Variable(s)	Estimated Impact
Brake-wood et al. (2015)	MBTA – Boston (commut-er rail)	2012	On-board surveys 903 participants	Real time information	Perceptions of wait times and services	Improved
Yoh et al. (2003)	Multiple		12 agency interviews	Transit pass programs, and fare integration	Increased ridership	NYC – *Metrocard attributed with ridership increase* 50% reported updated fare structures increased ridership 17% reported flash passes increased ridership

This table includes the key findings from the most relevant studies; additional notes are included in the text above.

Confidence

Evidence Quality

Among the studies included here there are a few issues that stand out. First, the reliability of ridership data varies depending on the means used to collect the data.

Two studies (Sharaby and Shiftan 2012, and possibly Brakewood et al. 2015) may have re-sampled individuals in the intercept survey implementation. If this occurred among travelers using transit more, or using the tools more, this could bias results.

The Tang et al. (2012) paper evaluates rail ridership resulting from real time information on the bus system – examining the interconnection between these two modes; but the resulting ridership changes are therefore not a direct result of real time bus information on bus ridership.

Caveats

For any of the transit ridership changes, there is not typically a static environment within which a single change occurs. Therefore it is difficult to attribute any change to a single action. For the purposes of seamless transit travel, many of the actions noted here may be taken at once – specifically fare integration and the introduction of a new payment system or card (Dydkowski and Urbanek 2023).

Also, if fare integration involves a fare increase, the overall change in ridership might be negative even if the integration does add riders/rides.

Many of the technologies that improve the transit experience are improving over time. This means that the ridership gains from the initial rollout might change with the next generation of fare payment and real time tools (Tang et. al 2012). However, the extent of the added ridership from new versions of these technologies also depends largely on the actual transit service itself.

Brakewood et al. (2014) point out that although some of these studies do show changes in ridership, in small or mid-sized areas, or areas that do not have large populations of higher-income commuters, the impacts may differ.

Technical & Background Information

Study Selection

Research on this topic evaluates ridership or individual transit use. No studies have been identified that assess impacts on traffic counts, VMT, mode share, or other auto-use measures.

The literature covering seamless transit travel features does not typically address ridership impacts directly. Instead, scholars target a particular feature or innovation in transit and evaluate some aspect of interest to them – whether it is perceptions, equity, challenges for agencies, or what it might mean for researchers (e.g., how can smart card data be used). Another, related body of work considers impacts to ridership and may or may not center on the impacts of a particular innovation and may or may not include a particular innovation as a control or explanatory variable in the analysis. This also means that the direct link of interest is not necessarily a topical thread in the transit literature and there are a limited number of articles covering seamless transit impacts on ridership. The studies selected for inclusion in this brief sit at the intersection of these two topics: seamless transit travel features and ridership changes. Of the seamless transit travel features noted in the brief, a few have been studied in the context of ridership change to a greater extent. First, studies concerning ridership impacts from integrated fares, including free transfers and smart card programs, are included here. And those studies looking at real time information are included. The remaining topics, related to smart cards, open-loop payment, and mobile ticketing have centered on other outcomes though a few cases relevant to this brief are included.

Because there are limited studies that evaluate ridership impacts of the various seamless travel features, this brief also draws on survey-based studies wherein study participants report on their behavior change or expected behavior change themselves. Based on the existing studies, it is not possible to translate these numbers into percent ridership increase, though an enterprising individual might use ridership information from these locations in a back-of-the-envelope calculation to deduce expected ridership impacts based on survey results.

In addition, since there are not many studies that evaluate ridership or transit use outcomes related to seamless travel features, international studies were included in this brief. Though the contexts are not identical, there may be lessons learned and useful outcomes for US transit operators.

Methodological Considerations

Considering studies that look at ridership outcomes, it is notable that ridership data can be collected in a number of ways: automatic passenger counters, smart card data, on-board passenger counts, or other means. Therefore, there is some inconsistency across studies and the ridership data they employ. Similarly, when comparing pre- and post-seamless transit travel feature ridership the means of gathering ridership information may change and influence results.

Ridership counts also may not differentiate between unlinked trips and trips that include transfers. Those that do not differentiate do not provide a count of how many people are using the system, rather they provide an estimate of the number of trips taken and the number of travelers on each segment of each route. There are some analytic methods to distinguish between the number of travelers using the system and the number of riders on each segment of a route. Specifically, smart card data can be used to track the trips of each user (based on an ID number) and identify where/whether transfers were made. Similarly, ridership increases mean more trips were paid for, more boardings occurred, or more passengers were counted on board. Without the use of smart card data or other tools that identify individuals, it is difficult to determine the extent to which ridership increases represent greater numbers of trips taken by existing travelers or trips taken by new riders. At the same time, smart cards may not capture complete ridership data if not all travelers use them. Each agency may have their own ways of accounting for this.

Studies that evaluate passenger-level behavior changes in terms of trip frequency (typically trips per week) differ in terms of the ways the questions were asked. Some (e.g., Brakewood et al. 2014 and Tang and Thakuriah 2012) ask in terms of how many more commute trips might have been made, while others asked about a particular trip and what mode would have been used instead, for example before the introduction of fare integration (as in Sharaby and Shiftan, 2014).

Because real time information may be provided by apps other than those managed by the transit agencies themselves and/or available to researchers, the estimates of real time information use by passengers and availability to passengers may or may not be fully known in any of the studies. In a potentially extreme example, Brakewood et al. (2015) point out that MBTA endorsed many apps (44 or more) that provided their real time data publicly. Further, real time information use can be measured in terms of whether it is used at all, or how often it is used. The latter may be directly correlated with the extent of transit use in the first place; a person is much more likely to use real time information when they are going to use transit (Zhang et al. 2008). This consideration may be important for a number of seamless transit travel features; they may be measured *only* when they are used, making it difficult to assess the impact of use.

Other methodological considerations include the limitations on the ability to attribute changes to each particular seamless transit feature when multiple features are introduced simultaneously, or when other aspects of the transit service—such as frequency, schedules, or fares—are also changed.

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