Implementation of Multimodal Electronic Payment Systems: Lessons from Los Angeles and Minneapolis-St. Paul

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ABSTRACT

Adoption of technology in the public sector typically involves a balance of willingness to take on risk and the development of a forward-thinking agenda (Mulgan & Albury, 2003). Technology adoption in the public transportation sector follows this process and as a result, adoption can occur long after the technology is available. As in other sectors, technology has and continues to transform transportation in the US and around the world. Shared mobility services like bikeshare, carshare, and ride-sourcing services are now part of many cities' mobility ecosystem, adding to the traditional modes of public transit, cabs, and private cars. Accessing these different modal options, however, require different payment media and separate mobile apps for each system to plan and pay for travel, thus creating a fragmented user experience. Technological change in existing payment systems, specifically, unified or integrated payment systems, could improve the user experience and reduce the barriers to adoption of more modes of transport–including those that might be more sustainable. While integrated payment, or multimodal payment convergence, appears to be a hot topic among policymakers and practitioners, implementation in US cities has been limited. In my research, I seek to understand the potential barriers to and drivers of multimodal payment technology, studying the adoption of these systems in two regions, Los Angeles and Minneapolis-St. Paul. The research uses literature in the adoption of technology in transportation to contextualize the case studies in Los Angeles and Minneapolis-St. Paul. Through the exploration of these two cases, the research provides evidence that while payment technology has matured to enable multimodal payment systems, institutional factors such as limited coordination between public and private operators and organizational resource constraints remain barriers to implementation. However, incremental collaboration, vocal advocates, and federal funding support for multimodal payment systems might be used as strategies to overcome these barriers.

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CHAPTER I: Introduction

Technology is transforming transportation in the US and around the world, expanding the options and modes available to help people get around. Shared mobility services like bikeshare, carshare, and ride-sourcing are now part of many cities' mobility ecosystem, adding to the traditional transport modes of public transit and taxicabs. Between 2008 and 2016, more than 60 US cities have launched bikeshare programs, while carsharing membership grew from 100,000 members in 2006 to 1.6 million in 2014 (DeMaio & Meddin, 2016; Shaheen & Cohen, 2015). In six years, Uber has expanded to more than 500 cities in more than 70 countries (Goodall, Fishman, Bornstein, & Bonthron, 2017). Accessing these different modal options require different payment media and use of separate apps for each system to plan and pay for travel every day (Tavilla, 2015). As a result, trip-planning apps have emerged to unite these disjointed sources of information and help users identify and compare different multimodal options for reaching their destination but an integrated payment system remains elusive in US cities.

A user may have a transit card to access the bus or train, a key fob to access the bikeshare program, mobile apps for ride-sourcing services, and a separate app to purchase commuter rail tickets—each with a separate account management platform. Visitors and new residents have to learn the new transport ecosystem and obtain the appropriate payment media (e.g., paper ticket, smart card, key fob, mobile app, etc.) and accounts to get around the city. Thus the increase in transportation options has also increased the time and effort required to understand and maintain the range of media, payment system and cost structure. The advent of smart cards for use on transit systems has streamlined some of this experience by standardizing ticketing for intra-agency and interagency travel but for the modern multimodal traveler using both traditional and nontraditional transport modes, unified payment media is a logical next step. However, US cities continue to lag behind their European and Asian counterparts in implementation of a multimodal transport payment system, or multimodal payments convergence, though some efforts are underway.

Hypothesis and Research Questions

I hypothesize that while the technology exists to support multimodal payment convergence, a combination of organizational and technical barriers has resulted in few cases of adoption in the US. Specifically, my thesis seeks to answer the following research questions:

- What are the technical and institutional barriers to multimodal payment convergence in the US, using the cases of Los Angeles and Minneapolis-St. Paul to better understand these issues?
- How have stakeholders in Los Angeles and Minneapolis-St. Paul overcome these barriers?

This thesis will explore the challenges to implementing a multimodal, multiagency payment system and the factors that enabled Los Angeles and Minneapolis-St. Paul to overcome the institutional and technological challenges. It describes a qualitative assessment of policy documents and interviews with senior officials at the various organizations involved. The goal of this research is to provide some best practices for local and state-level policymakers involved in multimodal mobility planning and decision-making.

Motivation

Sustainable mobility

In the United States, transportation is the second largest source of greenhouse gas emissions, comprising 27% of total emissions in 2015 (US EPA, 2015). One strategy to reduce emissions from the transport sector is to encourage modal shifts to lower-emission transportation choices. Today, the primary mode of passenger transport in the US remains the private car. In 2014, 83% of total passenger miles, excluding air travel and ferry service, was served by the passenger car (U.S. Department of Transportation, 2015). Nationwide, 86% of workers get to work by car (US Census Bureau, 2015). Within cities, public transit's mode share is relatively larger but the private car remains the dominant mode (*Ibid.*). In addition to environmental concerns, single occupancy vehicles are inefficient in dense urban areas, and congestion has significant economic impacts such as increased travel costs, business operating costs, and loss in productivity (Weisbrod, Vary, & Treyz, 2003). As such, most major cities in the US include "travel demand management" strategies and policies in its development plans to improve and promote sustainable transport options. For example, in New York City's One New York Plan, Mayor Bill de Blasio calls for a rail transit capacity increase of 20% by 2040 and a doubling of the number of cyclists by 2020 (City of New York, 2015). Boston's Climate Action Plan calls for an increase in bike commute mode share from 2% to 10% by 2020 and a reduction in vehicle miles traveled by 7.5% under 2010 levels by 2020 (City of Boston, 2014). Salt Lake City's, Sustainable Salt Lake Plan, aims to increase, improve, and promote transit service and pedestrian and bicycle facilities within the city (Salt Lake City, 2015).

The burden of transfers

One of the primary barriers to shifting individuals from single occupancy vehicles to public transit is the access and egress connections required in public transit. Public transport unlike private vehicles, does not offer the flexibility of convenient, on-demand, door-to-door travel. Individuals traveling by transit must typically make a multimodal connection at both ends of the trip, which may require additional payments, wait time and transfer time. The more burdensome the transfers are, the less likely an individual will make that trip. One solution to reducing the transfer burden is to standardize payment media and fares so that individuals can move more seamlessly across modes.

However, standardizing payment systems is only part of an overall strategy to create a seamless transport network, encourage modal shifts to more sustainable forms of transportation, and increase mobility options. While the two case studies selected here do focus on the integration of payment media via a smart card, the lessons of overcoming organizational and technical barriers are applicable to broader efforts of multimodal transport integration and planning.

Electronic Payment Systems

In this thesis, payment media refers to the forms of technology used to gain access to a transport system such as smart cards, bankcards, mobile apps, and other RFID (radio-frequency identification) technology like key fobs and wearable devices. As an example, while many transit systems accept cash and bankcards at ticket vending machines, customers must ultimately use the system's accepted payment media like an agency-issued smart card to pass through the fare gates. Thus in this example, cash and bankcards are not considered payment media.

Implementation in public transit

In the US, 7.3 million people commute to work every day by public transportation (US Census Bureau, 2015). About 40 transit agencies have electronic fare payment systems; nearly all use agency-branded smart cards as the primary fare medium (Okunieff, 2017). Some transit agencies have recently launched mobile ticketing apps citing greater flexibility for its customers, reduced fare collection costs, and increased efficiency (Tavilla, 2015). Fewer agencies have deployed—though more are in the planning stages of—open payment systems which would allow users to choose from compatible payment options, including contactless bankcards and near field communications (NFC) contactless mobile payments (Okunieff, 2017).

Benefits

The transition away from cash-centric payment systems to electronic payment systems has resulted in numerous benefits for both users and operators.

For users, benefits include:

- Convenience
- Ease of transfers
- Faster boarding
- No need for cash or exact change
- Durability and balance protection

For transit operators, benefits include:

- Fare flexibility
- Improved fraud prevention
- Reduced operational costs
- Greater reliability compared to magnetic strip cards
- Decreased vehicle dwell times and thus, improved service reliability

Implementation in other transportation services

Other transportation services, including parking, tolling, and shared mobility services (e.g., carshare, ridesourcing, and bikeshare) also rely on a variety of electronic payment technologies, such as smart cards, RFID-enabled tags, and mobile payments. The widespread adoption of electronic payment systems and the rapidly growing number of modal options make integration of payment systems for any type of transportation, or multimodal payments convergence, a logical next step.

Multimodal payments convergence

Multimodal payments convergence can take many forms but the goal is the same: to make it more convenient to pay for and use any type of transportation service. The most basic is the use of a common payment media or technology such as a contactless smart card or bankcard, a mobile phone, or a wearable device. Payments convergence can also entail linked or integrated mobile apps, providing a centralized platform uniting information from multiple transport modes, or common or linked payment accounts, enabling users to pay for multiple transport services with a universal travel or mobility account. Multimodal payment convergence can also support policies or marketing efforts to encourage the use of shared mobility services and transit. Incentives may entail discounts on use of shared mobility services to reach transit, for example.

Research Methods

This thesis uses a mixture of methods to address the research questions, including a review of the literature in the fields of technology adoption, transportation payment systems, and a review of public planning documents. This research was supplemented by interviews with key players involved with transport payment policy and implementation.

The interviews were conducted in March 2017 using a snowball method. I first contacted transit agency staff whose primary role involves fare payment systems planning and administration. Those contacts recommended others who were involved in payment integration efforts or could provide insight on payment systems. Through this method, I was put in touch with individuals in the private and nonprofit sectors. The interviews were all conducted by phone and ranged from thirty minutes to an hour. The objectives of the interviews were to develop a better understanding of the processes to implement an integrated payment system and steps taken to overcome challenges associates with implementation. Most of the questions remained consistent across interviews but some of the questions were tailored towards the interviewee (see Appendix I for a list of sample interview questions).

After the conclusion of all interviews, I arrived at an understanding of key challenges of multimodal payment convergence and the experiences of two metropolitan areas in overcoming these challenges. This thesis is a synthesis of those findings.

Introduction to Case Studies

The reason Los Angeles and Minneapolis-St. Paul were selected as case studies is that these are some of the only examples in the US where common payment media is available for transit service and a nontraditional shared mobility provider.[1] The other cases of multiagency, multimodal payment systems involve traditional transit providers (bus, rail, or paratransit, ferry). Nontraditional mobility services include parking, electronic road or bridge tolling, and shared mobility services like bikeshare, carshare, and rideshare.

While there are key differences between Los Angeles and Minneapolis-St. Paul in terms of size, population, and transit governance structure, they and most US cities share the same objective of reducing single-occupancy vehicle trips. In addition, in both cases, the fare payment media is a transit smart card. Thus, these two cases can shed light on different approaches to the challenge of integrated payment systems. These case studies were developed from a review of public planning documents and interviews with key players involved with multi-modal transport policy and implementation. Chapters III and IV describe transportation trends in both cities and the process that resulted in integrated payment media.

Thesis Overview

Chapter II is a review of current literature on electronic payment systems in transportation and of current practices, trends, benefits, and challenges to implementation of multimodal payments convergence. Chapters III and IV provide an in-depth case study of Los Angeles and Minneapolis-St. Paul and describes the payment integration achieved. Chapter V analyzes common themes and barriers to implementation synthesized from my interviews and research. In Chapter VI, I present my resulting recommendations to transportation planners and policymakers,

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[1] There are a few examples of transit smartcards in use for parking payment at some parking lots and garages owned by the transit agency. The Clipper card and the SmarTrip card are two such examples.

as well as a discussion of future research in the field of implementation of multimodal payment convergence.

CHAPTER II: Literature Review

There is growing interest among planners to consolidate payment media and accounts for multiple modes of transportation and increase the convenience of multimodal travel. However, implementation of multimodal payment systems remains restricted to traditional transport modes. For example, a single contactless smart card to pay for transit across several agencies in the region. Thus research on implementation is also fairly nascent. This literature review will give a broad overview of electronic payment systems, the supporting technology, and evidence of its benefits. It will also frame this research within the literature on the adoption of innovation by transit agencies in order to better contextualize the barriers of and drivers to adoption of multimodal payment systems, a new technology for most cities.

Challenges of Multimodal Travel

A chief concern of public transport planning is intermodal connectivity. Public transport does not offer the flexibility of private automobiles in enabling, convenient, on-demand, door-to-door travel. Individuals traveling by transit must typically make a multimodal connection at both ends of the trip, which may require additional wait time and transfer time. From the operator perspective, mode integration can optimize resources and reduce duplication of services. From the user perspective, increased transport mode integration is desirable to reduce travel time and travel costs, which would also increase the range of destinations possible (Luk & Olszewski, 2003; Ülengin, Önsel, İlker Topçu, Aktaş, & Kabak, 2007). That users are negatively disposed to transfers is well-documented and transfers are a key consideration in the ridership potential of a public transport system (Guo & Wilson, 2004, 2007). In addition to the time and effort required to make transfers, the complexity of using several transport modes with different payment systems, subscriptions, schedules, and mobile applications, can be discouraging to users, particularly, new or infrequent users. For public transport to be a viable alternative to the private car, reducing the burden of transfers is critical. The next section discusses the main types of integration and examples of each.

Types of integration

- *Network integration* involves optimizing the transport network to support an adequate coverage area while minimizing duplication of services. One example is aligning routes with frequent transfer closer together to a common stop. *Physical integration* of stations is an extension of network integration and involves creating comfortable and safe station facilities for transfers between routes and modes.
- *Schedule integration* involves coordinating schedules across routes or modes to minimize wait times during a trip. It can also involve schedule adjustments to ensure routes serving a particular terminal have the same span of service so passengers are able to complete a transfer and are not stranded at a terminal.
- *Information integration* minimizes the number of sources a passenger must consult for trip planning purposes. It aims to provide accessible and easy to understand information before and during the trip irrespective of the routes, modes, and service operators. This aspect is particularly important for new or infrequent travelers to encourage mode shift and reduce anxiety about travel. Information should be easily available at the station and elsewhere as well as on-board during a trip. The rise in smartphone ownership and open data from transit providers have resulted in numerous third-party trip-planning mobile apps.
- *Fare technology and policy integration*, which has become known as *multimodal payment convergence*, refers to standardizing physical ticketing infrastructure and fare media required for travel as well as the policies governing fares, fare types, discounts, etc. Minimizing the tickets or cards a user must carry—and the accounts a user must manage—reduces the inconvenience of a trip involving multiple services. Likewise, coordinated fare policy reduces the cost of a trip and the perceived burden of a transfer.

While all of four of these approaches to integration are critical to create a seamless transport network and encourage users to use public transport (Chowdhury & Ceder, 2016), this thesis will focus on the fourth approach: multimodal payment convergence. This is important because payment systems are the first contact point for customers as they enter a public transit or other transport system and integrated payment systems can facilitate use of dynamic pricing and other price cues to shift travel behavior.

Evidence for the Need of Multimodal Payment Systems

As multipurpose, multimodal payment systems are still relatively new, particularly in the US, studies on multimodal payment systems are also more limited. However, the research on transit smart cards is more developed thus this section will focus on the literature on smart card implementation. Benefits and challenges associated with adoption of smart cards will likely extend to the adoption of multimodal payment systems.

Benefits of transit smart cards

Benefits for users

The advent of smart cards has facilitated fare integration within a single transit agency (intra-operator) and across multiple agencies (inter-operator) by standardizing fare technology and policy and the benefits of such efforts are well-documented. One study found that integration of fare systems across operators had a positive effect on the perceived ease of making transfers (Buehler, 2011). Another study found that free transfers increased the likelihood passengers used routes that required transfers (Sharaby & Shiftan, 2012).

Benefits for operators

Benefits that accrue to transit operators typically result in benefits for transit users as well. Decreased operational costs and reduction in fraud and fare loss can reduce the pressure to raise fares. The transaction time savings compared to previous payment systems are also substantial: the average processing time for contactless smart cards is less than 300 milliseconds (Smart Card Alliance, 2006). Tokyo's Suica smart card boasted a passenger throughput of 60 passengers per turnstile per minute at subway stations while Montreal's OPUS card achieved a passenger throughput of 45 passengers per minute on buses (Quibria, 2008). Reduced boarding times translate to reduced dwell times for vehicles, particularly buses, and thus enhance the ability for vehicles to maintain their schedule and improve service reliability.

Ridership impacts

Evidence also suggests integrated fare systems are associated with increases in ridership though it is difficult to attribute ridership changes specifically to fare integration. In Madrid, researchers attribute the reversal of declining transit ridership to the integrated fare system for the whole region but acknowledged that economic recovery also played a role (Matas, 2004). After the Metropolitan Transportation Authority introduced a new fare system in New York City, which included the introduction of the MetroCard, free intermodal transfers, discounts on bulk purchase of stored value, and weekly and monthly unlimited passes, weekday ridership increased on subway and bus by 12% and 40% respectively (Hirsch, Jordan, Hickey, & Cravo, 2000). In Maryland, ridership went from a 1% per annum decrease to a 4% growth following the replacement of a five-zone fare system with a flat fare (Taylor & Carter, 1998).

Other benefits

Moreover, smart card systems produce a wealth of data critical for transit planners to understand the day-to-day operation of the system and long-term planning of the network, reducing the need for labor-intensive manual data collection (Pelletier, Trépanier, & Morency, 2011). Such systems also expand the potential base of users, provide an opportunity to offer customer-loyalty and reward incentives, increasing attractiveness of public transport overall (Blythe, 2004).

Emerging trends

The rapid rise in new technologies and services, many of which require proprietary smart cards, means that a typical wallet holds a number of cards (debit, credit, transit, carshare, loyalty programs, identification, etc.). While mobile wallet applications on smartphones have reduced the need for some physical cards, they have also added to the increasing amount of security information that must be stored and recalled by the consumer to access their accounts. To simplify this cognitive load and recall of information, consumers typically rely on one password for multiple accounts, thus compromising overall security. Some researchers suggest a high-security, multi-application smart card as one solution (Mayes & Markantonakis, 2003). Clearly, a more integrated payment solution is needed. An integrated payment system would leverage the benefits observed in smart card-based systems and also enable users to better plan, track, and budget their travel funds. It will also enable planners and transport providers to shape travel behavior through the use of pricing cues and incentives (Dinning & Weisenberger, 2017).

Challenges

The most comprehensive research in the field of integrated multimodal payments systems are the studies published by the Transit Cooperative Research Program (TCRP). One TCRP report on integration trends in transit finds that the goal of integrated payment media is both high in complexity, and high in financial costs (Goldman et al., 2014). Another TCRP report identified media and equipment interoperability as the major challenge to integration (Okunieff, 2017). The next section describes the technology common in existing electronic payment systems.

Current Electronic Payment Systems

Smart cards

A smart card is any pocket-sized card with an embedded integrated circuit and communicates with radio frequency identification (RFID)-based readers. Smart cards come in two types: contact and contactless. While contact cards must make physical contact with the reader, transmitting data from the card to the reader and writing information back to the chip, contactless cards, as the name implies, communicates with the RFID-based reader and derives its power from the electromagnetic field generated by the reader. Contactless cards are relatively newer but since the 1990s have been widely implemented for retail purchases, vehicle tolling, and transit fare payments around the world. In the US, transit agencies in Boston, Washington D.C., Atlanta, Chicago, Los Angeles, and several others now rely on contactless smart cards as part of their fare collection systems. In this thesis, the term 'smart card' will be used to refer specifically to the contactless smart card.

Use in transit

The first contactless smart card for transit ticketing in the United States is Washington Metropolitan Area Transit's (WMATA) SmarTrip card, introduced in 1999. Since then, nearly 40 smart card systems have been deployed in North America. Nearly half of these systems involve multiple transit operators in a region and a majority support multiple traditional transit modes. A few agencies use the transit smart card for parking at transit stations including the SmarTrip card and San

Francisco Bay Area's Clipper Card. Partnerships linking payment media or technology between traditional transit operators like rail and bus operators and non-traditional transport providers like shared mobility service providers remain rare. The challenge seems to lie in the proprietary nature of the smart cards and the reader equipment, increasing the cost of modification or expansion (Okunieff, 2017).

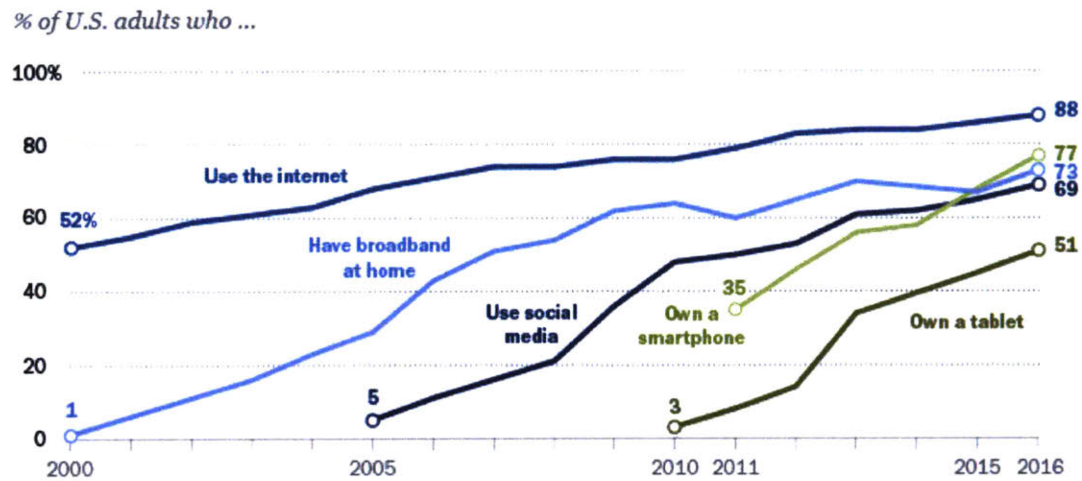

Figure 1: Technology adoption and usage by US adults from 2000 - 2016. (Pew Research Center, 2017)

Mobile ticketing

Smartphone ownership has drastically increased in the US over the last decade (Figure 1). Not surprisingly, the development of software applications, or "apps", for use on smartphones and other portable devices has also exploded, including apps developed for commuters. Ticketing apps enable commuters to use their smartphones to pay transit fares and avoid waiting in line or carrying cash or a fare card. The first mobile ticketing app in the US launched in 2012 but since then, more than 21 transit agencies have launched their own apps and dozens more have implemented pilot programs (Okunieff, 2017). Most of these programs rely on visual or QR (a Quick Response) code validation as they require minimal hardware changes and are relatively easy to deploy (Tavilla, 2015). Two regions in the US use near field communications (NFC) contactless mobile payments, the Utah Transit Authority (UTA) and the Chicago Transit Authority (CTA) and Pace in Chicago.

Contactless bankcards

Contactless bankcards, or open payment bankcards, are a new form of media emerging for transit ticketing. These bank-issued cards contain encrypted identification numbers validated at the point-of-sale terminal through the banking network similar to a standard magnetic stripe bankcard. Since 2005, MasterCard, Discover, Visa, and American Express have issued contactless cards (Smart Card Alliance, 2011). Transit agencies that accept contactless bank cards for ticketing typically accept any compatible payment media (hence the name "open payment system" to describe such systems) including media issued by a transit agency (e.g., proprietary smart card), mobile "tickets", and smart phone-based payment apps like Samsung Pay and Apple Pay (Okunieff, 2017).

Architecture of Electronic Fare Payment Systems

Closed versus open payment

Historically, transit payment systems are closed payment systems, which, unlike open payment systems, accept only the agency's proprietary media for travel. Users can purchase passes or add value with cash or a bankcard but those funds are limited to purchasing transit fares and are unavailable for other purposes. Nearly all transit agencies in the US use this model. In contrast, open payment systems allow users to choose from a range of payment media so long as it is compatible with the system. As of this writing, three regions in the US have an open payment system: the Utah Transit Authority, the Chicago Transit Authority and Pace, and the Southeastern Pennsylvania Transportation Authority (SEPTA). The Utah Transit Authority launched its open payment system in 2009 after adding readers at all doors of 520 fixed route buses, 170 validators on light rail and commuter rail platforms, and wireless communications gateways and internet links (Smart Card Alliance, 2011). Other agencies are planning open payment systems, including Boston, Los Angeles and New York, suggesting that other transit agencies will also move in this direction as their current equipment reaches end of service life (Okunieff, 2017) .

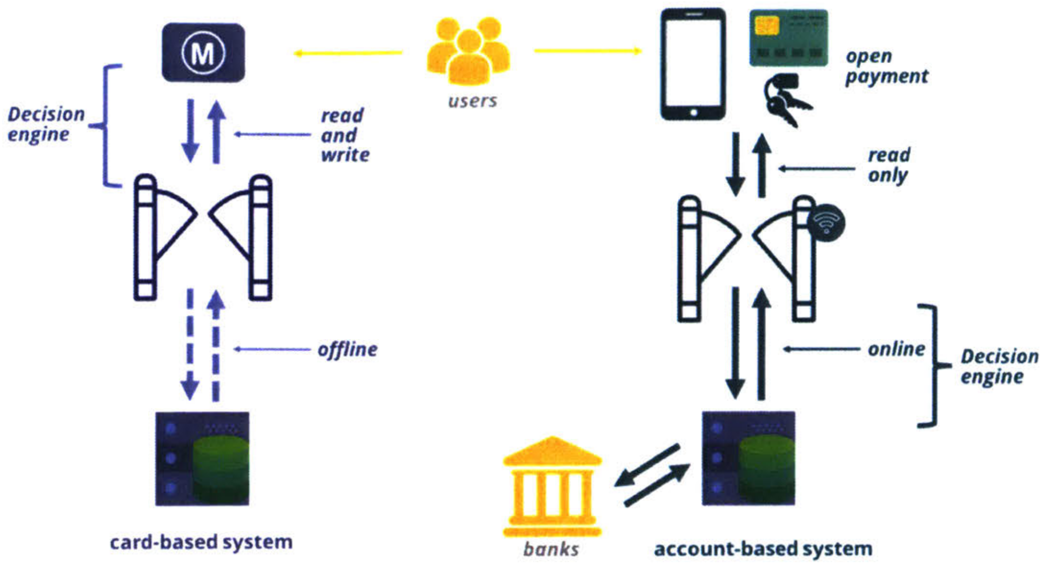

Figure 2: Architecture of electronic fare payment systems. In a card-based system (left), the card and the reader at the faregate determine whether to grant access. In an account-based system (right), the back-end office and the reader determine whether to grant access. Source: Author's own image. Icons created by Freepik.

Card-based versus account-based

Card-based systems

The backend architecture of payment systems is either card-based or account-based (see Figure 2). Most transit systems have card-based systems thus data regarding a user's transit passes and stored value are stored on the card itself, and not in a backend database. In addition, rules regarding fares, transfers, discounts, etc. are directly programmed into the card readers. In this system, the card and the reader determine whether to grant access. Card-based systems have been the preferred model by transit agencies for its transaction speed and reliability; typical transaction times are between 300 millisecond to 500 millisecond and transactions can occur in an offline environment, updating data to a central system when a connection is available (Okunieff, 2017). Moreover, prior to the widespread availability of low-cost, high-speed, wireless internet connectivity, this was the only viable option. However, these systems also have drawbacks: even slight changes to fare policy require software updates on all field equipment, transaction data is available only after offline equipment has uploaded its data, and remote purchases of fare products (e.g., adding value to a card through a website) are typically not available until the following day (Smart Card Alliance, 2011).

Account-based systems

In contrast with card-based systems, in account-based systems, payment devices read information stored on the card and send it to a back office over a communications network. The back office then processes the transaction, applying the relevant business rules, determines the fare and returns a signal to approve or deny the transaction. In this case, the card is only used as an identifier that points to an account and data is stored in the back office, not on the card. Advantages of account-based systems include greater flexibility for transit agencies in choice of fare media and ease of updating fare policy (Smart Card Alliance, 2011). The most significant drawbacks appear to be the slower transaction time, with transactions averaging 500 millisecond to 700 millisecond, greater need for security throughout the system, and dependence on network connectivity (Okunieff, 2017; Prakasam, 2017).

Account-based systems in use by public transit today indicate that linkage with a bankcard is not mandatory; as with card-based systems, users are able to add value or purchase passes using cash or a pre-paid bank card. This feature is important to one, protect vulnerable riders such as those without bank accounts and two, provide alternatives to those wary of linking personal financial data.

Implementation Barriers to Multimodal Payment Convergence

Recent reports on multiagency payment convergence identified payment media and equipment interoperability as the major challenge to payment convergence (Okunieff, 2017). This challenge is thought to be further compounded by institutional factors and the complexity of interagency collaboration (Dinning & Weisenberger, 2017). Several unsuccessful payment convergence attempts provides evidence for this hypothesis (John A. Volpe National Transportation Systems Center, n.d.).

Technical

Technical barriers

While the technology of payment systems has matured to a point where integrated services are feasible (Evans, Guo, Blythe, & Burden, 2015), the primary issue appears to be of standardization: how to coordinate the activities of transit operators, municipalities, private mobility providers, and technology suppliers to develop an interoperable system (Quibria, 2008). Some operators may have recently replaced its payment equipment and others are concerned about path-dependency. Multimodal payment convergence also requires data sharing. On the public sector side, licenses and terms of services covering its transit data makes it time consuming for developers to review the limitations and uses of its data, hindering data sharing (Carlin, Rader, & Rucks, 2015). On the private sector side, researchers have identified fear of commoditization and brand dilution as the barrier to data sharing (*Ibid.*). Both public and private sector agencies are concerned with issues of information control, concerns over liability, and potential lost opportunities for revenue generation (Rojas, 2012). When organizations are willing to share data, they base their decision on a business case considering the expected benefits and all relevant costs (Dawes, 1996). Thus various stakeholders will have competing and at times, opposing interests concerning hardware and software and policies related to data sharing, and absent an agreement on these issues, integration will not be successful (Quibria, 2008).

One promising trend is the shift to account-based systems which significantly reduce the complexity in integrating payment systems as compared to card-based systems by reducing the reliance on field equipment (Okunieff, 2017). Integration would then primarily entail programming changes in the backend. Adopting account-based systems would not only simplify system operation, but also facilitate integration with nontraditional mobility providers like rideshare and bikeshare services which typically employ account-based systems. Existing partnerships involving integration with nontraditional modes, though few, have one common feature: at least one of the partners has an account-based system (*Ibid.*).

Case example

One of the earliest examples of payment integration with nontraditional partners is the partnership between Chicago Transit Authority (CTA) and IGO, a carshare service. Though the program has since ended, CTA modified its fare card, the Chicago Card Plus (CCP) (which has since been replaced), by affixing an RFID sticker to the card for users who opted into IGO. Through one online platform, users were able to manage their transit account and reserve a car. The project manager attribute the success of the program to the account-based nature of both CCP and IGO (*Ibid.*). The program ended when IGO was acquired by Enterprise in 2013 (Okunieff, 2017).

Innovation adoption by transit systems

As recent industry reports and research suggest multimodal payment convergence is technically feasible, literature on innovation adoption by the public sector may shed some light on the lag in implementation of multimodal payment convergence.

While innovation can mean new technology, it is generally defined more broadly as a technology process or policy that is new to an organization thus technologies do not have to be new to be innovative. The existing literature on innovation in the public sector breaks down drivers of and barriers to innovation into four main categories:

1. *Environmental Factors*

Environmental factors refer to the context or conditions surrounding innovation activities. (Bekkers, Edelenbos, & Steijn, 2011) suggest that innovation adoption is the product of pressures from media attention, political demands, and public demands. Other research supports the notion of isomorphism or 'looking alike' whereby agencies and organizations in the same field become more alike and adopt similar innovations (DiMaggio & Powell, 1991). This can occur through specific rules and regulations (coercive isomorphism), through the adoption of values and norms developed by relevant peers and professional networks (normative isomorphism), or modeling another organization's behavior (mimetic isomorphism). Research suggests public sector organizations are more vulnerable to all three types of institutional isomorphisms compared to for-profits and nonprofit organizations (Frumkin & Galaskiewicz, 2004).

Environmental barriers to innovation by transit agencies include low public tolerance for failure, the lack of a profit motive (which in the private sector stimulates innovation), the need to address multiple social goods, and negative media attention (Hikichi & Beimborn, 2005; Transportation Research Board, 2001).

2. *Organizational Factors*

Organizational factors refer to the structural and cultural aspects of an organization and research suggests they play the most significant role in enabling innovation (De Vries, Bekkers, & Tummers, 2016). Damanpour's work is frequently cited in this area and his meta-analysis on organizational innovations found that determinants such as organizational slack resources, managerial attitude toward change, professionalism, and technical knowledge are positively correlated with adoption of innovation (Damanpour, 1991).

Transit agencies, like other public organizations, can be resistant to change: in a survey of over 100 transportation officials in the US, respondents identified "resistance to change" as the most serious barrier to innovation, followed by lack of executive sponsorship (Orcutt & AlKadri, 2009). Irwin cites lack of resources (funding and personnel), lack of management support for risk-taking, resistance to risk-taking, and inflexible regulations, incentives and rewards as major impediments to innovation at transit systems (Irwin, 2004). If public officials are uncertain of the benefits of innovative technology, they are reluctant to adopt it (Orcutt & AlKadri, 2009). One report analyzing nine case studies on implementation of innovation by transit systems identified two factors that helped overcome these barriers: funding and presence of a champion for the change or innovation (Hikichi & Beimborn, 2005). The presence of a champion and a visionary to coordinate and lead the effort was critical, helping bring innovation to fruition whether it is an individual like a senior level staff or an elected official or a group like transit planning staff. Funding can serve as an impetus (in cases where an agency hopes to cut costs) or an initial barrier to implementation (lack of funding). CMAQ funding played an important role in implementation in two of the nine case studies analyzed (*Ibid.*).

3. *Characteristics of Innovation*

Much of the research on innovation adoption is informed by Rogers' Diffusion of Innovation Theory which proposes four critical elements in the diffusion of innovation: the innovation itself, communication channels (how participants create and share information), time, and the social system (who are the stakeholders) (Rogers, 2003). Rogers finds that 49-87% of the variance in the rate of adoption of innovations is explained by five characteristics of innovations (as perceived by the potential adopter): 1) its relative advantage, 2) compatibility, 3) complexity, 4) trialability, and 5) observability. Relative advantage is "the degree to which an innovation is perceived as being better than the idea it supersedes" *(Ibid.,* 229) while compatibility refers to the degree the innovation is consistent with the adopter's existing values, previous experiences, and needs. Complexity refers to the perceived ease of use. Trialability refers to the ability to test the innovation in a limited setting and observability is the extent that others can see the results of an innovation. These traits are all positively correlated with adoption of innovation with the exception of complexity (*Ibid*).

With regards to innovation in transportation, barriers previously identified include four of the five characteristics described by Rogers: technology that is unsuitable for the agency's needs (compatibility), technology that is high in complexity (complexity), innovation has unclear or immeasurable benefits (relative advantage), and difficult to pilot/introduce (trialability) (Hikichi & Beimborn, 2005). All of the innovations described in the case studies previously mentioned had one factor in common: need—the innovations either were in response to a particular problem or stemmed from a transit agency's desire to better serve its customers (*Ibid.*)

4. *Factors related to the Individual/Employee*

Factors at the individual level are varied but include employee autonomy, employee's organizational position, creativity/entrepreneurial spirit, and demographic characteristics. In the cases of the individual champions identified by Hikichi and Beimborn, (2005) the individuals were typically high ranking. In one example, the Director of Planning at the university, was critical to the success by coordinating and negotiating with various student leaders, administration officials, and the transit agency (*Ibid)*.

Influence of institutional factors on multimodal payment convergence

Several streams of literature suggest institutional factors can either hinder or encourage multimodal payment convergence. Transportation policy literature finds that institutional factors strongly influence the success of planning a high quality public transport network (ECMT-OECD, 2002; Mulley, Nelson, & Nielsen, 2007). In studies of interoperable smart card implementation, existing organizational cultures has been identified as one of the most significant challenges (Acumen Building Enterprise, Inc. & Booz Allen Hamilton, Inc., 2006). Thus this next section will provide a review of institutional factors that may influence multimodal payment convergence.

Multiple institutional structures and business approaches

(Orcutt & AlKadri, 2009) cite system diversity and complexity as a barrier to innovation in transportation. Transportation projects are often inter-jurisdictional and involve many players. Coordinating across transport operators necessitates resolving disagreements stemming from differences in institutional and financial structures. These entities must establish new policies and rules for making decisions, governance, system operation and administration, etc. In particular, collaboration across public and private lines may be especially difficult given conflicting interests and incentives: transportation executives have an obligation to act in the best interests of its company while public agencies must act in a manner that serves the public. Researchers find that a lack of trust between stakeholders is a major obstacle to more integrated transport systems (SPUR, 2015). Exacerbating the situation is the uncertain future of mobility services and the perceived competition for riders between traditional transit providers and emerging mobility services. Analysis of regional transit smart card implementation efforts suggests that existing relationships, focus on the customer experience, and precedence of revenue sharing are critical to successful payment convergence (Iseki, Taylor, & Yoh, 2008).

Consensus building leads to a better result

Evidence from regional transit smart card implementation suggests that processes that emphasize consensus-building, though they require more time and patience, lead to better results (Okunieff, 2017). If partner agencies lack authority in the decision-making process, they will likely be less invested and implementation may be delayed or unsuccessful (*Ibid.*)

Leadership is important

In addition, another critical factor to success is a leader to get all stakeholders to prioritize cooperation and commitment to implementation (Carlin et al., 2015). Further, it will serve as a "unifying force" and simplify governance (Okunieff, 2017). The leader could be a single stakeholder or multiple stakeholders but a single agency should have the contractual relationships with vendors/suppliers (*Ibid.*).

Emerging trends

The increasing adoption of open payment systems could bypass the difficult challenge of collaborative decision-making by making compatibility automatic. With widespread adoption of open payment systems, a customer can use her contactless bankcard for payment everywhere: at retailers, on the transit system, to access bikeshare, etc. However, open payment systems will not absolve the need for collaboration to create an integrated fare/payment policy and create incentivizes to reward certain travel behavior.

Financial barriers

Cost has previously been identified as a barrier to adoption of innovation by transit agencies (Hikichi & Beimborn, 2005).

Capital costs

To upgrade and overhaul an existing fare collection system and create an interoperable system requires significant capital costs. Costs include the purchase and installation of new equipment, integrating the old and new systems and equipment, and production and distribution of new payment media. Capital cost estimates from US implementations of new smart card systems range from $35 million - $48 million per 1,000 peak vehicles (Iseki, Demisch, Taylor, & Yoh, 2008). The new Ventra system in Chicago, which spans three transit agencies, allegedly cost nearly $519 million while SEPTA's new fare collection system, cost an estimate of $225 million (Hilkevitch, 2015; Laughlin, 2015).

Operational costs

While open payment systems have lower operating and capital costs, operators must also consider the transaction processing costs for contactless bank card payments as individual transit fares may be expensive to process using traditional processing for each transaction (Smart Card Alliance, 2011). Aggregating these individual fares or using prefunded accounts can reduce the cost of processing numerous low-value transactions (*Ibid.*).

In general, lifecycle costs of new electronic payment systems are dramatically lower and the initial capital expenses are compensated through reductions in fare collection costs (Pelletier et al., 2011). And yet, in a tight budgetary environment of declining revenues and decreased local, regional and state funding, transit operators are uncertain the long-term benefits and cost-savings outweigh the significant short-term capital investments and expenditures, resulting in delayed implementation (Iseki, Taylor, et al., 2008).

Federal funding opportunities

In recognition of the funding challenges faced by transit agencies, federal funding programs have emerged to support innovative ideas in integrating transportation modes. In 2015, The U.S. Department of Transportation launched the Smart City Challenge asking mid-sized cities to submit ideas for creating "an integrated, first-of-its-kind smart transportation system" using data, applications and technology ("Smart City Challenge," 2016). The winner of the challenge, Columbus, OH received $40 million to fund its vision, which includes creating an integrated payment system for all transportation options in the city. US DOT notes that a majority of the seven finalists included strategies for integrated mobility marketplaces in their proposals (US Department of Transportation, 2017). Another program, one that is even more tailored to supporting integrated transportation is the Federal Transit Administration's Mobility on Demand Sandbox Program. In particular, it hopes to foster partnerships between public and private transportation choices. In 2016, it allocated $8 million in funding to twelve projects including $1.2 million to Dallas' proposal to expand its transit ticketing app, Go Pass, to allow transit riders to plan and pay for first and last mile options (rideshare, bikeshare, carshare), within the same app (US DOT, 2016). Other potential sources of funding for integrated mobility projects include federal programs including the Congestion Mitigation and Air Quality Improvement Program (CMAQ), Transportation Investment Generating Economic Recovery (TIGER) Grants, and Intelligent Transportation Systems (ITS) Funding and state and local programs aimed at innovative transportation or travel demand management.

CHAPTER III: Case Study | Minneapolis-St. Paul

Overview

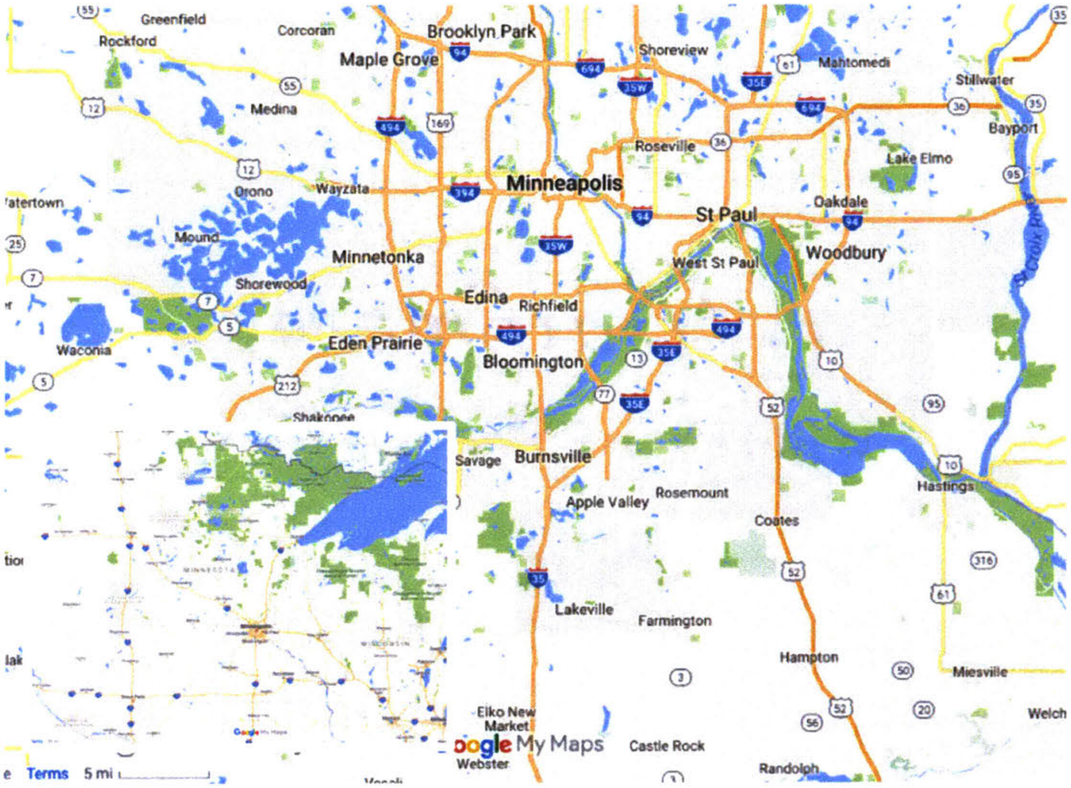

Figure 3: The Minneapolis-St. Paul region is the largest metropolitan region in Minnesota.

The Twin Cities metropolitan region, commonly known as Minneapolis-St. Paul after its two largest cities, Minneapolis and Saint Paul, is the largest metropolitan region in Minnesota. The region is unique in that it has two urban central business districts just nine miles apart. The area is home to about 3 million people, nearly 62% of the state's population, in 182 communities, across seven counties, and encompassing nearly 3,000 square miles. Minneapolis and St. Paul are neighboring cities built around the Mississippi River, with a population of 382,000 and 285,000 respectively (US Census Bureau, 2010).

Existing public transportation system

Metro Transit

Metro Transit is the largest provider of transit service in Minneapolis-St. Paul, providing service on 128 bus routes, two light rail lines, and one commuter rail line.

In 2016, Metro Transit provided an average of 267,000 weekday trips, for a total of 82.6 million rides (Metro Transit, 2016). It also provides a variety of services for other transit operators in the region, including transit police and trip planning. Similar to other transit agencies, it relies on state and federal funding to finance its operations and capital programs.

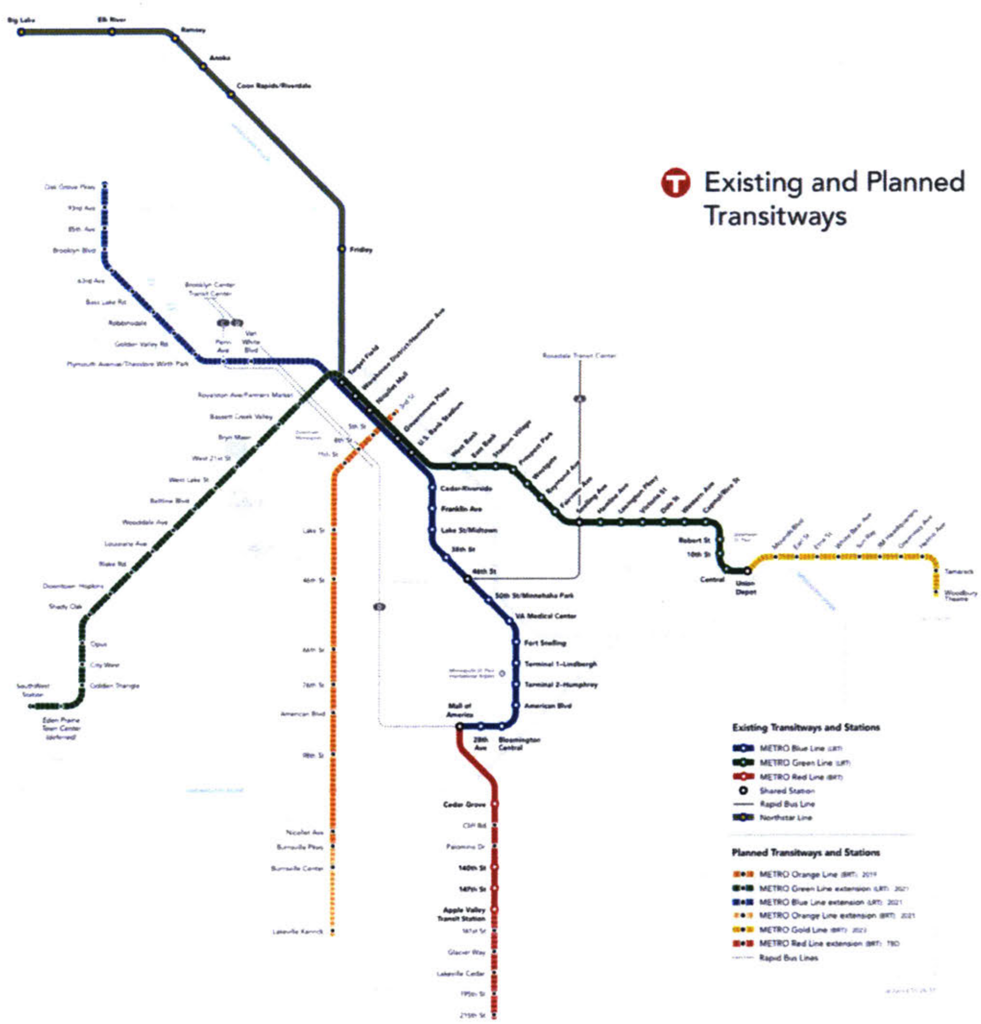

Figure 4: Existing and Planned Metro Transit rail and BRT (bus rapid transit) service. Dotted lines indicate planned service. Source: Metro Transit, 2016

Metro Transit's rail service is a fairly new development (Figure 4). The 12.3 mile Hiawatha light-rail line (now known as the Metro Blue Line) connecting downtown Minneapolis to the Minneapolis-St. Paul International Airport and the Mall of American in Bloomington opened in 2004. The region's commuter rail service, the Northstar Line, opened for service in 2009. The Metro Red Line, a bus rapid transit line connecting Apple Valley and the Mall of America opened in 2013. The other light rail line, Metro Green Line opened in 2014 and connects downtown Minneapolis, University of Minnesota campus and downtown Saint Paul. Significant extensions are currently in the works for both the Green and the Blue Lines, and are expected to open in 2021 (see Figure 4) (The Metropolitan Council, 2017). Travel on Metro Transit is facilitated by its contactless smart card, the Go-To Card which is accepted on all Metro Transit service, including commuter rail. Beyond transit service, Metro Transit also implements a regional carpooling program which helps match commuters and offers reduced-price or preferential parking.

Transit-spurred development

The Minneapolis-St. Paul metropolitan region is growing. By 2040, the area will add 800,000 new residents and 550,000 new jobs (Metropolitan Council, 2014). Some local leaders attribute the region's growth to the Metro Green Line that opened in 2014, improving residents' access to jobs and spurring development along the line (Trickey, 2017). According to the Met Council, two years after the system opened, $4.2 billion in planned new development will be within half a mile of a light-rail station (Metropolitan Council, 2016). Development projects are also underway in communities along the future Blue Line Extension and the Green Line Extension (*Ibid.*).

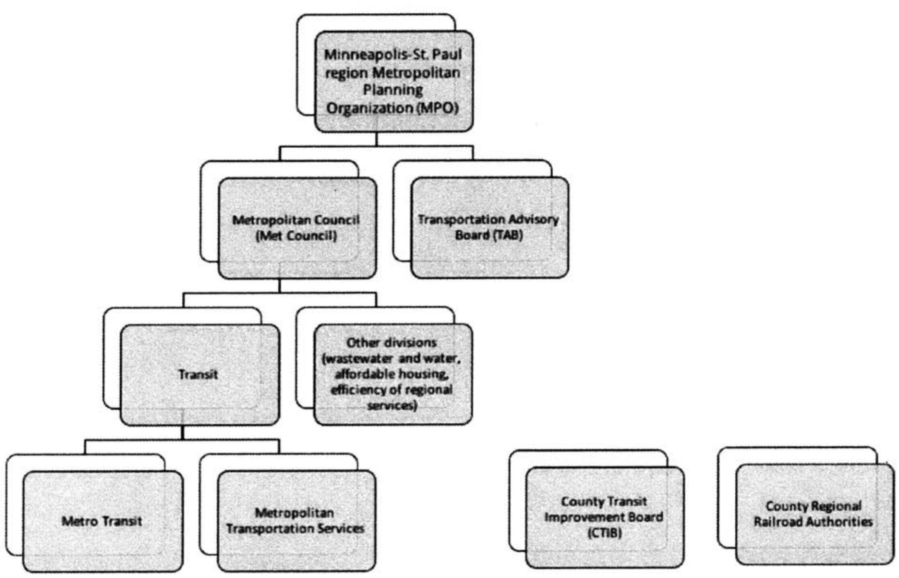

Figure 5: Organizations involved in transit planning in Minneapolis-St. Paul. Some entities have been excluded for simplicity.

Transit governance

Metro Transit is operated by the region's designated metropolitan planning organization (MPO), the Metropolitan Council (Met Council). Met Council is governed by a 17 member-board, appointed by the governor and operates other regional services in addition to transit including wastewater treatment, coordination of regional parks, and affordable housing. Because federal law requires local elected officials to serve on the Metropolitan Planning Organization and members of the Met Council are not elected officials, the state legislature created a separate board, the Transportation Advisory Board (TAB) comprised of elected and appointed officials. Together, the Met Council and the TAB make up the Minneapolis-St. Paul region's Metropolitan Planning Organization (see Figure 5) (State of Minnesota, 2011). TAB is responsible for allocating federal funding from the Surface Transportation Program, the Congestion Mitigation Air Quality program, and the Transportation Alternatives Program.

In addition to the Met Council, the Counties Transit Improvement Board (CTIB) also plays a role shaping transit projects in the region. The state legislature authorized the creation of the CTIB in 2008 upon the introduction of a one-quarter cent sales tax to be levied on a county-basis. Currently, five of the seven counties in the region are on the CTIB and have chosen to levy the tax. CTIB is responsible for allocating revenue generated by the tax, about $110 million annually, to support transit improvements and provide operating assistance (State of Minnesota, 2011). Metro Transit built its rail transit projects with the help of CTIB funding.

Collectively, the two entities, Met Council and CTIB, have significant power over the creation, coordination, and operation of the regional transit network. The creation of CTIB and its role as the primary funder of capital costs of proposed projects, has decentralized decision-making for investment decisions. Project selection is thus a collaborative process involving Metro Transit, CTIB, and the regional railroad authorities in each county (Eno Center for Transportation, 2014).

Transport mode share

Trips predominantly made by single-occupancy vehicles

The roadway system in Minneapolis-St. Paul is well developed; the region has a total of 17,500 miles of roads and ranks eighth in highest number of centerline miles of road per person in the US. In part, this is due to the outward, low-density development in the 20th century facilitated by the car (Metropolitan Council, 2015). This is evident in the population trends of Minneapolis and St. Paul as compared to the surrounding suburbs (Table 1).

	Minneapolis	St. Paul	Suburbs
1950	522,000	311,000	234,000
1970	434,000	310,000	1,283,000
1990	368,000	272,000	1,899,000
2010	382,000	285,000	2,612,000
% Change, 1950-2010	- 26%	- 8%	1,029%

Table 1: Population change in Minneapolis, St. Paul, and surrounding suburbs. Source: US Census Bureau

Thus not surprisingly, most trips in the region are made by car, with 78% of workers commuting alone by car. According to the Minnesota DOT, traffic congestion on the Minneapolis-St. Paul freeway system has trended upward and in 2015, congestion reached a record high since the agency started collecting data in 1993 (Minnesota Department of Transportation, 2016).

Indication of shifting behavior

However, within the cities St. Paul and Minneapolis, public transit and other non-driving modes make up a larger portion of commute to work trips and recent trends suggest mode shares are changing. In Minneapolis, 24.4% of individuals take public transit, bike, or walk to work (US Census Bureau, 2015). See Table 2 for a breakdown of commute modes. Nationwide, Minneapolis ranks third in highest percentages of commuters that bicycle to work after Portland, Oregon and Washington D.C. (US Census Bureau, 2015). Minneapolis has also made significant investments in bicycle and pedestrian infrastructure, dedicating a total of $25.6 million of the city budget in 2014. Relative to similarly-sized cities, it has the highest density of bike infrastructure in the country (Alliance for Biking & Walking, 2016).

	Minneapolis-St. Paul-Bloomington, MN-WI Metro Area		St. Paul		Minneapolis	
		MOE		MOE		MOE
Car, truck, or van - drove alone	78.0%	0.2	69.4%	0.8	61.4%	0.7
Car, truck, or van - carpooled	8.4%	0.1	10.4%	0.5	8.2%	0.4
Public transportation (excluding taxicab)	4.6%	0.1	8.5%	0.5	13.1%	0.5
Walked	2.3%	0.1	4.1%	0.3	7.0%	0.4
Bicycle	1.0%	0.1	1.6%	0.2	4.3%	0.3
Taxicab, motorcycle, or other means	1.8%	0.1	2.6%	0.2	5.2%	0.1
Worked at home	5.0%	0.1	5.1%	0.4	5.2%	0.3

Table 2: Commute to Work Mode Shares: Minneapolis-St. Paul – Bloomington, MN-WI Metro Area, St. Paul, Minnesota, Minneapolis, Minnesota. MOE Margin of Error. (Source: 2011-2015 American Community Survey 5-Year Estimates)

Multimodal Payment Convergence

Metro Transit's smart card: The Go-To Card

In 2007, following a trial period involving Metro Transit employees and select area riders, Metro Transit launched its transit smart card, the Go-To Card to the general public. Metro Transit contracted with Cubic Transportation Systems to procure rail and bus validators, ticket vending machines, and a central management system. The Go-To Card is accepted for travel on bus, light rail, and commuter rail operated by Metro Transit as well as on service operated by other transit agencies in the region including the Minnesota Valley Transport Authority and SouthWest Transit.

Congestion Mitigation Air Quality (CMAQ) Travel Demand Management funding opportunity

In 2013, the Metropolitan Council (Met Council), the region's designated metropolitan planning organization, released the Congestion Mitigation Air Quality (CMAQ) Travel Demand Management (TDM) biennial regional solicitation for $1.2 million in available funding. CMAQ is a federal program administered by the Federal Highway Administration that was created under the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 to support transportation projects that contribute to air quality improvements and provide congestion relief. Since its inception, it has been reauthorized under every successive transportation bill, providing more than $30 billion to over 30,000 transportation projects. In the Minneapolis-St. Paul region, thirteen applications were submitted, and six were recommended to be fully-funded and one partially funded. One of the approved applications was submitted by a local nonprofit carshare company known as HOURCAR.

Carshare programs

Current practice

Contemporary programs are characterized by a decentralized network of shared vehicles which members reserve in advance in hourly increments. While the term carshare is also used in conjunction with carpooling programs, carshare in this context refers to private use of vehicles in a shared fleet. The programs bear much similarity to bikeshare programs in that users subscribe to a membership and vehicles are self-accessing—users can walk up to a vehicle they have reserved and unlock it via a contactless card or a mobile phone application. Car-sharing programs provide an option to individuals who typically rely on other modes like public transit, walking, or bicycling to get around but still may need a car from time to time – for example, in reaching destinations not accessible by transit, or to transport large packages.

Carshare in Minneapolis-St. Paul

The Minneapolis-St. Paul region boasts three active carshare program, two of which are operated by national or global companies, Zipcar and Enterprise Carshare. HOURCAR, which introduced carshare to the region, debuted in 2005 and unlike the others, is a local entity; it is operated by a St. Paul-based nonprofit, the Neighborhood Energy Connection (NEC). NEC works with residents and communities reduce energy usage through services and programs that support and finance energy efficiency projects. It launched HOURCAR to, "make car ownership optional in the Twin Cities." (Neighborhood Energy Connection, n.d.) The program has grown from a dozen vehicles to over sixty vehicles, and include locations situated along Metro's 11-mile Central Corridor light-rail line and other transit centers to encourage members and potential members to make connections between the two modes (Figure 6).

HOURCAR offers two types of membership plans, and varying rates depending on the time of day (Figure 7). HOURCAR's growth was in part helped by grant funding from the McKnight Foundation and the Central Corridor Funders Collaborative (Owings, 2014).

Figure 6: Map of Metro light rail stations and HOURCAR locations.

Figure 7: HOURCAR Rate Plans. Source: HOURCAR

Partnership between HOURCAR and Metro Transit

HOURCAR had initially sought out Metro Transit to explore potential partnerships as it felt their goals were similar—to provide alternatives to car ownership in the region. One idea identified was to bring together the two services, transit and carshare, onto one card and bring visibility to the shared goal to existing and potential customers (Eull, 2017). The TDM Regional Solicitation in 2013 provided a potential funding source to make this project a reality. In addition, HOURCAR hoped to reduce some of the burden associated with carshare membership registration. One barrier common to most carsharing programs is the waiting period following the initial sign-up for the HOURCAR access card to arrive in the mail but an HOURCAR survey revealed that nearly 90% of its 2,500 members already have Go-To transit cards (Harlow, 2015). Thus it submitted a proposal requesting $144,000 to upgrade the electronic locking equipment on its vehicles for compatibility with Metro Transit's Go-To Card technology with the stated goal of improving multimodal accessibility region-wide ("Metropolitan Council Transportation Committee Report. Meeting on April 30, 2014," 2014).

CMAQ funding secured

HOURCAR's proposal was federally-eligible according to the Transportation Advisory Board (TAB), under the category of "Transit and Transportation Demand Management Projects" and TAB recommended the project receive funding. Met Council, charged with reviewing TAB recommendations for consistency with regional goals and plans, concurred with the recommendations and found it to be consistent. In April of 2014, Met Council's Transportation Committee announced that seven projects would receive funding, including full funding for NEC/HOURCAR's request ("Metropolitan Council Transportation Committee Report. Meeting on April 30, 2014," 2014).

Multimodal payment convergence planning

The first step in this process was for HOURCAR to understand the card technology that Go-To transit card uses so they could procure a compatible system (Eull, 2017). The Go-To card uses a standard MiFare classic smartcard compliant with the ISO 14443 standard. ISO (International Organization for Standardization) is a 162-member country board charged with developing worldwide standards for products, services, and systems in many industries, including standards for contactless smart cards (ISO 14443). ISO 14443 defines how smartcards establish a communication protocol with contactless smart card readers. Each smart card contains an integrated chip with a unique permanent identification number (UID) assigned during the manufacturing process. This number is not encrypted and any reader that is ISO compliant can read the UID.

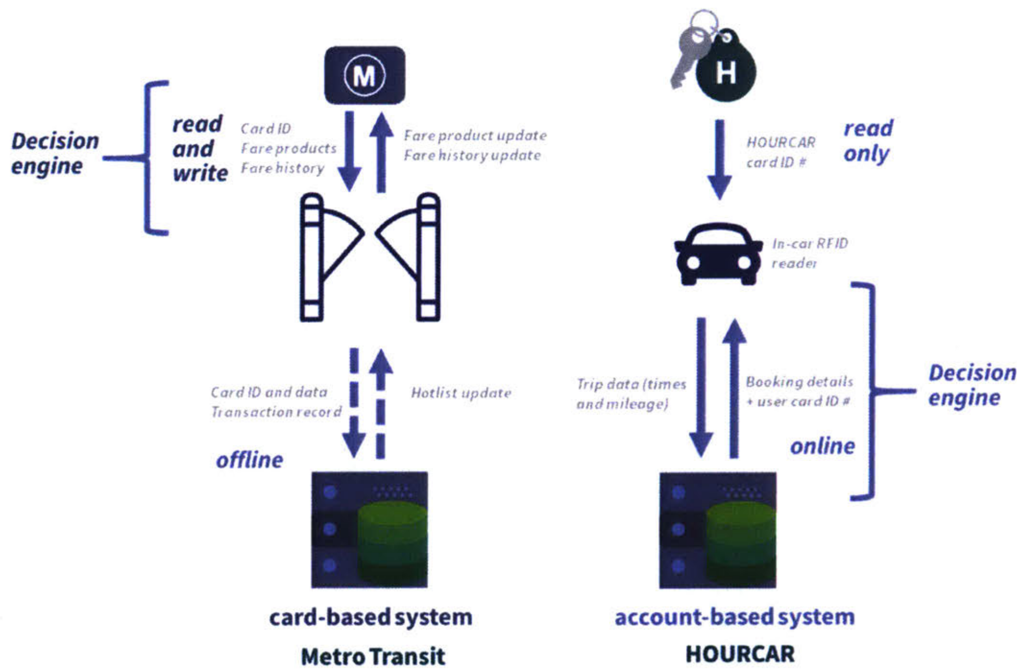

Figure 8: System Architecture of Metro Transit (left) and HOURCAR (right) prior to payment media convergence. Previously, HOURCAR issued members a RFID-enabled key fob to access its vehicles. Source: Author's own figure. Icons made by freepik from www.flaticon.com, licensed by cc 3.0 by.

Different system architectures

While Metro Transit relies on a card-based system to validate fare transactions and store data regarding passes and stored value, HOURCAR's system is account-based. Prior to the upgrade, HOURCAR's readers recognized the card serial number of the user's key fob, validates it and grants privileges through a backend system (Figure 8). As it was important for Metro Transit to protect its customers' privacy and not put user data at risk, the two entities realized, HOURCAR did not need to use or access any of the memory on the Go-To card: it only had to read the serial number (UID) on the card. This realization was critical as the integration would require no software changes or operational input on Metro Transit's end.

New HOURCAR technology

HOURCAR then reviewed vendor and equipment options based on this information and with an eye toward future technology changes, contracted with Invers, a market leader in hardware and software for shared mobility providers including carshare programs. HOURCAR replaced the in-car technology for its entire fleet and also made significant changes to its software system. One issue that became apparent with a flexible, multi-card reader was vehicle security as there are more than 100 million MiFare cards in circulation but HOURCAR wanted users to easily link their Go-To card with their HOURCAR account (Hansen, 2015). To address this, HOURCAR opted to add another layer of security with an in-vehicle keypad. The keypad sits in the glovebox of the vehicle and the first time someone uses their Go-To card for HOURCAR, the user must enter a one-time use PIN into the keypad to verify their identity (see Figure 9). This process then automatically links the Go-To card's UID with the user's HOURCAR account and stores it in the backend database. This added security feature significantly increased the cost of equipment but it does bypass the need for users to provide HOURCAR with a lengthy card number manually, whether via the online portal or by phone (Hansen, 2015).

Figure 9: HOURCAR's in-vehicle keypad provides an added layer of security to counteract potential issues related to Go-To card phishing. Source: HOURCAR

Figure 10: HOURCAR vehicle readers now compatible with Metro Transit's Go-To Card. Source: Elizabeth Flores, Star Tribune.

The result

In September of 2015, HOURCAR and Metro Transit announced that HOURCAR members could use Go-To cards to access HOURCAR's entire fleet of vehicles (Figure 10). Art Guzzetti, vice president of policy for the American Public Transportation Association praised the new partnership and noted that while there's certainly discussion among policymakers for unified payment media, "Minneapolis-St. Paul is one of the pioneers" in terms of actual implementation (Harlow, 2015).

CHAPTER IV: Case Study | Los Angeles

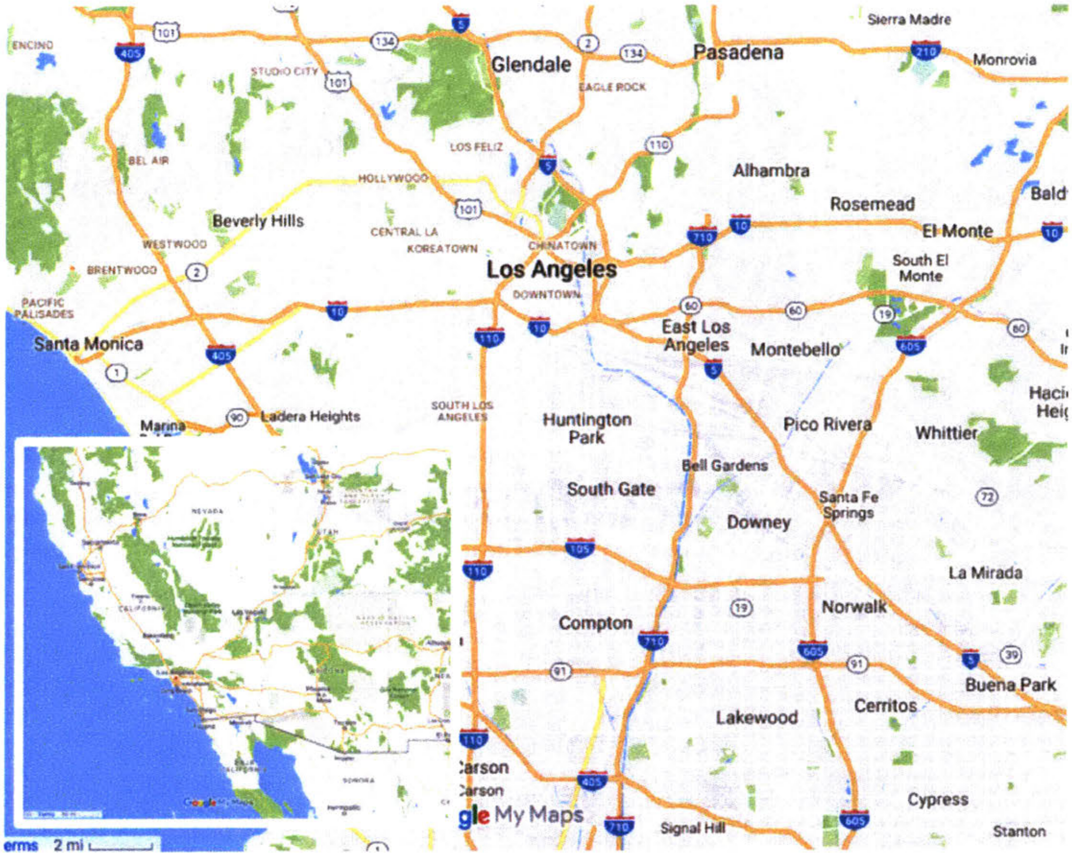

Figure 11: Los Angeles, California

Existing Transportation Systems

Unsustainable trends

Cities are known by their landmarks. As the Sears Tower symbolizes Chicago, Los Angeles is often associated with the freeway. Not surprisingly, among the largest metropolitan areas in the country, Los Angeles also has the densest road network, providing more than 50% more lane-miles per square mile than Detroit, its nearest competitor (Sorensen, 2009). Los Angeles is also notorious for its traffic congestion. In 2014, the Los Angeles metropolitan area ranked second behind only the Washington, D.C. metropolitan area in terms of annual hours of delay per traveler at 80 hours in delay per year, but ranked first in terms of the ratio of travel time increase during peak period travel versus during free-flow conditions (Schrank, Eisele, Lomax, & Bak, 2015). While Los Angeles is known for its sprawling development, it is the densest metropolitan area in the country. The problem lies in the fact that relative to its density, Los Angeles has a surprisingly high level of per capita vehicle-miles-traveled (Figure 12).

FIGURE 4

Population density vs. daily per-capita VMT in major metropolitan areas in 2007

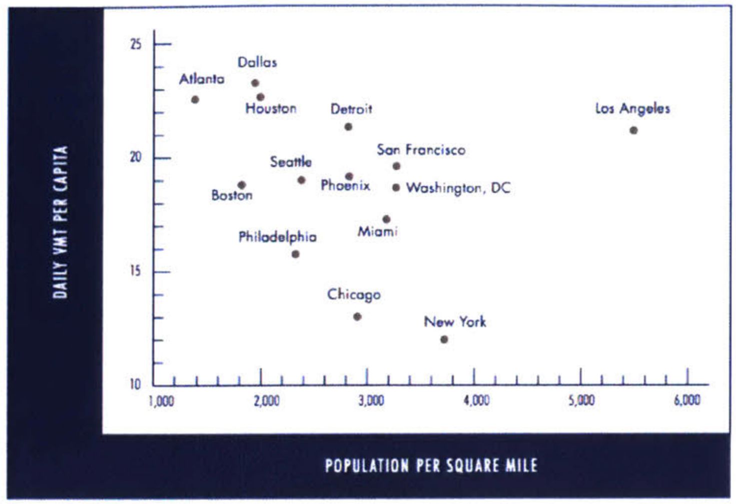

Figure 12: Population density compared to daily per-capita VMT (vehicle miles traveled) in major metropolitan areas in 2007. Source: Sorensen, 2008

Overwhelming public support for change

The severity of Los Angeles' congestion problem and its potential impact on economic growth in the region, combined with years of severe budget shortfalls for transportation projects, resulted in overwhelming public support for increased funding for transportation through two major funding bills (Hawthorne, 2016; Tasci, 2008). Where other agencies have faced funding challenges for operations and maintenance, the Los Angeles County Metropolitan Transportation Authority (LA Metro), the regional multimodal transportation planner and operator of the transit system, has an ambitious plan to double the size of its fixed-guideway transit system from 105 miles and 93 stations to 236 miles and 200 stations. To help fund this plan, voters in the county have passed two major funding bills: Measure R in 2008, a half-cent sales tax increase that would provide $40 billion in funding for transportation projects in LA County over 30 years, and more recently, Measure M in 2016, an additional half-cent sales tax increase. As of 2016, two rail projects funded by Measure R, have been completed: the second phase of the Expo Line, connecting downtown LA and Santa Monica, and the Gold Line Extension connecting Pasadena and Azusa. Once fully completed, it is expected to double the size of LA County's fixed-guideway transit system from 120 miles and 103 stations to 236 miles and 200 stations (Metro). The Measure R sales tax is set to expire in 2039 but Measure M is permanent and will increase to one-cent in 2039. It is expected to raise $890 million per year.

Los Angeles County Metropolitan Transportation Authority (Metro)

Metro is unique among the nation's transportation agencies as it also serves as the transportation planner, coordinator, designer, builder, and operator to the county, which comprises of 9.9 million Californians. It is the third-largest public transportation system in the United States by passenger volume, after New York City and Chicago, and offers 105 miles of rail service across 6 rail lines, and 170 bus routes covering 1,433 square miles in operation. Beyond public transit, Metro is also responsible for highway construction funding and traffic flow management and funds 16 municipal bus operators. It also provides funding for carpool and bike lanes and Metrolink, the regional rail transport service. More recently, Metro launched the first transit-agency operated bikeshare program in the nation, installing 65 stations with approximately 1,000 bikes throughout downtown Los Angeles.

Metro governance

Metro's Board consists of 14 members: five members of the Los Angeles County Board of Supervisors, the Mayor of the City of Los Angeles, two public members and one member of the City Council of the City of Los Angeles appointed by the Mayor of Los Angeles, and four members, each of whom shall be a mayor or a member of a city council, appointed by the Los Angeles County City Selection Committee. Metro's budget consists of federal, state, county, and city tax dollars as well as bonds and fare box revenues.

Transport Mode Share

The City of Los Angeles is home to 3.8 million people, making up about 10% of the entire population of California, and 38% of the total population of LA County. (US Census Bureau, 2010) It is one of the 88 municipalities making up the LA County. The median age is 34.9+/-0.2, slightly younger than the state (35.8+/-0.1) and the country (37.6+/-0.1). While a large share of workers living within the city limits of Los Angeles, 68%, drive alone to work, the City, compared to the rest of Los Angeles County, has the highest share of workers commuting by public transportation and lowest share of workers driving alone. See Table 3 for breakdown of commute to work modes (US Census Bureau, 2015) Most residents of the City also work within city boundaries (56.5%) (Southern California Association of Governments, 2015).

	California		Los Angeles County		Los Angeles City	
		MOE		MOE		MOE
Car, truck, or van - drove alone*	73.4%	0.1	73.0%	0.2	67.9%	0.3
Car, truck, or van - carpooled	10.8%	0.1	9.9%	0.1	9.3%	0.2
Public transportation (excluding taxicab)*	5.2%	0.1	6.8%	0.1	10.6%	0.2
Walked	2.7%	0.1	2.8%	0.1	3.6%	0.1
Bicycle	1.1%	0.1	0.9%	0.1	1.2%	0.1
Taxicab, motorcycle, or other means	1.4%	0.1	1.4%	0.1	1.6%	0.1
Worked at home	5.3%	0.1	5.1%	0.1	5.7%	0.1
Total	16,869,052		4,516,714		1,819,104	

Table 3: Commute to Work Mode Shares: California, Los Angeles County, City of Los Angeles. Number in blue indicate estimates are statistically different at 95% confidence level. MOE Margin of Error. (Source: 2011-2015 American Community Survey 5-Year Estimates)

Future of Transportation

Los Angeles is growing

Evidence suggests the city of Los Angeles is undergoing an urban transformation. Along with massive investments in rail and bus, Los Angeles is experiencing a large population and construction boom. Since 2010, 42 developments of at least 50,000 square feet have been built in downtown LA while 37 large projects are under construction (Khouri, 2016), Between 2000 and 2013, the downtown population nearly doubled, from 27,000 to 52,000 (US Census Bureau). The Downtown Los Angeles Business Improvement District estimates that this number will reach 72,000 once current construction projects are complete (Downtown LA Business Improvement District, 2016). Countywide, the Public Policy Institute of California projects the population will rise to 11.5 million from 9.9 million in 2025. This population growth affects the traffic patterns of Los Angeles and the number of cars on the road. Beyond the increased time commuters spend in traffic congestion, these traffic patterns have public health consequences. Los Angeles remains the city with the worst ozone pollution and ranks fourth highest for year-round particle pollution levels (American Lung Association, 2016).

Local leaders committed to a new vision for LA

The city is cognizant of these trends and is taking measures to shape the future of mobility in LA. It is undertaking several projects to transform the built environment to support the new transit investment, spearheaded by several vocal champions for multimodal mobility. The Mayor of LA, Eric Garcetti, was credited for helping bring the region and a broad coalition together to pass Measure M (Linton, 2016). Other Metro initiatives Garcetti had a hand in include expansion of student passes, fostering affordable transit-oriented development, and the bikeshare program. In 2014, Mayor Garcetti and the Los Angeles Department of Transportation, launched a strategic plan to make LA's streets better and safer for people using all modes of transportation. Work has begun on the much-anticipated pedestrian- and bike-friendly transformation of a four-mile stretch of Figueroa Street which when complete, will offer 2.6 miles of protected bike lanes, and exclusive bus rapid transit lanes.

Multimodal Payment Convergence

Los Angeles regional smart card: the TAP Card

Los Angeles' regional smart card, TAP, which stands for Transit Access Pass, first debuted in 2008 following a pilot test with college students, select businesses, and Metro staff. The project, though coordinated by Metro, involved 16 other municipal operators and Metrolink, the multi-county commuter rail service. Today, 26 transit agencies accept TAP but this integration came after years of negotiations. Researchers identified three common issues raised by transit agencies involved in the process: 1) revenue distribution and clearing, 2) individual agencies' shares of clearinghouse and administrative costs, and 3) the adoption of smart cards in the context of formula allocation of local, state, and federal funding (Iseki, Taylor, & Yoh, 2008). Factors that enabled the transit agencies' to come to an agreement included the precedence of a revenue sharing program which established the institutional agreements needed for an interoperable fare card and the agencies agreeing on absolute amounts to be paid for shared costs between operators, rather than proportional amounts (*Ibid.*).

Today, the TAP card is administered by LA Metro. The card and fare collection systems are manufactured by Cubic Transportation Systems, the primary contractor for smart cards and readers around the world. Metro staff manage the website and provide customer support functions. Though not all transit agencies in LA County accept the TAP card, those that do not either issue TAP-compatible interagency transfers or use TAP-compatible fare media. As of 2016, it is one of the largest smart card systems in North America, with over 650 different fare types from 26 agencies and over one million customers with registered TAP cards (O'Hara, Navarro, & Melicor, 2016).

Policy objectives

Metro

In December 2012, the Metro Board of Directors adopted the Countywide Sustainability Planning Policy (CSPP) which requires that the agency incorporate sustainability in all aspects of planning, programming, and project delivery. Metro's definition of sustainability goes beyond environmental considerations and it sets forth three principles in its vision of sustainability: to connect people and places, create community value, and conserve resources . While the policy does not specify projects for Metro, it does establish discrete objectives and program metrics to evaluate Metro's implementation of the policy. The agency is also responsive to the universal sustainability policies that apply countywide including Assembly Bill 32, Cap and Trade, the Active Transportation Program, and the Regional Transportation and Sustainability Communities Strategy.

City of Los Angeles

In April 2015, Los Angeles Mayor Eric Garcetti released his sustainable development plan for LA, "Sustainable City pLAn". The plan provides a roadmap for the city to address issues related to the environment, the economy, and social equity, and details specific milestones and metrics against which to measure progress annually. Similar to sustainable development plans of other cities, LA's plan recognizes the critical role transportation plays in fostering a healthy economy and livable city. To that end, it establishes the following goals:

> By 2017, the city will establish bikeshare with at least 65 stations and 1,000 bikes.
>
> By 2025, the city will reduce vehicle miles traveled per capita by 5%.
>
> By 2035, at least 50% of all journeys will be on foot, by bike or by using public transit. (Office of Los Angeles Mayor Eric Garcetti, 2015)

Currently only 16% of workers commute to work by public transit, by bike, or by foot (US Census Bureau, 2015).

Contemporary bikeshare programs

Contemporary bikeshare programs are characterized by self-serving bike stations where users access bikes with a credit card, smart card or key, electronic bicycle locking. Stations are typically concentrated in urban areas and provide numerous pickup and drop-off locations. Users can choose between short-term (24-hours) or long-term subscriptions (30-365 days) and can use bikes for an unlimited number of short (typically <30 minutes) trips within the subscription period. Longer trips incur additional fees charged to the credit/debit card on-file. The credit card requirement can be a barrier to individuals who are low-income or un-banked thus some programs have responded by offering subsidies and cash memberships, including programs in Philadelphia, PA, Boston, MA and Portland, OR. Many bikeshare programs also provide real-time information on bike and station location and availability at the stations, on websites, or via mobile apps. Some systems also have solar-powered docking stations and dynamic pricing to smooth out demand. One of the newest systems, Portland, Oregon's BIKETOWN, does not require users to return a bike to a station; for a small fee, users can secure the bike to any public bike rack within its service boundaries (Motivate International Inc., 2016). As of April 2016, there are bikeshare programs in over 100 US cities (Bureau of Transportation Statistics, 2016).

Bikeshare in the City of Los Angeles

An earlier effort

The City of Los Angeles had attempted to launch a bikeshare program earlier in 2012 through a deal with Bike Nation, a private corporation, which would own and operate the system at no cost to the city. Bike Nation would generate revenue via user fees and corporate sponsorships and ad sales. The deal fell through when it was revealed that the city had an existing and exclusive deal with CBS/ JCDecaux to sell ads on all street furniture which includes bike kiosks (Nelson, 2013).

A new business model for bikeshare

The City then explored alternative business models for a bikeshare program and pursued a Metro-led program. In October 2013, the LA Metro board approved Motion 66 by Mayor Eric Garcetti, Supervisors Zev Yaroslavsky and Don Knabe, and Directors Mike Bonin and Pam O'Connor (MTA Board, 2013). Motion 66 adopted as policy, LA Metro's support for bicycle use as a formal transportation mode and ordered a bikeshare industry review and a business case analysis. Then in January 2014, the LA Metro Board approved a study on implementation of a Metro-led bikeshare program in Los Angeles County, citing the success of programs in cities including New York City, Chicago, Denver, and San Francisco, and numerous others. The argument for a LA Metro-led program, was to enable LA Metro, through a bikeshare program, to "connect and expand its transportation coverage to multiple jurisdictions along its transit system" (MTA Board, 2013). Furthermore, a "single-point agency will also ensure inter-operability among the different jurisdictions and can also provide a **multi-modal transportation system through the use of the Transit Access Program ("TAP") smart card**" (*Ibid.*, emphasis added).

Bikeshare planning: Working group convened

Metro staff convened a working group comprised of Metro staff, including TAP, OMB, and Creative Services, representatives from the cities of Los Angeles, Pasadena, Long Beach, Santa Monica, and several consultants, to develop the Bikeshare Implementation Plan. To aid in the development of the implementation plan, Metro held 20 meetings with the working group or individually with cities in Los Angeles County, as well as public Metro Bicycle Roundtable meetings. In addition, Metro engaged the community through crowdsourcing maps to identify one, bikeshare stations in downtown Los Angeles and two, future bikeshare communities (Planning and Programming Committee, LA Metro Board, 2015). Through this process and drawing from Metro's own Vision and Mission, the working group developed the following objective for bikeshare:

> Provide new and existing transit users with an accessible, reliable, and efficient mobility option as an integrated part of Los Angeles County's world class transportation system. (Metro, 2015)

Bikeshare Implementation Plan

The implementation plan consists of a business plan recommendation, a bikeshare suitability analysis including potential bikeshare station locations for phases 1 and 2 and a ridership forecast, and existing bikeshare hardware and technology and siting considerations. Metro would own and manage the system's equipment and contribute 50% of the capital cost of the equipment while the participating jurisdictions would contribute the remaining share of capital costs. For operations, Metro would contract with a vendor. In the development of the business plan, the group explored two general fare structures for the bikeshare program: conventional and integrated. An integrated fare structure would be:

> consistent with Metro bus and rail fares, along with payment media integrated through Metro's TAP card, [and] will provide a seamless passenger experience, encouraging use by existing Metro passengers and promoting use of Metro bus and rail services by new bikeshare customers. System branding, still under development by Metro Creative Services, will further integrate the system with the Metro brand while providing opportunities for sponsorship and recognition of participating jurisdictions (Metro, 2015).

Integrated fare structure proposed

The group focused on two types of integrated fare structures: *Integrated as Metro Service* and *Integrated as Muni*. *Integrated as Metro Service* is intended to encourage users to use both systems in a single trip by providing free transfers from Metro bus or rail service to bikeshare. In other words, users who use bikeshare after disembarking from Metro rail to complete their trip, would only pay the Metro fare of $1.75. Alternatively, *Integrated as Muni* is based on Metro's existing fare policy on transfers from Metro service to non-Metro transit service. Users who use bikeshare after disembarking from Metro service would pay a 50-cent transfer fee. In either fare structure, users would still have the option of purchasing a period-based (e.g., monthly) bikeshare subscription.

A conventional fare structure would be unrelated to bus and rail transit fares, akin to the fare structure of existing bikeshare programs in the country.

The result

The implementation plan played a significant role in Metro's development of the Request for Proposal (RFP) for a bikeshare system. In December of 2014, Metro released its RFP and received five proposals, of which four were determined to be within competitive range (LA Metro Board, 2015; Metro, 2014). In June of 2015, Metro Board awarded a $11.8 million contract to Bicycle Transit Systems, Inc. (BTS) to launch the first phase of a countywide bikeshare program beginning in downtown LA with expansion to other municipalities in the years following (Sotero, 2015). A year later, on July 7 2016, the first phase of LA's new bikeshare system, Metro Bike Share, opened as a joint partnership between LA Metro and the City of Los Angeles. The system features 65 stations with 1,000 bikes distributed across downtown Los Angeles (Figure 13). In the first month of operation, users had to use a TAP card in order to access the system. Users can either register an existing TAP card when registering for a bikeshare pass online by entering the card's unique serial number.[4] Or, they can opt to receive a new TAP card in the mail that would be paired with either a 30-day pass or a flex pass:

- A 30-day pass for $20. Trips 30 minutes or under would not incur additional charges. Longer trips would incur $1.75 per 30 minutes thereafter. With a 30-day pass, a trip lasting 27 minutes would be free/included in the pass but a trip lasting 37 minutes would cost $1.75.
- An annual "flex pass" for $40. Trips are $1.75 per 30 minutes. With a flex pass, a trip lasting 27 minutes would cost $1.75 while a trip lasting 37 minutes would cost $3.50.
- A walk-up, one-time trip is $3.50 for 30 minutes. Trips longer than 30 minutes would incur additional cost of $3.50 per 30 minutes. With a walk-up pass, a trip lasting 27 minutes would cost $3.50 while a trip lasting 37 minutes would cost $7.00.

[4] This is in contrast with HOURCAR's approach which automatically pairs a transit card with an account the first time it is used. However, LA Metro expressed concerns that the manual pairing required to use an existing TAP card with Metro Bike Share may increase the burden of registration thus the current system, by default, is set to send users a new TAP card.

Figure 13: Map of Metro Bike Share locations and rail stations in downtown Los Angeles.

Phased rollout to emphasize integration

Restricting use of bikeshare to monthly or flex pass members was part of a phased rollout strategy which was intended to, one, encourage users to subscribe to a monthly or a flex pass and two, provide MTA and BTS a buffer to conduct quality assurance tests and identify issues and refinements before opening the system up to casual users (Metro, 2014). Metro Bike Share also offers a corporate pass program where employers can purchase memberships in bulk (minimum of five memberships) and offer memberships as a benefit to employees at a discounted rate. Similar to other bikeshare programs, pricing is structured to encourage short trips. A unified fare policy between transit and bikeshare has not been adopted as of April of 2017.

Bikeshare as an extension of LA Metro's system

From the day Metro Bike Share launched, the program has been consistently marketed as an extension of the transit system. Metro's blogpost describing the launch states, "Many bike share stations are located close to the Metro Rail and Bus network, giving transit riders direct access to Metro Bikes to easily combine bicycle and transit trips" (Sotero, 2016). The bikes and the kiosks in the system carry LA Metro's logo (see Figure 14).

Figure 14: Metro light rail train (left) and Metro Bike Share kiosk (right). Source: LA Metro

Payment method convergence

While a user can use their TAP card to access both transit and bikeshare, on the back-end, the two systems do not share information. Thus only front-end integration was achieved. TAP uses a card-based system and not an accounts-based system and as a result, data regarding a user's transit passes and stored value are stored on the card itself, and not in a backend database. In this system typology, the card and the reader determine whether to grant access. On the bikeshare system side, the TAP card is used as an identifier as in an account-based system and data regarding bikeshare accounts and trips are stored in a back-office system and not on the card. When a TAP card is used at a bike dock, the RFID reader reads the TAP identifier number on the chip and sends the number via API (application program interface) for BTS to verify the card is associated with a valid bikeshare membership and is not on the list of "hostlisted" card numbers and then grants access. Thus the back office determines whether to grant an approval or a denial.

CHAPTER V: Findings

As discussed in Chapter II, payment media and equipment interoperability has been identified as the primary challenge to multimodal payment convergence. While interoperability is technically feasible, institutional factors influence whether payment convergence is adopted. Common themes from the experiences of Los Angeles and Minneapolis-St. Paul are presented below, shedding light on potential factors critical to supporting multimodal payment convergence efforts.

Findings

Payment integration requires a hardware upgrade

Consistent with previous cases of unsuccessful payment integration, equipment interoperability is a major barrier. In Minneapolis-St. Paul, HOURCAR had to procure and install new hardware on its vehicles for compatibility with Metro Transit's Go-To Card. While the total costs and staff time expended for this upgrade are unreported, the CMAQ funding amount of $144,000 and a total fleet size of about 60 vehicles, suggests that at minimum, payment integration (in this case) cost roughly $2,400 per vehicle.[5]

In Los Angeles, TAP card compatibility also required an equipment change. While HOURCAR had to upgrade equipment on approximately sixty vehicles, BTS was dealing with much more equipment, approximately two thousand bike docks, each with its own RFID reader. BTS' subcontractor for bikeshare equipment, B-Cycle, uses passive, low-frequency RFID readers, tags, and cards to manage bike access. However, TAP cards operate on a high-frequency thus B-Cycle had to install multi-frequency readers on bike docks for the LA system to enable reading of both low-frequency bikes and high-frequency TAP cards. Multi-frequency readers are more complex and more costly (Shavit, 2017). Cost of the multi-frequency reader as compared to the cost of a standard low-frequency reader is unreported though capital cost of the bikeshare system in downtown LA was estimated to be $5.8 million, about $5,300 per bicycle (Metro, 2014). The few reported estimates of capital costs of other US

[5] Some of the CMAQ funding may go towards operational costs thus actual hardware costs may be less than $2,400 per vehicle.

bikeshare systems range from $4,000 to $5,000 per bicycle (Institute for Transportation & Development Policy, 2014).

Interoperability between payment systems with differing system architecture is possible

As with most transit systems in the US with electronic payment systems, LA Metro and Metro Transit have a card-based fare collection system. Likewise, the shared mobility services, Metro Bike Share and HOURCAR, have an account-based system. Figure 15 illustrates these system architecture types. These cases suggest interoperability between the two system typologies is possible without changing the fundamental architecture of either system. However, one of the systems must be account-based, which is consistent with previously documented cases of integration with non-traditional partners where at least one of the partners has an account-based system (Okunieff, 2017).

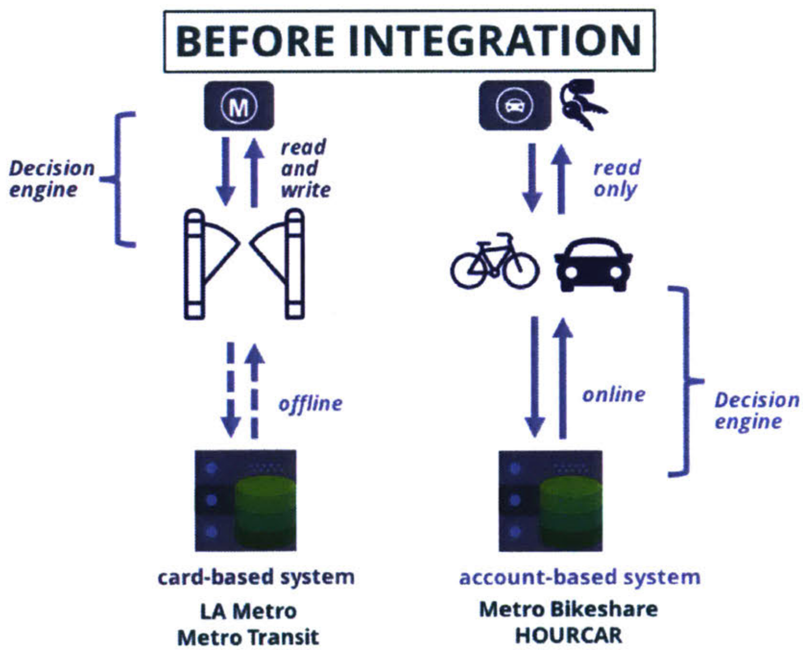

Figure 15: System architecture of transit systems compared to that of shared mobility services in Los Angeles and Minneapolis-St. Paul before payment integration. Different payment media are requierd to access the two systems. Note that Metro Bike Share never had its own access media. Rather this image is illustrative of other US bikeshare programs' system architecture and what LA's system would potentially have looked like absent an intentional decision by LA Metro to integrate payment media. HOURCAR's system architecture is as

depicted prior to payment integration. Source: Author's own figure. Icons made by Freepik from www.flaticon.com, licensed by CC 3.0 BY.

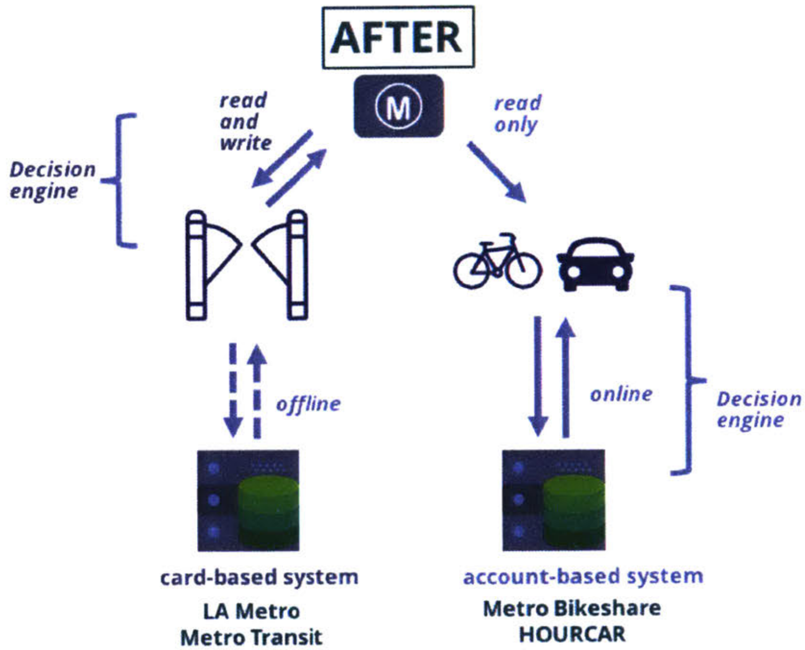

Figure 16: System architecture of the two systems remain largely the same after payment integration. The only change is in the media used to access the systems. Source: Author's own figure. Icons made by Freepik from www.flaticon.com, licensed by CC 3.0 BY.

Both public and private sectors are reluctant to share data

Previous research suggests both public and private transport operators are reluctant to share its data (Carlin et al., 2015). The findings in this case are consistent with previous research. In the Minneapolis-St. Paul case, the fact that HOURCAR did not need to access any proprietary or confidential data on the Go-To card or on Metro Transit's databases, helped it win the support of Metro Transit for payment integration (Hansen, 2015). In Los Angeles, BTS also does not have access to TAP databases. LA Metro, as the owner of its bikeshare system, has encountered some obstacles in obtaining bikeshare data from the operator, BTS—data that Metro legally owns according to the legal contract between the two entities (O'Hara, 2017). However, due to the structure of BTS's database, restricting data access to only LA's data while protecting user data on other BTS-operated bikeshare systems in the country, is complicated and difficult (*Ibid.*). As a result, it raised privacy and legal concerns for both parties—how to protect its customers' data and Metro's liability if that data were inadvertently made public. Efforts, however, are ongoing to enable LA Metro to access this data without compromising the security of other BTS data (*Ibid.*).

Data sharing more likely to occur when clear benefits exist

TAP does provide BTS some data: on a daily basis, BTS receives an updated list of "hotlisted" TAP card numbers, i.e., cards that have been identified as expired, expiring, or reported lost or stolen (O'Hara, 2017). This allows BTS to cross-reference TAP cards presented at bike checkout and ensure the card is valid, and protect its users if the card was reported stolen. It also allows BTS to notify users to get a replacement card if their card is to expire soon. While data sharing is minimal, that TAP shares "hotlisted" card data with BTS supports previous research findings that collaboration is more likely to occur when there are clear benefits for both parties.

Differing system architecture can pose a barrier to fare policy integration

The more difficult challenge is integrating the backend of the two systems and neither of the cases has yet to achieve this. Backend integration is critical in order to facilitate implementation of an integrated fare policy and in both cases, the challenge primarily stems from the card-based system architecture of the transit card.

The most critical difference in these two system typologies, account-based and card-based, is in the storage location of user data. While a user's transit data is stored locally on the user's smart card, bikeshare or carshare data is stored remotely in a back office. As a result, transit card validators are able to grant free or discounted transfers based on a local read of the user's recent activity. For shared mobility services, trip data is not read from or written to the card; the card only acts as a token to the account in the back office (see Figure 16). If existing transit validators were programmed to read remote data (in addition to reading and writing local data), the transaction processing time would dramatically increase, and so is not a viable option for transit agencies for which rapid processing is crucial (Okunieff, 2017). Similarly, to program RFID readers on bikeshare or carshare systems to read local card data is also difficult and expensive as these readers, unlike transit validators, rely on the back office for most processing.

Real-time transfers or incentives are unlikely but workarounds exist

Though the challenge of integrating data has yet to be resolved, in LA, BTS and Metro are actively working to transition to a single back-end system, bringing bikeshare data into TAP's databases. In the foreseeable future, however, immediate transfer discounts akin to those available on Metro's bus and rail system are unlikely for bikeshare and transit until the agency transitions to an account-based transit system. Rather LA Metro envisions a system similar to retailers' customer loyalty programs that give users rewards based on certain account activity. Adding a delay between user activity and granting of rewards or reimbursement would enable information systems to reconcile data and is thus easier to implement (Shavit, 2017). As an example, one reward scheme could be if you use bikeshare for *x* total minutes in a week, a free single-ride fare is loaded onto your TAP card. In other words, backend integration of a card-based system and an account-based system is technically feasible. However, given that some of the equipment in the card-based system is offline (e.g., fare validators on buses), real-time data integration is not feasible as time is needed to reconcile data between field equipment and system databases.

Strategies for Overcoming Barriers

In addition to the barriers and challenges transport providers face in implementation of a multimodal payment system, this research also illuminated several strategies Los Angeles and Minneapolis-St. Paul have used to overcome barriers.

Multimodal payment convergence need a leader and financial support

In the previously documented cases of innovation adoption by transit agencies, researchers found that the presence of a champion and funding were two themes common throughout successful cases (Hikichi & Beimborn, 2005). The examples of Los Angeles and Minneapolis-St. Paul are no different.

In LA, the effort was led by LA Metro, and its success stems from the agency's commitment (as directed by its Board) to payment convergence. As an agency, it is also committed to supporting bicycling as a means of transportation in the region and has funded bicycling/pedestrian projects for over a decade (Shavit, 2017). As a result, its decision to add a bikeshare program to its portfolio, in particular one that would serve as an extension to its existing transportation system and offer TAP card interoperability, afforded it complete control over the design and implementation of bikeshare and bikeshare's role in transportation in the region. Metro's commitment and willingness to devote resources and staff time to the effort helped overcome the technical challenges that existed, from installing more costly hardware on the bikes to coordinating with BTS to provide it an updated list of "hotlisted" TAP cards.

In the Minneapolis-St. Paul case, HOURCAR, a nonprofit organization, led the payment integration effort, recognizing the mutual benefits in an integrated payment card. With support from a federal grant and a team of nimble and committed staff, it was able to quickly implement the equipment upgrade. (The process from when the grant was approved to launch lasted about a year.)

Payment integration efforts benefit from existing relationships between stakeholders

Metro Transit and HOURCAR had an existing working relationship; Metro Transit has allowed HOURCAR to park vehicles near light-rail platforms and transit centers since HOURCAR's inception and staff at the two organizations knew and trusted one another. NEC, HOURCAR's parent company, is a local company with decades of experience working in the region and HOURCAR, at the start of the partnership had already been in operation for seven years. That HOURCAR does not operate in any other region and is committed to serving a broad demographic, also fosters trust between the two entities. This partnership suggests that establishing trust reduces the perception that the other party is a market competitor, increasing the likelihood that public and private parties collaborate with one another. This finding is consistent with previous research on the importance of sustained relationships and building trust over time to foster collaboration.

LA Metro did not have an existing relationship with BTS but this was less critical as Metro remains the owner of the bikeshare system, allowing it complete control over the design of the system.

Prior experience with interagency collaboration is beneficial

Both transit agencies, LA Metro and Metro Transit, have previously worked with other transit agencies in the region to use a common smart card. After years of negotiations with other transit operators, twenty-six agencies today in LA County accept the TAP card. Though this is not inclusive of all transit operators in the region, this is a significant feat and speaks to LA Metro's extensive experience in navigating the technical, legal, and operational challenges associated with payment integration. Likewise, Metro Transit's Go-To card is accepted by other transit agencies in the region. These experiences help build up an organization's inter-organizational collaborative capacity, as well as a gradual track record of success, increasing the likelihood of future interagency partnerships.

CHAPTER VI: Conclusions

This research provides evidence for the hypothesis that while electronic payment technology has matured to enable multimodal payment convergence, payment media and equipment interoperability remains the key challenge to implementation. However, critical institutional factors as in the cases of Los Angeles and Minneapolis-St. Paul, can support implementation of multimodal payment convergence. These projects along with general trends in the electronic payment industry are reducing barriers to seamless and flexible payment systems critical to creating high-quality public transport networks.

The opportunities for multimodal payments identified through this research are summarized in the recommendations that follow.

Recommendations

Incremental collaboration to build trust between stakeholders

The examples of Los Angeles and Minneapolis-St. Paul highlight opportunities for payment integration to occur incrementally, without overhauling existing system hardware and architecture. Specifically, opportunities such as partnerships with on-demand/shared mobility services that already have account-based, electronic payment systems. By integrating payment media only, stakeholders are able to make progress towards complete payment integration without the need to work through complex governance and operational rules around financial costs, allocation and settlement and decision-making authority thus also minimizing potential risks associated with payment integration. These partnerships also set the stage for future integration efforts by increasing interagency collaborative capacity and establishing trust between stakeholders and a gradual track record of success. Shared mobility providers also tend to upgrade their hardware and software more regularly thus coordination between transport providers (discussed in more detail below) can help identify such prospects. Federal funding programs provide opportunities to pilot such programs.

Implementation can be expensive but federal funding helps reduce cost barriers

Technology adoption is expensive both in actual capital costs and in personnel resources needed to bring the project to completion. For transit agencies with extensive field equipment, upgrading payment systems for the express purpose of compatibility is not practical. However, transport providers, traditional transit providers and nontraditional transport providers like carshare and bikeshare, should seize opportunities to implement multimodal payment systems as HOURCAR and LA Metro did. For example, when existing equipment reaches the end of service life, or if a transport provider has a flexible RFID reader such that only programming changes are needed to read a different smart card. Transport providers should also consider creative "workarounds" as in the case of CTA affixing an IGO carshare RFID sticker on its transit card for multimodal compatibility.

Federal funding can help bridge the financing gap when opportunities do emerge. Initiatives like US DOT's Smart City Challenge and the Federal Transit's Administration's Mobility on Demand Sandbox Program are critical to encouraging innovative public transit projects and developing evidence for integrated mobility projects. They are particularly helpful in mitigating the perceived risks of public-private ventures. Furthermore, these projects help establish best practices and models of integrated payment system design and implementation for other regions.

Make interoperability/compatibility a priority when procuring a new payment system

As transit agencies begin planning their next generation fare collection systems, the ability to integrate with other payment media and other transportation providers should be part of their evaluative criteria. Given the speed with which technologies evolve, it is difficult to predict exactly how payment systems will look in the future but open payment systems are a practical choice given consumer demand for flexible payments and the benefits of open payment systems. Not only will such systems reduce payment media issuance and fare collection costs, interoperability will be automatic between providers and merchants that accept open payments. Furthermore, stakeholders will be able to bypass the need for complex governance rules and agreements to achieve interoperability. After deployment, stakeholders can then negotiate cost-sharing and revenue-sharing and add transfer discounts and other fare policies through changes to back-end processes. Leveraging standards-based hardware and software developed for the larger market of financial payments will also lower costs for transit agencies and reduce the risk of vendor lock-in and costly proprietary equipment maintenance.

There are drawbacks to open payment systems as discussed in Chapter II. For example, slower transaction times, greater need for data security and compliance with Payment Card Industry (PCI) standards, involvement of financial institutions, and need for network connectivity. Agencies can look to the experiences of TfL, UTA, and others with open payment systems and their strategies to minimize such risks. To address the issue of comparably slower transaction times, for example, UTA requires riders to first register their cards with the agency to facilitate authorization. When a rider boards a vehicle and taps a card on the reader, the central system validates that the card is authentic without a full authorization process and grants entry. Then, a full authorization is performed in the background. At the end of the trip, the passenger taps again to complete the trip or get a transfer. The final charge is processed in the back-end by matching all card taps within a two-hour window to determine the final fare (Smart Card Alliance, 2011).

New systems should have account-based capabilities

Next generation fare collection systems should employ an account-based system architecture while retaining part of a card-based system if necessary. Findings from the experiences of Los Angeles and Minneapolis-St. Paul are consistent with previous research on the criticality that at least one of the partners uses an accounts-based system in order to achieve interoperability. While interoperability with card-based systems is possible, complete payment integration involving common fare passes and transfers requires that both systems be account-based. With an account-based system in place, agencies can more easily integrate other services and providers in a modular fashion through software changes in the back office. This will also support the creation of a more seamless account management interface for the customer. LA Metro is moving toward a hybrid approach by adding account-based system architecture to a card-based system. Customers will have one primary Metro TAP account from which other accounts, e.g., transit, bikeshare, rideshare, will draw. Information related to a user's transit passes will still be stored on the card itself but they can purchase passes or fares using credit in the central account. The agency can then link user activity data through back-end processes and offer rewards or other incentives for future travel.

Emphasize regional mobility planning and management

Finally, I recommend that transit agencies go beyond the traditional model of public transit provision and take on a broader role as mobility managers. In many cases, transit agencies already manage multiple transport modes and programs, thus are well positioned to coordinate mobility needs across departments, jurisdictions and public/private lines. Some transit agencies are already moving in this direction, including LA Metro and San Francisco Municipal Transportation Agency, and agencies in Seattle. Doing so would support a more integrated transport planning approach, not just in terms of payment systems but also in improving network, schedule, and information integration. In addition, I recommend that cross-agency working groups consisting of multiple stakeholders across public and private sectors (some already convened by opportunities like joint grant applications, e.g., USDOT's Smart City Challenge), continue to work together to create policies toward common mobility goals. At a minimum, convening information-sharing sessions of regional transport operators help start the conversation, establishing relationships and trust among stakeholders. Especially when previously unknown business models are entering the marketplace, these opportunities ensure everyone's goals are on the table.

Future Research

Impact of multimodal payment systems on travel behavior

More research is needed to determine whether multimodal payment systems encourage modal shift. Is the upfront cost associated with implementing integrated payment media justified? Does it actually change user behavior and/or improve customer satisfaction? Expanding on this, does an integrated fare structure, which requires an even greater investment of organizational resources to coordinate, encourage modal shift by non-captive riders to a degree that justifies the investment? For example, if the agency offers a discounted transfer from transit to bikeshare, are users more likely to use transit instead of drive? Or are integrated payment systems insufficient to address overall public transit deficiencies such as unreliable service?

Potential business models for integration of fare policy

This thesis did not explore business/financial models for integrated fare policies between traditional and non-traditional transport providers. While transit operators using single, regional fare card have successfully negotiated agreements on costs, and revenue sharing, transit fares structures and policies tend to be more similar. As a result, new business models are needed to support a common fare structure across private/public operators and mobility services with substantially different cost models. Should there be a subsidy for shared mobility services, similar to public transit? How should transfers between services be priced? Who should manage the backend system? Does a customer have to contact multiple customer service offices to resolve an issue and if not, which organization will retain control of customer support? In addition, market research is needed to determine pricing of multimodal trips and passes. Recent partnerships between transit agencies and transportation network companies for first-mile, last-mile service and international examples of multimodal transit period passes (e.g., TAM in Montpelier, France) can shed light on consumer preferences and best practices.

Equity and social justice of electronic payment systems

The modernization of fare collection systems has raised significant equity and social justice issues. Transit agencies in the US and internationally, must accommodate cash fares to comply with universal service obligations, which is significantly more expensive to support compared to electronic payments. For instance, the transition to reusable media, like contactless smart cards, has posed problems for social service agencies that purchase single-trip tickets in bulk to distribute to their clients. In Chicago for example, community organizations can either opt to distribute reloadable cards to its clients, which cost $5 each, or purchase single-fare tickets at CTA stations that cost $0.50 more per trip (the cost is intended to discourage single-use tickets). Though the cost of the card can be applied for future travel if the card is registered online, the system currently does not provide a way to register or manage cards in bulk. Even more problematic is the cards can run a negative balance. Research is needed to ensure that open payment systems and account-based systems do not disproportionately impact the most vulnerable riders or exclude certain riders from enjoying savings through integrated fares. Though most shared mobility service providers like bikeshare services, require a credit or debit card on file, some systems are offering alternatives for users without credit cards. Research on such programs can inform best practices in protecting riders without bankcards or riders without smart phones in new electronic payment systems.

Mobility as a service (MaaS)

Multimodal payment convergence is the foundation of an emerging concept known as "Mobility as a Service" (MaaS). MaaS refers to a digital marketplace or platform to plan and purchase mobility services across all modes of public or private transportation. As a single trip often spans service on multiple modes, rather than plan, book, and pay for each of transportation mode separately, a MaaS platform would allow users to purchase the "package" of services using a single app or website. Helsinki, Finland launched a MaaS app known as Whim at the end of 2016 to a limited group of users. Users enter a destination and the app provides a choice of door-to-door routes by a combination of public transport, taxis, and rental cars, and in the future, long-distance buses and trains, and carshare and bikeshare. Users can pre-pay for the service as part of a monthly mobility subscription or on a pay-per-use basis, all in the same app. The group behind Whim is planning expansions to markets in the UK, Canada, and potentially US. MaaS is still relatively new and more research is needed on its impact on short-term and long-term behavior changes. In the short-term, could MaaS increase car usage by reducing barriers to car rentals but in the long-term, could MaaS reduce car ownership? Furthermore, what institutional structures are necessary in order for MaaS to succeed? What are the incentives for public and private operators to relinquish the control necessary to implement MaaS?

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APPENDIX I: Sample Interview Questions

Name

Role / Title

Experience of multimodal planning in your city

Why did the city decide to integrate transit with another mode?

Advocates?

Any opponents?

Describe the process that took place to result in multimodal integration.

What were the technical limitations?

What were the non-technical barriers (environmental/ organizational / financial etc.)?

How were these barriers overcome?

What would you have done differently if you had to do it again?

What lessons or takeaways that may help other cities with multimodal integration?

Future plans

Does the city/agency have plans for integration with other modes?

Does the previous experience with integration help or hurt future opportunities to work with public/private sector?

Wrap-Up

Is there anything else that you think might be useful that we have not covered yet?

Are there other people I should connect with?

Are there resources that may be helpful to my research?

May I follow-up if I identify other questions?