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“One card to rule them all:”

Towards a Critical Understanding of New Fare Collection Technology

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“ONE CARD TO RULE THEM ALL:” TOWARDS A CRITICAL UNDERSTANDING OF NEW FARE COLLECTION TECHNOLOGY

A THESIS APPROVED FOR THE
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Abstract

Payments for public transit are changing, as agencies adapt to the near-ubiquity of smartphones as well as credit- and debit-cards in order to secure fare revenues. These developments have enabled many transit agencies in the U.S. to implement new fare collection technology (NFC). Previous forms of fare collection, which relied on paper tickets, tokens and magnetic-striped cards, are giving way to "automated" and "smart" modes of payment via smartcards and mobile apps. In their roll-out of these technologies, transit agencies typically claim that they will operationalize "convenient" and "seamless" forms of mobility through their chosen mode of fare collection. However, these technologies serve instead as a "fix" for transit agencies, which employ light infrastructure investments that support a market for private mobility services. While NFC technology shapes public transit to serve capitalist imperatives, it also must contend with the social infrastructures which also shape urban mobility.

Keywords: mobility fix, fare collection, infrastructure, critical transportation

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This work is dedicated to anyone who has had their money eaten by a token machine, had their fare card swipe rejected by a turnstile, or had value stuck on an expired card.

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Acronyms

AFC – Automated fare collection
API – Application programming interface
APTA – American Public Transportation Association
BRT – Bus rapid transit
DART – Dallas Area Rapid Transit
EFC – Electronic fare collection
EMV - Europay, MasterCard, and Visa
FTA – Federal Transit Administration
GTFS – General Transit Feed Specification
ICT – Information and communications technology
MBTA – Metropolitan Massachusetts Bay Transportation Authority
MTA – Metropolitan Transportation Authority
OTP – On-time performance
SEPTA – Southeastern Pennsylvania Transportation Authority
TfL – Transport for London
TIF – Tax increment financing
TNC – Transportation network company
TRB – Transportation Research Board
WMATA - Washington Metropolitan Area Transit Authority

Chapter 1: Introduction

One card to rule them all? Introducing new fare collection technology

In 2015, CityLab heralded the imminent arrival of new fare collection technology in the U.S., declaring "Coming Soon to America: One Card for All Transit" (Spector 2015).The headline of the article, by Julian Spector, seemed to inspire several near-facsimiles published between 2015 and 2020 (fig. 1). Each headline conjured an imaginary future where transit payment would only require a single form of fare payment media. In the CityLab article, Spector highlights the extrospective nature of urban technological change, pointing to the leaps in transit ticketing technology that have taken hold in other parts of the world. One example, Transport for London's (TfL) OysterCard, integrates payment for dozens of public and private transit services across the metro, allowing riders to pay for downtown buses and suburban rail lines with a single "tap" of a smartcard.

For Spector and subsequent journalists, an integrated ticketing system like TfL's promises convenience, alleviating the mental burden of carrying exact change, as well as providing sophisticated data for transit agencies, with the caveat that this technology must reach a certain economy of scale to be useful (Spector 2015). The emergence of this discourse in the U.S. is contemporaneous with the increased reliance by public transit agencies on fare collection revenue for operations funding (FTA 2019, APTA 2019). In this thesis, I will explore why new technologies of fare collection have been implemented by transit agencies in the U.S. I argue that they serve as a mobility fix for transit agencies looking to streamline and secure this increasingly important revenue stream, while allowing for further integration between public transit and heavily-capitalized private mobility firms.

While this "one card" imaginary resonated with me a few years ago, I eventually found that the political economic implications of new fare collection (NFC) technology demanded greater attention. As someone who relied heavily on public transit in the Philadelphia metro region, the era of exact-fare required, no change given on Philadelphia's trains and buses is still ingrained in my memory. In my early-20s, I had the experience of using TfL's OysterCard, enjoying the convenience tapping the same fare card for any transit service in the region, along with TfL's "customer-friendly," rational fare policy. In Philadelphia, SEPTA began rolling out their own smartcard, called Key, in 2014. The convenience and integration that smartcards could supposedly deliver were missing from my experience of using Key for travel in Philadelphia. As the excitement of Key waned, proportional to its messy roll-out, I realized this imaginary is bound by the logics of transportation governance in the U.S. When I started to think about this technology in-terms of mobilities and critical transportation scholarship, I also realized this promise of convenient public transit as delivered through new technology such as smartcards was laden with contradictions and deserved further scrutiny.

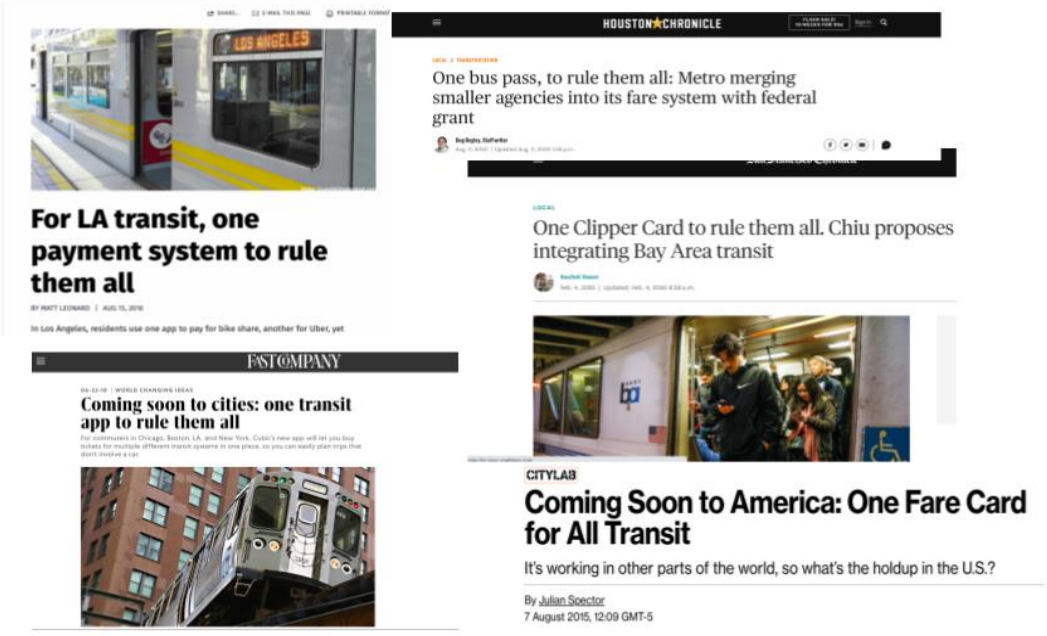

Figure 1: The spread of the "one-card" imaginary in transit journalism, 2015-2020

Defining NFC technology

The smartcard technology which SEPTA rolled out in Philadelphia is only one among several new fare collection technologies deployed in the U.S. The FTA uses the terms "Electronic Fare Payment" and "Automatic Fare Collection" interchangeably to refer to the use of smartcards and mobile tickets as payment for transit (2020). However, they also include in these categories "legacy" technologies like magnetic stripe cards. In order to distinguish the objects of my study from these "legacy" technologies, I draw on the concept "next generation fare payment" from Wallischeck (2015). In a report sponsored by the TRB, which serves as an advisory and policy agenda-setting institution for transit governance in the U.S., Wallischeck writes:

> It is an aspirational, self-defining phrase that might best be described as, something better than what we have now… As new technologies such as smart phones and mobile applications are introduced, new opportunities emerge to apply those technologies to public transit fare payment systems...Such a transit fare payment system would have a high degree of flexibility and adaptability, so that it is better able to accommodate evolutions in technology (p. 4).

Some of the "opportunities" afforded by smartphones and EMV-chipped bank cards that transit agencies have embraced include smartphone-based mobile ticketing apps and agency-issued smartcards, in addition to "open loop" systems which accept credit cards and other near-field communications-enabled tokens. In order to account for the increasing, but uneven, deployment of mobile applications, smartcards and open-loop systems, as well as limit my study to those technologies, I have termed the objects of my study new fare collection technology (Table 1).

	Legacy fare collection	NFC technology		
Media	Tokens Paper tickets Mag-striped cards	Smartcards	Mobile ticketing	Open payments
Examples	TfL Travelcard; Multi-trip hole punch tickets; MTA Metrocard; SEPTA TransPass	TfL OysterCard; WMATA Smartrip; MBTA Charliecard; CTA Ventra; LA Tap; TriMet Hop Card;	Masabi Justride; TokenTransit; DART/Vix GoPass; Transit App	Trimet HOP; MTA Omny; EMV-chipped cards; Near-field communication enabled devices ("wearables", key fobs, phones)

Table 1: Simplified overview of NFC technology with examples

When I discuss NFC technology in my study, I am referring to the entire suite of hardware, software and payment media which make-up a fare collection system. When I discuss NFC payment media, I will refer to a specific media like smartcards, mobile ticketing apps, or open payment media such as bank-issued cards. When I discuss NFC infrastructure, I am referring to the fixed hardware components of the system, such as fareboxes and turnstiles.

Approaching NFC technology critically

At transit agencies across the U.S., the purchase of a fare grants riders access to extensive, public networks of mobility infrastructure. Meanwhile, for agencies, the fare represents a substantial portion of their directly generated revenue. Directly generated revenue from fares makes up about 36% of transit operations funding nationwide, a greater share than any form of government assistance or other agency revenue source (FTA 2019). This increase in directly generated revenue for operations funding comes alongside a decrease in public transit ridership between 2010 and 2019, which is most acutely felt on buses (APTA 2020, FTA 2019). In that

same period, the share of agencies offering smartcards increased from 12 percent to 48 percent, with mobile ticketing apps and open loop systems growing apace (APTA 2019). According to the TRB (2020), these new technologies, along with declining infrastructure and operations funding, present "opportunities" for public transit agencies to integrate with app-based private mobility services.

The deployment of NFC technology is growing, in tandem with pressure for agencies to complement so-called "new," private mobility services from transportation network companies (TNCs) and micromobility solutions like e-scooters and bikeshare. Despite an understanding of mobility infrastructure as a political terrain, and an attentiveness to these recent shifts toward "new" mobility provision, the transition that agencies are making to NFC technology has been overlooked by academics. To address this gap, I develop a critical understanding of this technology by deploying methodological approaches from policy mobilities and infrastructure studies in a study of the implementation of NFC technology at transit agencies in the U.S. I take a "distended" (Peck and Theodore 2011) approach to NFC technology to examine how it has been adopted and territorialized in different transit agencies, by actors across the public and private sector. I situate my findings in a framework informed by critical transportation and mobilities scholarship. I argue that NFC technology serves as a mobility fix, that insufficiently addresses the needs of public transit riders while heightening the enclosure of urban mobility.

Structure of the thesis

I will proceed in Chapter 2 by providing scholarly antecedents for my study. I review literature from policy mobilities and infrastructure studies, from which I draw an understanding of infrastructure and policy as socially produced and conditioned by political-economic imperatives. I then turn to critical transportation scholarship to show how mobility infrastructure serves as a

fix, produced and productive of similar political economic imperatives. From critical transportation scholarship, I also discuss recent work on attempts to wrest mobility away from these imperatives, toward a mobility commons.

In Chapter 3, I provide a methodological justification for my study, returning again to policy mobilities. I also provide an overview of my participants and reflect on my own position in relation to them. In Chapter 4, I provide an overview of my results, highlighting five themes drawn from semi-structured interviews with key actors in NFC technology at public transit agencies and in the private sector. In Chapter 5, I discuss my results. I show how NFC technology has served as a fix for transit agencies, allowing them to extend services limited by budget constraints and urban form, with minimal investment in fixed infrastructure and while serving the interests of private mobility firms. I discuss how NFC technology follows other technological and infrastructural enclosures of mobility. I also highlight the social infrastructures and labor which shapes and limits the digital infrastructures of NFC technology. In Chapter 6 I conclude with suggestions for future study and implications for practice.

Chapter 2: Literature Review

Introduction

To develop a critical understanding of NFC technology, I draw on scholarly antecedents from across the social sciences. Work from policy mobilities and infrastructure studies helps to understand policy and infrastructure as unstable and political, attending closely to its production and circulation. I explore how policy mobilities has examined the production of mobility infrastructure. I then highlight the mobilities turn, which enlivened studies of movement — aboard transit and beyond—with critical social theory. However, more recent strains of critical transportation scholarship are better able to contend with the political economic imperatives of recent mobility infrastructure paradigms. I highlight three key concepts from this literature: the mobility fix, the mobility commons, and the Right to the City. I conclude with a discussion of why these concepts should be extended to the study of NFC technology.

The production of infrastructure and the concretization of policy

Work from the infrastructure turn in the social sciences, and in geography in particular, has emphasized the uneven, gendered and racialized *outcomes* of infrastructure provision—infrastructure's 'what and where'—but few have attended to the processes and structures that have shaped infrastructure's production (Lin, 2018; Siemiatycki et al., 2020). Meanwhile, policy mobilities draws from social studies of science and technology, economic geography and political science in order to attend to the networks of policy production (Lovell 2019; Temenos & McCann 2013). but has rarely explored the material infrastructures through which it is concretized. This is in spite of the "strangely familiar feeling" (Temenos & McCann 2013, p. 344) that accompanies seeing a policy-model materialized in the urban environment. There is a need to analyze, not just the differentiated effects of policy and infrastructure on urban lives, but how "the material fabric

of the city" (Levenda 2019, p. 646) is enrolled in and impacted by infrastructure and policy deployments. I suggest that this might be accomplished by foregrounding the actual work of producing policy and infrastructure, which can unsettle dominant narratives about the production of urban space; showing how the "fleeting spaces" of policy production have lasting impacts on the built environment in which they are deployed; and that, subsequently, those impacts reverberate as (un)successful policies go mobile and infrastructure is copied.

Both policy mobilities and infrastructure studies foreground the previously "backstage" and "mundane" work of production and maintenance of their respective objects of study, contributing to broader understandings of urban space as socially produced, unbounded, and relational (Leigh-Star 1999; McCann 2011; Temenos & McCann 2013). Of particular importance to policy mobilities scholars is the co-constitutive production and circulation of policy knowledge and capital within and across cities (McCann 2011). Revealing such mundane and background work has the effect of unsettling "master narratives" that can suffuse the production of policy and of infrastructure, such as that they're the result of self-reliant rational state actors and "master builders" (Leigh-Star 1999; Lin 2018; Siematycki et al. 2019). Scholars working in policy mobilities have contributed to this by showing how policies and the infrastructures that they are worlded through are shaped outside formal institutions of governance. For example, corporations have emerged as policy actors contributing "model" policies shaping infrastructure from energy grids to airports (Bok & Coe 2017; Levenda 2019; Lovell 2019).

Work in policy mobilities shows that the production of policy is topological, connecting geographically far-flung places through the export of policy models and the travel (literal and figurative) of policy and its practitioners. This makes policy both mobile and emplaced - both relational and territorial (McCann 2011l Ward 2018a). For example, in Ward's (2018a) example,

tax increment financing does not just lifelessly prime cities for global investors, but rather is taught, archived and adjusted within an "informational infrastructure" that not only transmits model policies but will eventually shape the landscapes in which they are placed (Ward 2018a). The dual relational/territorial nature of contemporary policymaking is also evident in the case of bus-rapid transit (BRT). For Wood (2015), bus-rapid transit (BRT) serves not just as a means of transport, or a transportation planning trend, but becomes one point at which "South-South connections" might be forged via the interactions and learning experiences of South African planners in Bogota. While the sites and moments of policy learning and exchange are often held to be "fleeting" (Ward 2018b), and policy implementation is "fast" (Peck & Theodore 2015) policy mobilities scholarship should acknowledge the much more legacy of policy once it's in place, as it so often is enacted through material infrastructures.

Policy and infrastructure shape the spatial contexts in which they are placed. Policy successes as well as its failures may reverberate over vast distances, potentially influencing projects on the other side of the world. The dual purpose of infrastructure as both technical and semiotic (Larkin 2013) is also true of policy: policy is produced, assembled through the work of many different policy actors, before it takes off as a model, representative of best practice to other policy actors, serving as a vector for certain logics to spread (Bok 2015; Lovell 2019; McCann 2011). Along the way, these actors and logics imbue policy with a "poetic" quality (Larkin 2013) as it is conditioned through particular political, economic and ideological channels (Peck 2011). Policy mobilities work elaborates Larkin's (2013) claim that infrastructures are often deployed to bring about some type of future or image of modernity; Bok (2015) for example show that an airport becomes more than just "a form of functionalist transportation infrastructure" but bears the "imprints" of national histories and visions of modernity that are reproduced by its corporate-state

managers and promoted abroad (p. 2725). Subsequently, the imbued meanings of an infrastructure or policy might limit their potential to be translated or learned from in other contexts (Bok 2015).

Similar to policy, infrastructure is also shaped by the histories of where it is placed. In Bok's (2015) case, the mobility of Changi airport as a model policy demonstrates how infrastructure may "reinforce the primacy" (Siemiatycki et al. 2019 p. 8) of certain areas in the imagination and practice of policymaking. The adaptation of Bogota's BRT model by South African planners is also demonstrative of this point. Rather than look to more proficient systems in similar contexts such as Lagos, those more provincial cities are marginalized by policymakers who aspire to emulate the successes of global model cities like Bogota (Wood 2015).

Going forward, scholars of policy mobilities might take seriously as well as challenge Larkin's claim that "many infrastructural projects are copies" (2013, p. 333) which occasionally fall into a "poetic mode...where form is loosened from technical function" (2013, p. 335) However, copying infrastructure is a process, laden with myriad contingencies. The notion of *mutations* (Peck 2011), which are argued to occur anytime policy is made mobile, might instead be substituted for copies. To "copy" implies that infrastructure itself is immutable, rather it is its meanings and "poetics" which mutate. However, as policy mobilities has demonstrated it is the "poetics" of policy — the best practices, solutions and models — which prove to be fairly resilient, taking on an impasto layering of political-economic imperatives as it is mobilized. Meanwhile the material form they take both as they travel and within the built environment at the site of their adoption become distorted and mutant.

Policy mobility and mobility infrastructure: what's been said?

In policy mobilities scholarship, "mobility" is deployed to thicken and critique orthodox policy scholarship on policy transfer and movement. However, the use of the policy mobilities

lens to understand recent trends in urban mobility and transportation policy has been limited. Before introducing mobility and critical transportation scholarship, I will provide a brief review of work which uses policy mobilities to understand recent turns in urban mobility infrastructure and policy.

Infrastructure which supports low carbon mobility, such as bike lanes, amenities for pedestrians and expansion of fixed-route public transit have taken hold as a "fix" which helps cities meet certain sustainability and development goals (Mahmoudi et al. 2019; Spinney 2016; Stehlin 2019; Stehlin et al. 2020). Rather than transform mobility per se, these projects provide targeted, quantifiable congestion relief or support a field of competitive alternatives to driving. They are bound by "the neoliberal framework for action" which necessitates that these interventions are flexible, foster entrepreneurialism and are revenue neutral (Stehlin 2019, p. 145-146). This framework conditions the extent to which the urban environment will be shaped by low-carbon infrastructure, as well as *what* infrastructure will shape it.

Stehlin draws attention to the material underpinnings by which policy is made "fast" (Peck & Theodore, 2015) and mobile. Bike lanes or mobility platforms such as Uber are by their nature able to be implemented quickly and at a much lower cost than hard infrastructure, while also aligning neatly with the neoliberal frame. Stehlin (2019), building on Peck and Theodore (2015), offers the concept of "fast infrastructure," describing how it may be distinguished from fast policy:

> ...because bikeshare is physical infrastructure embedded in the built environment, with a wide potential user base and a spectacular quality, often it must enroll larger infrastructural publics into its translation in place than the social programs Peck and Theodore describe. For example, bikeshare implementation mobilizes municipal staff, business communities, philanthropic institutions, and bicycle advocacy networks, as well as potential users, creating points of leverage over the shape of the resulting system. For the most part, however, substantive contestation is fleeting and occurs within established constraints. (p. 147)

As Stehlin notes, “fast infrastructure” must contend with a larger array of actors, across public and private sectors, as well as its embeddedness in the urban. Because of its position within and extended across the urban fabric, it is potentially opened up to contestation. However, the “leverage” to enact contestation is rarely exercised; in my review, it is typically the cooperation, or lack of, by local transportation authorities, operating within the neoliberal frame of action, rather than the larger public, that contributes to the success or failure of mobility infrastructure.

Another variety of “fast” low-carbon mobility infrastructure is bus rapid transit (BRT). Wood (2015) has studied the mobility of the “Bogota model” and its adoption by South African planners. For Wood, this south-south circulation of policy must be seen as uneven, not as unilateral acceptance of supposed best practice. Bogota’s export of BRT is also conditioned by the city’s overall image as a clean, safe destination for sustainable tourism (Wood 2015). For cities adopting the Bogota model of BRT, it becomes more than just a lightweight way to formalize fixed-route transit infrastructure, but to revitalize Southern urban places (2015). Silva Ardila (2020) shows how the Bogota model was adopted widely through social and political channels, conditioned by particular financial and extra-governmental imperatives set by extra state actors such as the World Bank and the Bogota-based BRT standards-setting organization. Despite the robust infrastructure promoting the Bogota model, it still had to contend with local contexts, such as the buy-in of regional transportation planning organizations (Silver Ardila, 2020). Once more, the form and extent of infrastructure deployment is conditioned by social and political realities in urban governance.

Work on the (im)mobility of heavier infrastructure serves as a contrast to work on the circulation of “fast infrastructure.” In the case of airports (Bok 2015, Lin 2018) and streetcars (Culver, 2017; McCann, 2013; Olesen, 2020) the circulation and movement of infrastructure is

limited and it is the "imaginaries" of these amenities which travel. However, the neoliberal frame remains a condition of the mobility of heavier infrastructure. For example, a number of studies have shown how streetcars are enrolled in entrepreneurial, creative-city and neoliberal urban development but for the most part have been marked by their inability to be successfully adopted in local transport networks. In Vancouver, a streetcar demonstration project during the Winter Olympics had no buy-in from the regional transportation authority; its limited utility rendered it an entirely symbolic form of transportation (McCann, 2013. McCann (2013) concludes by noting the resource-intensiveness of policies that go global, requiring robust social and material infrastructures as well as access to policy knowledge communities, which are not distributed evenly, creating a "limited mental map" (p. 21) of the global circulation of policy and infrastructure.

Specifically, for transit policy, there are also very real politically-imposed material limits on infrastructure here in the U.S. that may set up agencies for policy failures if they take on European or Asian transit models. Culver (2017) finds streetcar infrastructure, which in the U.S. has been animated by Portland's perceived successes with light rail, is almost entirely symbolic and argues that streetcar projects are as likely to heighten urban economic inequality as they are likely to serve the urban growth machine. Olesen (2020) locates a similar light rail development in a larger "infrastructure imaginary" which is bound by roughly the same neoliberal frame Stehlin identifies, where the provision of affordable public transit is undermined by entrepreneurial urbanism.

The utility of policy mobilities, particularly its attention to the circulation of policy knowledge is also demonstrated by Keblowski & Bassens (2018) in their study of the take-up of academic knowledge by transportation planners in Brussels. As is the case with fast infrastructure

and even in heavier mobility infrastructures, the neoliberal frame conditions the knowledge which is accepted and deployed in transportation planning practice. Augmenting Keblowski et al.'s (2019) work on fare free public transit policy (FFPT), Carr & Hesse analyze Luxembourg's "attention-grabbing" (2020 p. 3) experiment with FFPT as a form of fast policy, which completely bypassed any political struggle or bottom-up demands. Here, the fast mode of policymaking is an example of the post-political condition in urban transportation governance (Carr and Hesse 2020).

As this work shows, urban mobility infrastructures are a potent object of study for policy mobilities scholarship. They help reveal the logics of mobility and transportation planning regimes, as well as enlivening their study with a consideration of the social agents and material effects that shape their adoption. Policy mobilities then has a place in the larger critical transportation scholarship toolkit, which I will discuss in the next section.

From mobilities to critical transportation scholarship

Mobility in some ways seems like enlivening old subjects by employing new terms in their study. Transportation and the movement of goods and people has been a consideration of geographers as well as other social scientists since well before those disciplines were codified. However, mobility is far more than just a way to give life to old subjects; rather it brings in insights from decades of work in critical social theory to better situate movement—enlivening "the brute fact of moving" (Cresswell 2010b, p. 21) within political, social, cultural and technological relations. The mobilities "turn" has opened up long-considered areas like transportation to normative critiques: who is (im)mobile, and what are the conditions of their (im)mobility? For Sheller (2018 p. 14), revealing the multi-scalar politics of mobility links issues of (im)mobility at the level of the body to issues at the level of the urban (i.e. transportation justice), to the global climate crisis. However, while the mobilities turn has widely expanded notions of movement and

opened up important veins of scholarship on subjects beyond transportation, it still has much to offer studies of urban transportation, and particularly public transit.

Attending to mobility also requires attending to its conditioning by technology, politics and infrastructure. In the introduction to *Mobile Technologies of the City*, Sheller and Urry conclude that:

> Urbanism, in sum, has always been associated with mobilities and their control, and continues to be so more than ever. The technologies, infrastructures, material fabric and representational machinery of cities support these mobilities, while also being shaped and re-shaped by them. (2006 p. 2)

It is within this relational confluence of technology, infrastructure and mobility that I wish to situate my study of NFC technology. First, I will give a brief introduction to the concept of mobility as it is deployed by scholars in the mobilities turn. Then, I turn to work in this "turn" which directly explores this relational confluence of technology, infrastructure, materiality and representation through public transit. Then I will introduce a recent critical transportation scholarship that may be considered both of and beyond the mobilities turn. I will then address geographic and other social scientific scholarship related to fare payment and collection.

Public transit in the mobilities turn

Perhaps the fundamental way that geographers use the concept of mobility is to distinguish contemporary scholarship about all varieties of movement from earlier geographic and social scientific accounts of movement and transportation circa the quantitative revolution (Cresswell, 2010a; 2010b). Cresswell (2010b) compares the mobilities turn to the concept of place, which emerged from humanistic geography's break with spatial science, with a simile: space is to location as movement is to mobility (p. 18). The mobilities "turn" can be seen in some ways as return to the preoccupations of mid-century spatial scientists and classical transportation geographers *by*

way of the insights, approaches, strong critique, and politics of the various strains of "critical" geographies that emerged beginning in the latter half of the 20th century.

This has resulted in a varied body of scholarship that explores the relations between infrastructure, technology, materiality and mobility through an array of approaches. I am particularly interested in scholarship which uses transit as a window through which to explore these relations. For example, the ethnographies of bus travel by Koefed et al. (2017) and Wilson (2011) reveal the bus to be a microcosm of the urban experience, aboard which difference is accepted and negotiated but also reinforced through "techniques of differentiation" (Koefed et al. p. 12) that occur at scales as small as a bodily gesture. Lubitow et al. (2017) demonstrate the utility of a mobilities approach to critical geographic work on commuting. Their study of transit-dependent commuters in Portland, Oregon links differentiated experiences of mobility by riders that deviate from a universal, disembodied "normal" commuter to transportation planning regimes that construct and perpetuate that norm through planning paradigms (Lubitow et al. 2017). Bissell (2009) explores the relation between various "encumbrances" of the commute and differently-abled passengers, detailing the tactics as well as affects through which mobility is negotiated by riders outside a constructed ideal norm. Each of these scholars take seriously Sheller and Urry's (2006) description of the co-constitution of mobility and urbanism, while also demonstrating the liveliness of public transit infrastructure as a site of mobilities study.

Reclaiming transit's social goals through the mobilities lens

Evaluating the impact of the mobilities turn at the conclusion of the decade which followed the launch of *Mobilities* journal in 2006, Sheller and Urry (2016) note "a growing place for mobilities theory within applied transport planning and policy," highlighting the work of policy mobilities scholars in particular, and argue "that the underlying social organization of mobility"

needs to be changed. For example, it is not enough for planners to influence mobility "consumers" to make better mode choices without addressing the structures that determine those choices to begin with (Sheller & Urry 2016). Scholars not usually associated with the mobilities turn such as Grengs (2005) have similarly recognized the need to address the ideological and political-economic imperatives of transport planning and policy, which are seen to undermine its social goals. Scholarship highlighting the gulf between transit planning's social goals and its economic imperatives has culminated in recent calls from academics and activists alike for a mobility commons (Enright 2019; Sheller 2018; Temenos et al. 2017) and an understanding of transit as the medium through which urban dwellers exercise the Right to the City (Attoh, 2017; Attoh, 2014; Attoh, 2019; Kębłowski et al., 2019). I follow Enright (2019) who terms work in this vein critical transportation scholarship, related to but distinct from the mobilities turn.

From mobilities to critical transportation scholarship

Recent scholarship has taken the insights of the mobilities turn and re-oriented them, via political economy and political theory, *back* to transportation and particularly public transit. Among this scholarship, I include work at the intersection of policy mobilities, and transportation infrastructure and practice documented in the previous section. In the rest of this section I will consider two varieties of critical transportation scholarship. The first considers how the gulf between transit's social mandate and economic imperatives is exacerbated when transportation and mobility infrastructure are deployed as a "fix" by cities seeking to meet development and sustainability goals. The second is work that suggests how this gap might be bridged by transforming our received meanings of transit, advocating for its recapture as part of the Right to the City or as a mobility commons.

The fix of mobilities infrastructure and governance from bike lanes to platforms

Mobilities infrastructure and governance is conditioned by the larger imperatives of neoliberal urbanism (Grengs 2005; Spinney 2016; Stehlin 2019). Recent scholarship extends the concept of the spatial fix (Harvey 1981) to enhance our understanding of the relationship between urban development and mobility. Writing on the promotion of high-speed rail in the U.S., Minn (2013) speculates that high-speed rail can serve as a "mobility fix" to ameliorate automobile congestion, which in turn allows suburbanization and the production of megaregions to expand unabated. Spinney (2016) and Stehlin (2019) apply this notion to cycling policy and infrastructure.

For Spinney, any production of neoliberal urban space which follows cycling policy is a side-effect of cycling's production of neoliberal subjectivity; alleviating barriers to cycling, in current planning practice, is about supporting "alternative ways of moving" (p. 451) for individuals to choose, rather than re-orienting the urban fabric away from the current regime of automobility. However, Stehlin shows how cycling policy is indeed at the center of the production of space, situated within a larger urban development program alongside creative city placemaking, as well as through bikeshare infrastructure (Stehlin 2019).

Cycling infrastructure on the whole tends to be lightweight but also multifunctional, helping to meet sustainability goals (Mahmoudi et al. 2019) economic goals (Spinney 2016; Stehlin 2019) and broader development goals stretching limited public infrastructure and budgets while radiating a green glow. The investment in fixed, material infrastructure is minimal. This logic also underpins platform urbanism and the platformization of mobility, as participation by urban governance institutions in data platforms grows (Barns 2020 p. 32). In the "Uber model" of urban governance (Barns 2020 p. 27), data-intensive "soft," digital infrastructure supports a network of intermediary "multi-sided" markets for services ranging from policing to food. As the

allusion to Uber, one of the world's largest transportation network companies (TNCs), might imply, this model has shaped recent trends in urban mobility governance (Stehlin et al. 2020).

In their typology of "trajectories" of mobility platformization, Stehlin et al. offer two concepts which have enriched my understanding of recent developments in fare collection and transit planning. The first trajectory is *infrastructural thickening*: wherein agencies, in response to the proliferation of ridesharing and other TNCs, "extend their existing strengths in fixed-route transport" by integrating their services through mobility-as-a-service (MaaS) platforms (Stehlin et al. p. 1257). The second is the notion of a *governmental fix*: when municipal bodies foster the "take-off conditions" for private mobility firms by supporting the market through public capital. As examples, the authors include in this trajectory transit integration schemes and seamless ticketing platforms (Stehlin et al. 1258).

This "pump priming" (Stehlin et al. p. 1258) in support of private markets is a glimpse into the "backstage work" of infrastructure provision. By deploying and partnering with mobility platforms, urban governance institutions are able to side-step capital-intensive fixed-infrastructure investments in favor of supporting a growing marketplace of platforms proffering mobility solutions. Meanwhile urban mobility platforms become more deeply entrenched as wide swathes of public infrastructure are "digitized" through mobile apps.

Conceptualizing transformative mobility infrastructure

Platformization has been preceded by a gradual recession of politics from mobility infrastructure provision and governance. Recent examples of this depoliticization of mobility include FFPT (Carr & Hesse, 2020; Kębłowski, Tukivene et al., 2019) pedestrianization (Kębłowski, Van Criekingen et al. 2019), bike-sharing (Stehlin 2019; Temenos et al. 2017), airport rail connections (Golub et al., 2013; Farmer 2011) and urban trail networks (Mahmoudi et al 2019).

While the scope of earlier strains of "bicycle politics" has been winnowed down "from an indictment of urban capitalism to the celebration of the value of 'complete streets' that include all road users" (Stehlin 2019, p. 85), new activist movements are organizing around mobility infrastructure.

Academics have responded to recent activist interventions onboard and adjacent to public transit and mobility governance, which they read as attempts to re-politicize urban mobility and redirect its infrastructure back toward social uses. These activist interventions include mass protests against fare hikes in Santiago, Chile; the Swipe it Forward campaign in NY; the Fare Free Toronto campaign (Enright 2019); the L.A. Bus Riders Union (Grengs 2005; Soja 2010); and striking transit workers in the Bay Area (Attoh 2014; Attoh 2019). The mobility commons and the extension of Lefebvre's Right to the City (RTTC) are concepts through which these actions have been explored. Proponents of the mobility commons highlight the role of new technologies and post-political governing consensus in enclosing mobility from the public in the face of climate change. Meanwhile, proponents of RTTC show how transit is the medium of social reproduction and key to redressing alienation in cities, necessitating its democratization. These scholars reveal the politics of mobility infrastructure, which are obfuscated by dominant mobility governance regimes.

The mobility commons

Nikolaeva et al. (2019). offer the concept of a mobility commons as an alternate trajectory for low-carbon mobility transitions. The notion of a commons allows us to think of orthodox policies that support low-carbon modes of transportation as forms of enclosure, creating high-barriers to entry. In this framework, we can come to understand that recent platform-based "shared" and "smart" mobility schemes are driven by a logic of austerity; mobility must be limited

and should come at some cost that reflects its scarcity. Examples of "austere" low-carbon mobility policies include bikeshare and microtransit programs that require access to a smartphone, or policies that grant incentives to EV ownership. In both instances, access to low-carbon mobility infrastructure requires some kind of burdensome buy-in. For Sheller (2018):

> The enclosure, securitization, and colonization of the mobile commons—whether by the state, by corporations, by Smart Cities, or by our own technological hypnotization—is equivalent to the de-politicization of humanity, and the dystopian ending of communality. (p. 170)

By accepting a priori that mobility infrastructure must be enclosed with apps or expensive technologies in order to ameliorate transportation's contribution to the climate crisis (Sheller 2018), Nikolaeva et al. argue that current efforts by policymakers at a low-carbon mobility transition can never truly be transformative (2019). For example, mobility "sharing" schemes such as bikeshare, scooter share and rideshare, which require smartphones and credit cards to use, only deepen existing inequality by exploiting the digital divide. As an alternative, Nikolaeva et al. they offer an alternative logic of commoning which they define as "actions that can bring about a shift towards more participatory decision-making models whereby the impacts of mobility practices are collectively managed" (Nikolaeva et al. 2019; Temenos et al. 2019, p. 355). Enright (2019, 2020) has explored activist movements that are presently enacting this alternative logic of communing, often by protesting fare collection policies.

Enright (2019, 2020) uses public transit "as a platform and a perspective from which to view mobility relations more generally" (2019 p. 13) and her conception of the mobility commons is informed by activist campaigns, especially around free transit. She explicitly links commoning of mobility to de-commodification of transit. In campaigns for free transit, Enright (2019) finds campaigns to transform society more broadly. Decommodifying mobility is a step towards

alleviating other forms of alienation in capitalist urban life (Enright 2019 p. 7) and recapturing urban mobility from the imperatives of capitalist urbanization.

Infrastructures and technologies of mobility today serve as a tool for capitalist urbanization and reproduce inequality, segmenting mobile publics and reproducing a tiered mobility infrastructure. The mobility commons lens helps me understand that recent platform-based "shared" and "smart" mobility schemes are driven by a logic of austerity; mobility must be limited and should come at some cost that reflects its scarcity. Practices of commoning mobility go beyond current paradigms like "shared" mobility, revealing them to be new modes of enclosure, and demand mobility's outright de-commodification. Academics and their activist antecedents use the notion of a commons re-politicize mobility infrastructure and conceive it as a tool for redress alienation and other wages of capitalist urbanization. In this way, they are closely linked to scholars who conceive of public transit as a means to the Right to the City.

The Right to the City

Mobility infrastructures, whether as "heavy" as high-speed rail networks or as "light" as pedestrian crosswalks, are the more than just the stuff of 9-to-5 commutes, an exercise regimen or of congestion relief. Fostering mobility allows people to connect to the world at large and fosters the public sphere (Attoh 2016). In this way, Attoh claims that "struggles over urban transportation" are "struggles over the political possibilities of cities themselves" (Attoh 2019, p. 197). For Attoh, following Harvey (2003), debates over transit provision are debates over who can be a part of the public, participate in democracy and exert their right to the city (RTTC). The RTTC is a dynamic bundle of "positive" rights which could include living wages, free healthcare, social housing and mobility (Attoh 2019).

The demand to de-commodify mobility that Enright (2019, 2020) finds at the center of various activist movements can be extended to all aspects of social reproduction, in a stark contrast to modern legal bundles of "negative" rights such as the right to pursue one's interest without state coercion (Attoh 2019). A radical transformation in transit infrastructure would aim beyond quantifiable service improvements or revenue growth, but for addressing alienation and "the idiocy of urban life" in less tangible ways (Attoh 2016; 2019).

Keblowski & van Criekingen et al. (2019) operationalize the RTTC to provide a framework with which to assess transportation transport policy which goes beyond the "neoliberal frame" (Stehlin 2019) — of revenue neutrality, entrepreneurialism and flexibility — for successful infrastructure. For example, for transport policy to truly challenge existing urban regimes beyond automobility, it must involve city-dwellers in co-production rather than hold them as passive recipients of "improvements" (Keblowski et al. 2019 p. 27). Reaching back to policy mobilities, Keblowski et al. argue that critical transport policy cannot be constructed from a singular "blueprint" or model (2019 p. 30). Critiquing received notions of "radical" mobility, Davidson (2021) warns

> ...there is a risk of positioning a particular technology, mobility mode or policy intervention as essentially valuable and positive, without questioning its co-option within dominant relations of power, nor how these relations construct narratives and hierarchies. (p. 3)

Applying the RTTC frame to transport policy reveals how policymaking is captured in dominant hierarchies, while also showing how a transformative, critical transportation policy must think beyond any one particular technology or infrastructure fix. Additionally, adopting the Right to the City frame helps complement the mobility commons, linking mobility infrastructure to the means of social reproduction and the maintenance of a public sphere. Moving beyond the neoliberal frame

for mobility infrastructure would allow public transit agencies to go beyond “sustainable” transit to “transformative” urban life.

The politics and poetics of new fare collection technology

Larkin (2013) develops the concept of “poetics” to describe how political imperatives of the state are operationalized via infrastructure:

> In the case of infrastructures, the poetic mode means that form is loosened from technical function. Infrastructures are the means by which a state proffers these representations to its citizens and asks them to take those representations as social facts. (p. 335)

Critical transportation scholars provide us with a kind of counter-poetics, informed by activist contestations over the meaning and governance of mobility infrastructure. The broad questions of who is transit for and what logics by which transit is governed are inspired by activist contestations on the ground. Transit is a common "political flashpoint" owing in part to the contradiction laden nature of mobility technologies; as Attoh notes, “while certain bus designs may meet the needs of one population, they may restrict the mobility of others” (2019 p. 43). This observation about buses can be extended to all varieties of mobility infrastructure, particularly smart, platform and shared modes which undergird the latest forms of enclosure in the mobility commons. I include among these technologies of enclosure new fare collection technology. By adopting new fare collection technology, a “fast” infrastructural fix conditioned by the imperatives of capitalist urbanization, transit agencies accept the enclosure and commodification of transit.

The state of research on fare collection

Despite the recognition by scholars of how shared or smart mobility schemes and the digital infrastructures which support them are deepening the gulf between transit’s social and economic mandates, there is an absence of critical studies of NFC technology. In critical transportation

scholarship and mobilities more broadly, fare collection has been adjunct to vital work on transit activism (Enright 2019), FFPT policy (Carr & Hesse, 2020; Kębłowski et al., 2019), platform infrastructure (Stehlin et al. 2020) and passenger assemblages (Adey et al., 2012; Binnie et al. 2007; Bissell, 2009; 2018). Academic research that actually takes as its object NFC technology typically explores the applications of data generated by smartcards, ticketing apps and other data generated by NFC media to transit planning (see Faroqi et al. 2018). The frequent allusions to fare collection in mobilities and critical transportation scholarship point to a gap, which I address in this study.

In the mobilities turn more broadly, many scholars have called attention to tickets, passes, fare cards and turnstiles and how these "mundane" mobile objects come together to produce a passenger "assemblage" (Adey et al. 2010; Binnie et al., 2007; Bissell 2010). Bissell has suggested that turnstiles are a technology worthy of future study for their reification of "able-bodiedness" (2009). More recently, Bissell examines fare collection technology in his lively study of commuting, *Transit Life* (2018). Bissell takes seriously the supposedly "mundane" Opal smartcard, a "convergence" of physical and digital mobilities that, by automating fare collection, has alleviated some of the mental labor and inconvenience associated with riding transit (2018 p. 91-95). However, aside from alluding to its surveillance capabilities, Bissell stops short of critiquing Sydney's NFC technology.

In more recent critical transportation scholarship, fare collection infrastructure is exemplary of a fix (Stehlin et al. 2020) and subject to re-appropriation by activists (Enright 2019). The roll-out of NFC technology is an example of both the infrastructural extension and governmental fix trajectories of mobility platformization (Stehlin et al. 2020). The opening up of NFC infrastructure through ticketing platforms and open-loop schemes extends the capabilities of

transit agencies through soft, digital infrastructures. For example, users can pay for a TNC or e-scooter ride to cover a portion of their journey with the same media they pay for a bus or train ride. Opening NFC technology also serves as a governmental fix in supporting a marketplace where private mobility firms can operate alongside public transit agencies. I will discuss these examples more extensively in Chapter 4. Meanwhile, the activist movements in Enright's recent work contest the transactions which NFC technology mediates. Activist riders in New York City, for example, re-appropriate the unlimited-ride MetroCard and use it as a means to democratize and redistribute transit by "swiping-forward" - granting the next person through the turnstile a free ride. In Stehlin et al.'s study, they show how with the proliferation of digital infrastructure "code is the new concrete;" in the case of NFC technology, code is the new turnstile.

What foregrounding fare collection can do for our understanding of transit

NFC technology is about much more than a shift to electronic forms of fare payment and providing a suite of payment options to the ridership. The turnstile and the farebox - whether in a physical form or dematerialized within an app - is a convergence of mobility policy, infrastructure and technology. Transit riders must pay their fare, or risk criminalization These infrastructures explicitly enclose the public transit network.

As is the case with other mobility infrastructure fixes, NFC technology allows public transit agencies to extend their services with minimal investment in hard infrastructure. By "opening up" NFC technology, riders are able to choose from an expansive suite of payment options, mirroring transactions for other commodities. Meanwhile on the agency's side, their back office, turnstiles, data and revenue streams are opened to either one or dozens of technology providers and contractors. The adoption of this technology further encloses the mobility commons and reifies the notion that transit is a commodity.

Chapter 3: Methodology

Introduction

The goal of this study was to show how new fare collection technology serves as an urban mobility fix, heightening the enclosure of mobility and public transit. I approached NFC technology as a form of "fast infrastructure," (Stehlin 2019) valued by its adoptees at transit agencies for its quick and easily scalable implantation. Like the notion of "fast policy," (Peck and Theodore 2015) fast infrastructure provides cover for governance institutions to sidestep political processes in favor of a technocratic, prefabricated – albeit contingency- and contradiction-laden– solution.

However, there is substantial political work performed by transit industry professionals to adapt and territorialize these infrastructures and policies, during which "mutations" (Peck and Theodore 2011) arise. I sought insights into this work in order to enliven my study and capture how NFC technology is adopted at transit agencies. This approach was employed to answer three questions which contribute to critical transportation and mobilities scholarship:

How does NFC technology serve as an urban mobility fix?
How does the adoption of NFC technology reflect the logic of enclosure and commodification found in other low-carbon mobility infrastructures?
How do the social infrastructures of the public transit industry shape NFC technology?

With these questions in mind, I conducted semi-structured interviews with 12 participants and analyzed an archive of related documents. My participants were key actors involved with NFC technology at public transit agencies or had recently transitioned to the private sector. Meanwhile, my archive is composed of whitepapers and promotional materials for four NFC solutions: Masabi Justride, Uber Transit Horizons, Visa Cybersource and Cubic Umo. In this chapter, I provide a justification for my methodology and research design.

Motivation for the study of new fare collection technology

As I discussed in Chapter 2, mobility infrastructure under capitalist urbanization is contradiction-laden, prioritizing privatized and individual modes over public and collective modes, further entrenching automobility and exacerbating many of the elements which make cities unsustainable. Public transportation is particularly instrumental to ensuring cities remain places where many people can access public goods, in its promise to deliver anyone from their home to jobs, museums, libraries, parks and so on (see Attoh 2017). But, as I discussed, even public transportation, particularly in its adoption of platform mobility solutions, is increasingly privatized via infrastructure governance. New fare collection technology appears to be privatizing elements of public transit as public agencies attempt to compete or coexist with "new" mobility companies like Uber. It also individualizes this collective mode of transportation by offering a consumerist ideal of convenience to segments of the ridership who are banked, own smartphones and choose to opt-in. Meanwhile, private mobility services profit off of exploiting labor in addition to public infrastructure: they pay little-to-nothing for use of roads, curbs, and transit network; their reliance on already-existing fixed infrastructure is actually essential to their success.

My research is aimed foremost at providing everyday transit riders with a clear analysis of what is going on with fare collection and what is behind changes their local agencies are making to the process of riding a bus or train. I would like my work to also serve some utility to public agencies and other key actors in urban mobility provision, to perhaps counter some of the narratives around fare collection policy "best practices." As well, my work is situated in a lineage of critical transportation scholarship, as well as in recent mobilities and infrastructure "turns" across the social sciences. By exploring NFC technology through the lens of critical transportation scholarship, I aim to unsettle the "master narratives" (Siemiatycki et al., 2020) which pervade representations of infrastructure.

Both policy mobilities and infrastructure studies foreground the previously "backstage" and "mundane" work of production and maintenance of their respective objects of study, contributing to broader understandings of urban space as socially produced, unbounded, relational and structured by neoliberal capitalism (Leigh-Star 1999; McCann 2011; Temenos & McCann 2013). This also necessitates a particular methodological approach. I have approached NFC technology, as a mobile policy as opposed to a discrete and uniform technical solution. Rather than a discrete, technical solution which is transmitted wholesale with a single origin and destination, NFC technology, and the problems it solves, is best seen as a messy social construction, whose adoption follows ideological and political-economic channels (Peck and Theodore 2010). Conceiving of NFC technology in this way was inspired by my experiences using smartcard fare payment media in Philadelphia and London. As I discussed in chapter 1, the similarities between the SEPTA Key and TfL Oyster cards were limited to their "smart" qualifier. It was apparent that "new" and "smart" fare collection did not exist exactly, but were ideas somewhere in the ether and were brought to ground by different agencies and localities.

The master narrative I hope to unsettle with this study is that a technological innovation such as "smart" fare collection will easily "fix" public transit, allowing it to offer more expansive service with minimal hard infrastructure investments. In interrogating "seamless" and "convenient" mobility, I have to ask: seamlessness of what, and for convenience for whom? Is not the most seamless form of public transit the one that doesn't require turnstiles or any fare control barrier? I also hope to demonstrate the utility of a policy mobilities approach to answering these questions.

Infrastructure and technology are present in policy mobilities scholarship mostly as a metaphor; policy "technologies" move through knowledge "infrastructures" like conferences,

think tanks, and university research labs. However, MaaS, ticketing apps and other platform-based, data-reliant “solutions" are blurring the lines between technology, policy, and governance. Moreover, policy technologies are taking more cues from the technology sector internalizing notions like innovation. The result is no longer just “fast policies” but fast infrastructures, which are hastily assembled and ill-suited to the distinct needs of particular transit systems and metropolitan regions.

Critical geographers utilize the metaphor of policy mobility in their approach to the study of policy and policymaking as a situated and socio-technical process. This is in order to distinguish their contingency-laden and political conception of policymaking and diffusion from more orthodox accounts in political science of “best” policies that naturally assert themselves and are then transferred from innovative localities to adopting localities. Peck and Theodore, introducing a 2010 *Geoforum* special issue on policy mobilities, argue that policies are ripe for deconstruction and that methods familiar to critical geographers such as genealogy, discourse analysis and comparative urbanism have “extended” studies of policy beyond mere “positivist evaluations” (2010, p. 169). This echoes McCann’s (2011) conception of policy mobilities as an emerging field which brings together a post-structuralist appreciation for the diffuse networks and agency of objects in policymaking with insights from critical economic geography that hold that cities are nodes in the circulation of capital (and, it follows, other flows such as policy and knowledge).

Peck and Theodore outline a methodological approach which is able to capture both the movement of policy across places and through networks of expertise, knowledge and capital, as well as the fixing of policy “downstream” where it is adopted (2012 p. 21-22). This “distended case approach” combines the “low-flying” critical methodologies above, which can be used to analyze and critique transnational modes of policymaking orthodoxy, with situated methods like

semi-structured interviews and observation to capture mutation and fixing of policy in place (Peck 2011; Peck & Theodore 2010). I have designed my study of fare collection systems with this approach in mind. However, I was unable to "follow" policy through nodes in its production like conferences and planning offices due to the Covid-19 pandemic. As Bok (2015) argues, policy mobilities risks "methodological elitism" (p. 2726) in insisting on the primacy of these sites, when oftentimes they are closed off to researchers with limited resources or social clout.

Position in relation to transit industry professionals

My research subjects are professionals working at transit agencies or with start-ups who serve transit agencies. Nearly all participants in my interview are titled; several are CFOs or CEOs and have spoken at various industry conferences (see Table 2). This is an instance of "studying up." However, this does not come without risks to my participants or of my research. While my participants may be "above" me in terms of pay grade, there were still implications for participating in my study as their work can be quite sensitive. For example, a number of participants mentioned NDAs that would prevent them from discussing sensitive information, and several mentioned off-the-bat that I would need special permission if I was interested in data generated by NFC technology. One element I didn't consider was familiarity with academic research. Many of my subjects were sympathetic when I gave them the IRB overview and verbal consent information, having gone through the same thing in their own graduate studies. Others were guarded, perhaps anticipating deeply probing and sensitive questions following the consent.

I have done my best to establish trust with my subjects, as I am often being made privy to information that is not widely publicized, and is occasionally protected by various NDAs. Additionally, as representatives for public agencies and private firms, they need to uphold the reputation of their employers. This at once requires critically analyzing their statements - as there

may be instances of celebratory language in accounts of their work - and ensuring their confidentiality through uniform use of pseudonyms and anonymizing information that might identify specific employers.

Studying fare collection as a mobile policy: research design

I began designing my research project last spring beginning with background research to identify key actors and institutions of NFC technology. I started by "following" SEPTA Key, the new fare collection system for the Philadelphia metro area transit system, outward. Jerry Kane, the project manager of SEPTA Key, is chair of the Secure Technology Alliance's (STA) Transportation Council.

The STA's Transportation Council brings together actors from across public and private sectors of the transportation industry to "support the advancement of transit fare collection systems and explore linkages between and integration among transit payment systems and programs in the tolling, mobility services and financial industries" (Secure Technology Alliance, 2021). I identified several potential participants who had spoken at the STA's Payments Summit regarding fare collection at their respective transit agencies. Separately, I compiled a list of transit agencies who have deployed or are in the process of deploying new fare collection systems. I included all types of NFC technology outlined in the appendix, including smartcards, platforms and open-loop payment. I highlighted agencies who had also participated in STA, either through board representation or at the Payments Summit. I also began compiling an archive of documentation for NFC solutions from Masabi, Visa Cybersource, Cubic Systems and Uber

Interview design and justification

Meanwhile, I developed a semi-structured interview protocol. Interviews are an important tool for policy mobilities researchers to deploy as they follow policy models, helping to capture

how they are "learned" and territorialized (McCann & Ward 2012). Following Wood (2016), I designed my questions with an eye toward "probing beneath the socio-political exterior of the decision-making process." This "probing" via an interview can reveal how individual experiences relate to larger (socio-political) phenomena such as technological change and shifting paradigms of transit service delivery. This need to attend to the experience and knowledge of individual practitioners as well as key concepts from academic literature is reflected in my basic interview protocol. My basic interview protocol was informed by key concepts from policy mobilities literature as well as by reading industry publications such as *MassTransit* and *ITS*.

Arming myself with theory and methodological tools does not grant me special probing powers which delivers these revelations while the interviewee remains unaware. It is in fact *through* their words and telling that I might learn what is important and relevant to my participants (Dunn in Hay 2016, p. 151). The way in which *they* describe these phenomena will take precedence over tightly-held theoretical concepts, following Gioia et. al (2012, pp. 19-20).

This revelation of how phenomena are internalized and territorialized is not necessarily possible in a questionnaire or focus group. Questionnaires, for example, do not allow the chance for me to ask an participant "what do you mean by that?" or other opportunities to deviate from the interview protocol. There is also less of an opportunity to learn from my participants via a questionnaire (Dunn in Hay 2016, p. 151). If I am using wrong or imprecise terminology, for example (as I occasionally found was the case in my study), it is difficult to imagine being corrected via a questionnaire. In short, interviews have a dynamic and room for reflexivity *on the fly* not possible via questionnaire.

Recruiting and interviewing participants

In the fall I began recruiting participants. I developed a broad "form"-style email that I adapted to each individual participant (see App. C). I scoured Google and LinkedIn for contact info for the key actors I had identified in the spring and incorporated that into a "contacts" column on the key actors spreadsheet I developed. For those I couldn't find, I located email addresses used by transit agencies for media inquiries.

My initial list included key actors exclusively from the public sector, however after my first round of three interviews, it was clear I needed to incorporate actors from the private sector. I had learned that many new fare collection systems were simply using platforms developed by mobility as a service companies and were presented to transit agencies as "software as a service." I identified several of these platforms and recruited participants via their media inquiries address. Following advice from OU IRB, I used a verbal consent protocol since I am not conducting interviews in person. I delivered verbal consent after the small talk and pleasantries portion of the conversation was over and before I began going through my interview protocol.

Interviews were conducted in a variety of ways. Two of my participants immediately offered to "host," via their workplace conferencing tool. When asked when it would be "a good time to call," as was the case for four interviews, the conversations were recorded via Google Voice. When left solely to my discretion, I offered to host a Zoom meeting, as was the case with four interviews. However, one of my participants had trouble accessing my meeting and we elected to use their workplace's conferencing tool instead. My basic interview protocol consisted of eight questions and took an estimated 40 minutes. Interview length varied, with my shortest lasting 30 minutes, and several going longer than an hour.

This measurement of interview length does not capture the full "life" of my interviews. As Dunn (in Hay 2016, p. 149) observes, the interview begins long before the formal conversation

with an participant and ends much later, progressing from preparation and consent through transcription and analysis. Immediately following the conclusion of an interview, I turned to my "field" journal. This journal was analogous to the memo-writing Cope (in Hay 2016 p. 374) describes as an early form of coding. My field notes usually, but not exclusively, encompassed observations about my preparedness and other qualities of the interview, before turning to key takeaways. I typically highlighted 3 or 4 things I've learned, as well as other things that stick out such as certain words that call back to past interviews or literature.

There were several instances where I learned something that prompted me to return to my protocol and adjust certain questions. For example, I was asked to clarify, by two participants, whether a question I was asking was about fare payment or fare collection. I had been conflating the two terms, despite their very precise meanings. I adjusted the question in my protocol accordingly. I also adjusted by protocol to address questions about specific fare collection technology in place at each agency, often drawn from background research conducted ahead of time.

Analysis

I transcribed the interview recordings by hand. After transcribing the interviews, I highlighted key themes which served as descriptive and analytic codes from a first "pass" of my data. Using the qualitative coding software Dedoose, I completed two more passes to develop my final code structure. My final code structure is reflected in the organization of my results section. To complement my interview data, I analyzed a small archive of whitepapers and promotional materials for NFC solutions, which helped give "voice" to the private sector actors who developed NFC technology.

During my analysis, I approached these transcriptions as discursive texts which relate to wider power structures and ideologies that condition infrastructure production. Discourse analysis is used in urban geographic research to show how policy interventions are justified by actors in urban planning and governance in support of private property and other forms of economic orthodoxy (Jacobs 2006). In the case of NFC technology, I situate my participants' responses within a larger mobility regime that scholars have previously established prioritizes automobility and neoliberal urban development over collective, public mobility infrastructure (Nikolaeve et al. 2017; Spinney 2016; Stehlin 2019).

I approached coding inductively, following Gioia et. al (2013) beginning with interview data. Gioia et. al emphasize the importance of building theory grounded in practical experience, thus the need to begin analysis with interview data (2013). In the first pass, I generated hundreds of descriptive and analytic terms, drawn from my participants' responses. I then consolidated this "explosion" of categories based on broader themes, again, drawn from key participant terms. From these themes rose "aggregate" concepts, which were drawn both from my participants' responses as well as theoretical concepts from my literature such as commodification, the mobility fix and mutation.

Power and ethics later in the research process

Coding well entails honestly and effectively translating your participants' experiences and not simply ascribing them to pre-establish theoretical phenomena. The potential for harm, then, exists not only during the conversation portion of the interview — which the IRB might have you believe — but both after (in the analysis stage and beyond) and before (during preparation and selection). Nearly all of my participants expressed interest in seeing preliminary analysis of my data as well as the final draft of my thesis. This is borne not out of mistrust or fear of

misrepresentation as much as it is an interest in the process of knowledge production. However, to ensure I do not instil mistrust in the field of geography, I need to uphold the promises I made in the consent process — namely that their personal information and that of their employers would remain anonymous. While my participants are titled professionals, they are no less precarious and vulnerable to litigation than I am. And from many of them, I had the recognition of former grad students, who empathized with me and working within the IRB's stipulations.

Chapter 4: The adoption of NFC technology in the U.S.: Vignettes from the public transit industry

Introduction

In this chapter, I present my analysis of the interview and archival data I collected for this study. My interview guide sought to capture how benefits of NFC technology were framed by key actors involved with NFC technology. I explicitly asked questions about the benefits of their chosen NFC technology as well as broader questions about the importance of adopting NFC for their agency and other agencies. I asked my participants in the private sector to relate NFC technology to broader industry trends such as MaaS. During my analysis, I supplemented my interview transcripts with archival documents to give voice to the providers of NFC technology solutions and to relate them to the accounts provided by my participants.

My results are arranged into sections according to five themes:

1. Dematerializing cash and fare infrastructure
2. Integrating across public and private mobility services
3. Customer awareness/awareness of customers
4. Delivering fare policy with NFC technology
5. NFC technology and the barrier or proprietary fare collection infrastructure

These themes emerged from my interview data and correspond to capabilities and benefits of NFC technology reported by my participants. Within each section, I provide vignettes from my participants, stitching together their distinct experiences with NFC technology along with corresponding archival data to show how transit agencies in the U.S. have adapted this technology on the ground. These vignettes capture how, through NFC technology, agencies have improved their capabilities in fare collection, as well as how they have extended their service capabilities more broadly, often through integration with private mobility services. My participants have been

given pseudonyms to protect their confidentiality and their employers have been anonymized (see App. A for overview of participants).

I beginwith a discussion of the accounts by my participants which illustrate how eliminating cash and digitizing elements of fare collection infrastructure eliminate barriers to ridership and transit provision. I then turn to accounts of how NFC technology allows for different types of integration between transit and the private sector. I then turn towards the information provided by NFC technology, as well as the data generated by NFC technology available to agencies. I then explore the connection between NFC technology and fare policy. Finally, I explore proprietary fare infrastructure and how it limits as well as expands NFC technology.

1. Dematerializing cash and fare infrastructure

Cash-handling is a barrier to transit in multiple senses. For riders, who may be unclear on whether or not exact change is required, it can be so inconvenient that it serves as a barrier to riding. For agencies, handling cash requires a number of resources, from fixed assets at the point of collection, to carriage from stations to the agency "back office". Cash handling is so inefficient that agencies anticipate service improvements from digitizing cash with NFC technology. Need-based fares can also be digitized, streamlining delivery of discounted passes to eligible riders.

The barrier and expense of cash handling

Before implementing NFC, many transit systems required riders to use exact change when boarding a bus or otherwise purchasing a fare. Richard, drawing on his experiences working with fare collection at three different transit agencies, discussed this history:

> ...going back in time, riding transit was a challenge in the sense that 'oh' you had to have exact change; if you're going from one mode to another, one carrier to another, you had to pay different fares, trying to find out how much you have to pay...I just think there's a large

> number of customer benefits that would make using transit much easier and remove some of the barriers that might keep people from riding transit. (Interview 1)

The necessity of exact change combined with the complexity of paying for transfers between different modes or carriers constitutes multiple barriers to riding transit. The inability for drivers, ticketing machines and fareboxes to make change has only been recently addressed, as Curtis noted.

> I mean, first you had to have cash and exact fare only, for decades. It's only in the past 10 or 15 years where it became possible to not have to pay with the exact fare only... you could actually put in five dollars for a two-dollar ride and actually get a ticket that was worth 3 dollars in change. (Interview 2)

Cash fare collection is framed as mentally burdensome, in addition to being physically cumbersome NFC helps alleviate this mental burden for riders. For John at Agency 7, shifting to NFC technology "takes away a lot of the worries as they're riding our service, they don't have to worry about 'do I have enough change in my pocket?' They don't have to worry about that. All they have to do is tap their card, and we will calculate the fare for them" (Interview 10). Umo, a new platform-based fare collection solution from Cubic Systems, claims to take care of the details on behalf of their users. "Rather than focus on the details of a commute, Umo users simply Explore, Pay, and Go, an effortless way to get to wherever life takes them" (Cubic Systems, 2021, p. 3).

The hope is, as a number of participants expressed through various metaphors, that NFC tech will make paying for a bus or train ride as easy as any other small, everyday transactions. Alluding to the current circumstance, where different fare cards for are required for different transit agencies, and speaking on his agency's effort to provide an open payments ecosystem, Curtis noted

> I don't need a separate card to buy a coffee in San Francisco vs. here — and I should use the same card I buy my coffee with to buy my transit. Why can't I use that same card to buy my transit with? It would be intuitively obvious to the casual observer. (Interview 2)

Apps which bundle agency services with other mobility providers, following the "mobility as a service" (MaaS) paradigm, such as the one which Agency 5 has deployed, become a "one stop shop." (Rebecca, Interview 8). Dan, who recently helped add fare payment for dozens of transit agencies to MoveMent, a MaaS app, also described their service as a one-stop shop: "If you have to go to seven different supermarkets to buy your food it's a helluva lot more complicated than if you have to go to one supermarket." Christine at Agency 6 made a comparison to online retail: "I guess as a part of our vision is, we would love to become like the PayPal of mobility" (Interview 9).

Mike invoked his experience using the system he would later work with at Agency 3. He recounted an experience from the days before they rolled out a smartcard which should be familiar to anyone who rode public transit in a major metropolitan area area before the advent of NFC:

> And so, if you wanted to ride commuter rail, you'd have to go to the machine at a commuter rail stop. It didn't accept a credit card, you had to have cash. If you wanted a $2 fare, and you put in a $20 bill, you get $20 in quarters and change. Then, if you wanted to transfer to another agency's subway line...you'd have to go to another machine that didn't accept quarters, it only accepted like silver dollars, it was a mess. So, what the purpose of our card was, was so that there could just be one method or way to pay to at least remove that difficult barrier to make public transit a little bit more accessible in that way without needing to have the exact change for everything, you know, different fare systems. (Interview 4)

This elaborate movement of people and money between machines and their chosen transit mode helps to show how cash is not merely burdensome for the rider - it also absorbs agency resources. Richard highlighted this shared burden. When discussing the desire to minimize cash handling at one of his prior agencies, he cited a twofold benefit: "... it would be desirable to eliminate cash. One so the customer doesn't have to carry around change, and we don't have to deal with all the back-office stuff" (Interview 1). Compared to the infrastructure required for issuing paper tickets, Raina at agency 4 noted "Collecting cash is even worse. We have very old cash counting systems.

It's just a lot of work, a lot of people, and it's very expensive to capture and collect cash, and so it's much more cost effective for us to go digital" (Interview 5).

Curtis at Agency 1 described how cash-handling at his medium-sized agency is a drain on both capital and operational funds, between fixed assets like fareboxes which are required to collect and store cash on-board buses, to fees for carriage via armored truck. Alluding to the limited funding available to transit agencies, he finished: "Cash is very expensive to use in an industry that doesn't have a lot of money to spend on things" (Interview 1). As I discussed in Chapter 1, fare collection revenue makes up an increasingly large share of operations funding for agencies in the U.S. This increased reliance on fare revenues as other funder sources are pared back creates imperative to make fare collection as efficient and cost-effective as possible by digitizing and automating parts of the process.

The efficiencies gained by automating the work of the "back office" - a term that refers to the in-agency work of processing fares - is another benefit of moving away from cash and paper media. In a card-based system, the card, together with fixed fare collection hardware serves as a clearinghouse for information about the cardholder's fares. The back office is also deployed as a metaphor to describe the services offered by fare payment platforms such as Masabi. Masabi calls this elimination of cash and subsumption of the back office into their platform a "dematerialization" of fare payment, which helps both riders and the agency gain efficiencies.

> Dematerialization: Fare Payments platforms help move agencies away from legacy hardware and proprietary ticket issuance and riders from cash to digital channels using a mobile phone and contactless bank card, helping to reduce costs and increase convenience. (Masabi, 2019, p. 7)

Masabi calls the elimination, or digitization, of cash part of "dematerializing fare collection." Dematerializing fare collection could include loading cash onto a smartcard at a kiosk, eliminating

kiosks entirely and pushing riders to load value onto a smartphone app, replacing turnstiles with a proof of payment system, and digitizing "back office" processes such as logging transfers and providing need-based fares. The sense among some of my participants is to leave the payments infrastructure and work of handling transactions to the experts. As Curtis put it, "rather than put a dollar into the farebox on a bus, move the cash collection to the merchants" (Interview 1). Curtis' NFC solution was developed in partnership with Visa. His comment can be read as the devolution of work or scope of transit agencies to a contractor, or alternately it might be seen as a form of infrastructural thickening through fare collection platforms and payments processors.

Efficiency of service and NFC technology

In addition to the lighter fare collection infrastructure requirement and the increased customer convenience, moving away from cash transactions also allows agencies to increase on-time performance (OTP). Drawing on his experience working with fare collection on board buses at multiple mid-size transit agencies, Richard noted "Fare collection on transit, particularly on buses, delays buses" (Interview 1). This was a major concern for Agency 5, who not only have an OTP standard of 95%; they also recently started a bus rapid transit (BRT) service which relies heavily on speed of boarding to be successful. Greg at Agency 5 described some ways that handling cash or paper fare media is an issue for OTP:

> One is the consumers don't have their fare payment ready, it slows down boarding. Passes get wet, and so they can't be read by the fare boxes. So just there's intrinsic problems with the old system. I believe a lot of the impetus to instituting the new one is just how can we minimize that to help us reach our on-time goals? (Interview 8)

Their BRT service is unique in that for most of its length, it does not have a dedicated lane. Instead, the agency must find other ways to streamline the service to justify its "rapid" designation. One of those ways has been implementing a mobile ticketing app. Rebecca at Agency 5 explained how

the addition of the mobile ticketing app has been integral to the success of their BRT, despite the lack of fixed BRT infrastructure like dedicated lanes:

> We don't have a lot of room to grow, so putting in a dedicated lane was just not something that we had the ability to do, and still move the traffic we needed to move. There's still the car traffic. So, we had to find a way for that to work for both. And the mobile app is kind of, you know, the BRT and everything that came from the BRT in that momentum, the mobile app just kind of grows that even more. (Interview 8).

The potential OTP gains from implementing NFC technology, or "opening up" fare collection to accept any payment media, is promoted by Visa. Their Cybersource contactless solution claims it is central to "more expedited ticketing experiences" which speed passenger flows onto buses and through turnstiles onto trains. A pull-quote in their whitepaper attributed to Mary Kay Bowman, Head of Global Seller Product and Solutions reads:

> Contactless means there are fewer queues at the ticketing terminal. There aren't as many people in the line swiping to get in, because it's faster. And there are a whole collection of benefits that come with contactless. It creates a multiplying effect. (Visa Cybersource, 2020, p. 10)

Decreased passenger "lay-time" at ticketing terminals and turnstiles, Visa emphasizes, is also central to transit maintaining its reputation as a safe and sanitary transportation mode in the wake of the Covid-19 pandemic (2020 p. 10).

It is important to note that NFC technology is not the only way that agencies can increase OTP, or even the only way to speed boarding. For example, implementing all-door boarding or moving to a "proof of payment" fare collection system are other ways to speed boarding. Meanwhile, as Agency 5 noted, adding fixed infrastructure such as dedicated lanes, or consolidating stops could also increase OTP. However, adopting NFC technology allows agencies to improve OTP without costly changes to their operations or infrastructure.

Streamlining the delivery of need-based fares with NFC technology

In addition to simplifying cash handling through its gradual elimination, NFC technology has also helped agencies streamline their delivery of need-based or other discount fare programs. Agencies in the U.S. may offer discounted or subsidized fares for seniors, students, government employees, and low-income or disabled riders (APTA Fare Database 2019). Various NFC technology solutions typically accomplish this by having each token — mobile phone, smartcard, or other media — be associated with an account, hosted in the virtual back office of a fare collection platform. This is a marked contrast to the pre-digital solutions agencies used. Agency 6 used to process paper coupons which were sent to riders who qualified for discounted rides, but has eliminated them in favor of providing qualified riders with an account.

> There were these coupon books. Now because everything's integrated through our account-based platform, those discounts are given automatically. We have like 500 retail vendors throughout the county that sell our fare products. And so, these customers have to go and redeem those coupons. And then it was such a long process for even the vendors to have to mail back the coupons and get them get their reimbursement. So just in those processes, too, it's really cut down the time for vendors and some of the other groups that we work with. (Christine, Interview 9)

Following the addition of an accounts-layer over their existing smartcard system, Mike's agency will be providing need-based discounts for a large region in which multiple agencies operate:

> We're also doing a region wide means based discount program through our card...where people who qualify can get up to 20 to 50% off of their transit rides. And they just have to prove their eligibility for that. (Interview 4)

Both Agency 1 and Agency 5 discussed their newfound ability to partner with the state government to provide need-based fares through NFC technology. Agency 1 noted that they are one of the first pilots in a larger project to provide myriad public services, including transit and food assistance, through one card. Meanwhile, Agency 5 already has a program in place wherein "the same system that someone would apply for food benefits or medical benefits through the state, then they can apply for our benefits as well" (Raina, Interview 5) before being issued an agency smartcard.

It is important to note that while most agencies rely on some kind of back-office platform of the kinds provided by Masabi and Cubic, some agencies have moved the back-office *back* in-house. John at Agency 6 cited his agency's many partnerships with local institutions, like universities and large employers, to offer discounts via various smart fare payment media as one of the reasons they decided to end their partnership with a Masabi-like platform. According to John, his agency's emphasis on supporting their in-house IT capabilities allowed them to design their own fare collection system which has granted them flexibility to tailor agreements with regional employers who offer subsidized fares to their employees.

2. Integrating across public and private mobility services with NFC technology

NFC technology's ability to overcome the inefficiencies of cash handling, increase OTP and deliver need-based fares come together in support of its integrative power. NFC technology is integrative in multiple ways. It integrates payment across multiple transit agencies who operate in a region. In this form of integration, one fare card or other media is accepted by all operators as a form payment, adapting to each agency's unique fare policy. Agency 3 and 6 are examples of this type of integration. In open loop systems, such as at Agency 1, payment for transit fares is integrated with payment for other commodities since debit and credit cards, as well as smartphone wallets and other enabled devices are accepted as tokens.

But perhaps most importantly, NFC integrates payment for transit fares with private mobility services such as micromobility and transportation network companies (TNCs) such as Uber and Lyft. At Agency 6 for example, riders can use their fare collection account to purchase discounted Lyft rides. Riders may purchase transit fares for Agency 4 within the Uber app. MaaS platforms such as Google Maps or the MoveMent app (to use an example from this study) can also serve as payment integrators, offering transit fare payment alongside journey planning and

micromobility services through individual agreements with agencies. This is viewed as a benefit by transit agencies as well as NFC solutions because it allows transit to "plug in" to the larger MaaS ecosystem, offer greater customer convenience (via expanded options for both payments *and* mode choice) and generally serve a more seamless mobility experience, allowing riders to pay once per journey via multiple services. This is often seen as a step towards delivering the future of mobility and provoked many of my participants to compare their services with transactions for other commodities.

While this integrative power is in many ways made possible through ICTs, APIs and open data standards, there is also a good deal of work done within and across agencies to open up and maintain links between public transit, the larger mobility ecosystem and the payments ecosystem. Sandy discussed the necessity of this internal work, that at her agency (5) involves approaching MaaS with a cohesive vision that's maintained across departments within the agency:

> But I think that it also requires a lot of work internally, as far as being able to coordinate with the other groups within the agency to kind of come together and share and have a shared vision. There are a lot of different opinions in the transportation world, as you probably know about MaaS.... so, I think that, like Christine says, a big part of that internal work when we're trying to approach these partnerships, I think that's something else that we have to also consider and work through. (Interview 9)

Integration is important for the agency, as it increases customer convenience. Rather than in a purely negative sense of eliminating cash, thus alleviating the burden of counting out exact change, it achieves customer convenience in both a positive and negative sense. Customer convenience is achieved by increasing the range of services available to the rider through the agency's payment media. Convenience is also achieved by alleviating some of the burden of having to translate the shifting fare policies as a rider moves between services. Mike at Agency 3 explained how this is especially powerful in his agency's efforts to connect over 20 regional transit services:

> I think that that ultimately would be the goal where people don't even think about, "oh, I'm taking this mode, so I'm taking it out of my transit card versus now I'm going to use a credit card for this," you know, that kind of thing. To make it so that it is kind of one integrated experience.,, I think it solves one of the problems of the region in that there are 20 different agencies. And they all have different rules. They all have different fares. They all have different policies towards fares...So what it does is it demystifies that part for the average, you know, transit rider. (Interview 4)

At his agency, the card acts as a gateway to myriad public mobility services in the region, doing the work for the rider of figuring out the cost of transfers and so on. Christine at Agency 6 discussed how this helps her agency connect with private sector MaaS, comparing the ease of paying for transit alongside private mobility services, with the ease of online shopping transactions:

> I guess as a part of our vision is we would love to become like the PayPal of mobility. When you're shopping online, when you go to check out you're offered lots of payment options… But also, you're given an option to check out with PayPal, because you may have a PayPal account, it's just a one click, one button. So, you might be ordering a scooter share. When you go to purchase something you check out, you just have to click our icon. You don't feel like answering all the questions, filling everything out; but you already have an account with our agency, because it makes more sense to have our account than all these individual [MaaS] accounts. And so that's where the MaaS idea of consolidation can also play out with that deep integration and that little quick tap button the checkout is another example of like a quick payment function. (Interview 9)

At Agency 5, the potential to integrate with other mobility services via their ticketing app was an important draw. (Rebecca, Interview 8). For this agency, this is an opportunity to "redefine and reinvent" transit:

> We want to plug those things to the ticketing app as opportunities where someone can use you know, if you can use the bus service to get from point A to point B, but you need to go on to point C, but, you know, then I can get a scooter and go for another mile. (Rebecca, Interview 8)

Marketing materials for Umo, a product launched by Cubic Systems in early 2021 targeted at smaller agencies looking to implement NFC technology and plug into MaaS also presents itself as a sort-of single gateway for many modes of transportation:

> It's a world made possible with Umo, a smart travel companion and mobility platform that provides simple and flexible travel for users, transit agencies, and mobility service providers. It simplifies travel by integrating all of a region's transportation options—from

> buses, trains, trams, and ferries to rideshare, scooters, and bikes—in one place. (Cubic Systems, 2021 p. 2)

Note that Umo serves as a gateway for more than just riders, by presenting them with a suite of options to complete their journey, but also for transit agencies themselves who want to interface with other mobility service providers. Partnerships with Uber and Lyft, seen as increasingly important, are now possible through Umo and other solutions.

Rather than as competition, Christine at Agency 6 sees Uber and Lyft as integral to successful transit provision. Highlighting the wicked first-last mile problem that exists in their service area, she noted that their payments solution must be mode agnostic.

> ...we need bike share, we need scooter sharing, there's no way we will succeed if we don't work with our ride hailing services, so Uber and Lyft. And we've done some really cool partnerships with them, too. (Interview 9)

These partnerships, as Christine put it, allow the agency to grow and serve areas or journeys that fixed-route transit cannot serve on its own.

Uber also sees these partnerships as important for public transit. According to their 2021 whitepaper, “Transit Horizons,” Uber also sees these partnerships as important for public transit. It’s worth contrasting their recent overtures to transit with their 2019 Initial Public Offering filing, where Uber calls public transit its biggest competition in providing low-cost urban transportation (Gordon 2019). Meanwhile, in “Transit Horizons,” Uber states that public transit agencies are contending with increased consumer demand for convenience and integration with technology, as well as a mandate to “not leave anyone behind” (p. 3). According to Uber, meeting these demands in an austere budget scenario will require public transit to begin “transforming from decentralized networks, where different modes can often operate in silos, toward a system that is truly integrated, connected, and optimized in a highly agile way” (Uber 2021). Raina described how Agency 4

views their partnership with Uber as mutually beneficial, rather than just Uber helping support transit:

> Uber was happy to do that, because I think their customers were saying 'Hey how come I don't see transit in here? I want to be able to choose and have options' So this collaboration is really win-win. Uber wins in this as well. They're increasing engagement in their app - they haven't said this specifically, but I wouldn't be surprised - and we get to be in front of those customers that may not be taking transit. It was about being innovative. (Interview 5)

At Agency 4, Uber helps serve as a gateway to transit, as a feeder to the agency's service. This strategy was also deployed at Agency 6, who offer account-holders discounted tickets for agency services when they use Lyft. Christine framed this integration as strategic, helping serve the agency's goals: "So basically, if you are using Lyft, just how we want you to use Lyft — as a ride to our stations — then you get this discount on Metro." Christine called this a "light" integration of her agency's service with TNCs. Through their NFC technology, the agency has a "menu" of integrations they can perform, whether light promotions and discounts or deeper integrations. She then offered an example of a deep integration which their account-based NFC technology is capable of.

> ...we assume customer accounts, and we did that with the city's bikeshare program...although bikeshare may have its own website and you know, department and team - in terms of purchasing bikeshare passes, and releasing the bikes, that's all deeply integrated from the equipment to the accounts for that program. (Christine, Agency 6, Interview 9)

When these integrations are stitched together in account-based NFC technology, there is a great deal of work that goes on within the agency to make them possible. At Agency 6,

> …when you talk partnership at the metro agency level, I think it's, it's got a different dent, it's got a lot of like, cross-promotion. And there's a lot of legalities tied to it. There's actually like more structured outlines of the value tied to what's being — of the service that's being traded and offered. (Christine, Interview 9)

The complexity and work of negotiating and maintaining reciprocity between dozens of services the span public and private sectors is something several participants noted.

NFC technology also helps to integrate important information —such as scheduling and real-time arrival information, to assist with journey planning — and payments. This allows various mobile apps to serve not just as a payments clearinghouse for all mobility, but as an information clearinghouse. Within a single app, a rider may see bus schedules and stop locations alongside estimated time of arrival of an Uber driver and nearby micromobility hubs. John from Agency 7 discussed this merger of journey planning information and payments within the mobile ticketing app his agency developed internally:

> [It's] just simple for the rider. And I think that's the vision is, you know, you just decide where you want to go. And the technology figures out what, you know, what's the cheapest, or the fastest way to get from point A to point B, and you only have to pay once and everybody in that pipeline or in that service chain is, they get compensated for their portion of that journey. (Interview 10)

The General Transit Specification Feed (GTFS), an open data standard for journey-planning information first developed by Google in partnership with Portland State University and TriMet, has provided take off conditions for this integration of journey planning information with payments. This has led agencies to meet a more expansive set of ridership needs, rather than simply moving people from point to point. Recognizing and meeting this more expansive set of ridership needs is in part a response to decreasing ridership:

> As you know ridership is decreasing for a lot of agencies, and with Covid that question is especially ambiguous. Like what does ridership look like during covid and what does it look like in a post covid world? So, now, when agencies are talking about ridership, they talk about it differently. They talk about access to data and information and types of decision making and ease of payments. but I think the intention has always been there: how do we support our riders and how do we promote more ridership? (Sam, Agency 2; Interview 3)

The utility to riders of merging journey planning information with payments is also understood by actors in the private sector. Daniel's MaaS app, MoveMent, is integrating APIs and SDKs for different fare collection systems into its interface "so that users can purchase tickets in the same place that they're purchasing their journey planning app" (Interview 6). Another advantage to

doing it within their app is that agencies "don't have to go off and build something new or different;" meanwhile, customers can enjoy an app that's "easy to use and [will] give you all the information you need to get from A to B" (Daniel, Interview 6). However, unlike with GTFS and journey planning information, no such data standard exists for information about fares. Christopher alluded to this absence, which his organization, Movement Info, is helping to rectify by working with agencies and payments/fintech companies to standardize information about fares:

> We think there's a lot to be won just by...there's a lot of opportunities people are missing out on in terms of transportation because they don't have the information. GTFS has been really exciting, and it showed people a lot of different options they didn't really know about, but in my mind it's amazing how much is still missing from it - both in terms of the depth of information provided and the breadth of, the number of agencies or services that are providing GTFS. (Interview 7)

NFC technology provides a convenient way to pay, alongside integrating public transit agencies with sometimes dozens of other mobility services that have proliferated in the last few years, namely Uber and Lyft but also bikeshare and e-scooter share. It also integrates payments with journey-planning, serving as an information and payments clearing house, as well as sometimes a "gateway" to the regional mobility ecosystem.

3. Customer awareness/awareness of customers

NFC technology and increased customer awareness

NFC technology helps contribute to customer awareness in multiple ways. As discussed in the last section on the integrative power of NPT, NFC can help show the totality of mobility options available to a rider/customer. Along with integration and digitization of cash fares, NFC helps contribute to a "seamless" mobility experience by simplifying information presented to the rider. The construction of "effortless" mobility, as noted in Section 1, is as much about eliminating details as it is about information provision. One of the commute's "burdensome details" which apps like Umo help alleviate is the value of the token the rider is carrying. Carrying cash and

paying for services as John noted in Section 1 can be mentally taxing to the rider. NFC promises to alleviate some of the effort passengers expend at managing these details so that once it's time to embark, all riders have to do is "tap their card, and we will calculate the fare for them" (John, Agency 7, Interview 10). Riding transit with older fare media, like a prepaid mag-stripe card might involve some guesswork about how much value the card still holds. Agency 2's account-based NFC helps take away some of that guesswork. Sam at Agency 2 contrasted the information available to riders via her agency's recently developed account-based system to the lack of clarity endemic to a card-based system:

> If you're a rider here and if you create an account on the website or the mobile app, you know that what you're seeing, your account information, is the right information. Your travel history shows up within a couple seconds of travelling, your balance is going to reflect what your actual balance is. There are some systems out there where users literally have to, like, guess what's on their card because when they log into the website and see what the backend system thinks is on their card, it's actually a really different picture of what's actually on their card when they go to tap at a validator. (Interview 3)

John also touted the real-time information about the balance of riders farecard available through his agency's forthcoming mobile app:

> And they have online features that they can use to check their balance and manage the cards online and things like that. And that takes away a lot of the I guess the worries as they're riding our service. (Interview 10).

Riders are also made aware of other payment services, bus and station crowding, and other mobility services through NFC. Agency 5 hopes that their partnership with a network of bill payment kiosks, through which riders can also load value and purchase passes using cash, will grow awareness of the other options they have for bill payment.

> We actually think this will grow the relationship for a lot of people here, when they realize they can go pay their phone bill or they can pay this other bill that they have and they can go to one place and pay for four things at once. Rather than mailing this in or mailing that in. We think it'll be a convenience not just for their transit but also for some of their other needs. (Rebecca, Interview 8).

During the Covid-19 pandemic, the MoveMent app which Daniel works for rolled-out live information about bus crowding. Meanwhile at Agency 6, offering a suite of mobility services via their NFC might help grow awareness of alternatives to driving. In response to a question about replacing individual car ownership with MaaS, Christine said, "I don't think any one philosophy or any one *thing* can actually do that, especially here, but I think it can sure expand the minds of people who are driving in cars and offer just more possibilities" (Interview 9).

In the interest of making the system more legible to riders, sometimes more information isn't necessarily seen as helpful. There is a certain amount of mystification that can be accomplished through NFC technology. The merger of MaaS with fare payment which Masabi helps facilitate, along with the "dematerialization" of the transactions required to ride public transit, Masabi claims will make it "so passengers no longer even need a ticket or to understand fares. Instead, they just tap and ride using a contactless bank card, mobile phone or smartcard" (2019 p. 3).

The making-more legible of transit involves both clearly presenting certain kinds of information – particularly the value of the token a rider holds – and obfuscating other kinds, evidence of the translation work accomplished by both the NFC technology and people within the agency:

> Customers don't know… When they ride, I don't think they understand all the technology that's actually on the bus or a rail vehicle behind the scenes. And our IT department basically manages all that. We have to manage our own radio systems, got our own towers, we've got, you know, onboard technology that we are constantly maintaining and operating. And the customer doesn't even know it, they just have the card and the light goes green and then they sit down. (John, Agency 7, Interview 10)

Christine discussed how in her work, she serves as a conduit between "expert" engineers and the public her agency serves:

> So before, our department which manages fare payment was just made up of a bunch of engineers. And, you know, it's okay to have your experts, you just gotta get everybody

> together in one room and work together. So, under customer experience, our forte is to be like this barrier, this liaison between our engineers and the customer, so that the great stuff that's happening in the lab can be easily digestible by the customer. (Interview 9)

Platform solutions like Umo and Masabi promise to make riding easier for customers by alleviating burdensome information, automating the mental work of riding transit. However, this automation via digital infrastructures is also accompanied by a social infrastructure of translation through the work of agency employees. The relationship between transportation, technology and the rider is mediated not just through technology, but through the lively work of people like Christine at Agency 6 and John at Agency 7.

Awareness of Customers: NFC and improved data collection

I presumed that by digitizing cash and paper tickets, as well as automating some back-office functions of transit agencies, NFC technology would yield improved data for transit agencies. I asked my participants about this. I found that as NFC technology strategically presents information to make transit more legible to the rider, it also serves to make the ridership more legible to the agency. Additionally, NFC technology automates data collection; data that would be laborious or impossible to collect are now available to agencies that use NFC technology.

Sam at Agency 2 described the varying detail of the different data pictures granted by smartcards vs. a system which combines an account "layer" with a near-field-communication-enabled token such as a smartphone or credit card. In the card-based system, there's a cleavage between what the back office "sees" versus what is registered on a validator:

> That means that the source of "truth" for each customer and how much value or passes they have or what their fare type is — that information lives on the card… So, every time you tap or run your card through the fare gate, the fare gate is making a local decision by reading information of the card and comparing it to the fare policy that is stored on the hardware, and then giving a "go" or "no-go" choice to the rider. (Sam, Agency 2, Interview 3)

This gap varies temporally depending on how the validators communicate with the back office. In some systems it is near instantaneous. In others it can take hours:

> Then, that information is uploaded to some sort of central system in a variety of ways. Most fare gates are connected to the network so that they can upload in near-real time. Some of them, I don't know the frequency in NY or DC, but I wouldn't be surprised if that frequency was like every hour or every other hour. (Sam, Agency 2, Interview 3)

For the rider, this can distort their perception of the value of their card or other token. Sam also described how this is problematic for the agency:

> So, the reason card-based solutions are really challenging is that the transit agency never has a 100% accurate picture of what your ridership actually looks like, or what your outstanding liability from an accounting perspective to your riders actually looks like. So, the books that are kept in house from an accounting perspective won't necessarily line up with the "truth" which is out in the field in everybody's hand. (Sam, Agency 2, Interview 3)

On an account-based fare collection system, meanwhile, because the information doesn't have to live on a card, or on stationary validators aboard buses or at fare gates, the picture agencies see is much more accurate and closer to real-time. In their system, many different ICT devices can serve as a "token" or account identifier, in place of a card or ticket (it could also still be a card, confusingly). It's just a container for the rider's account information:

> That account identifier is actually what's passed between the card and validator when the card is tapped. Then the validator is connected in real time to a back-end and it pulls up that account information, and pulls up the value associated with that card, and can make a real-time decision about validating or invalidating the card based on the account in the back end. Why that's way more flexible is that anything, or many more things, can be an account identifier. So, in our system, you can have a Fitbit, load your card or account identifier onto your Fitbit, and use that to travel. (Sam, Agency 2, Interview 3)

There is a twofold benefit to this: both the rider and the agency have real-time information about the value contained in user accounts; the agency has the added benefit of a real-time picture of who is using their system:

> The other benefit, from an accounting perspective, is that our agency has a pretty good idea what their ridership looks like and how much money is loaded onto people's accounts, so we can pull really good reports around the value and the passes that are loaded onto people's

> cards. Similarly, if you're a rider here in our city, and if you create an account on the website or the mobile app, you know that what you're seeing, your account information, is the right information. (Sam, Agency 2, interview 3)

An account that is associated with one rider can provide pretty granular ridership data that way. Rebecca at Agency 5 described the limitations of cash and paper fare media as lacking this granularity:

> So, with the traditional rider someone who is using cash or even a paper ticket, like we can't track that individual rider like ticket per ticket. So, all it would really have is that ticket got on the bus here, this ticket got on the bus there. But then maybe the next day they have a new ticket, we can't connect to see how many riders we have regularly riding. (Interview 8)

More than just provide an accurate picture of revenue and numbers of riders, the data provided by NFC technology also has a valuable spatial element. Now that they've rolled out a mobile ticketing app, Rebecca's agency can "follow" riders through the system each time they ride:

> With the mobile app's data, everybody sets up an account. So, there's at least an account where your tickets go in your wallet, that's going to be associated with your phone number, or I think your email in the future. So, there's an account that kind of follows all of the ticket purchases and the travel of that individual and it lets us kind of see how everybody's riding… Now we can see how people are purchasing tickets. And then we can look at the ridership data and see where the ridership data is and kind of make a correlation, where before we didn't have that information. So, I can make average rider statistical conclusions, based on solid information that I couldn't make about a paper ticket rider. (Interview 7)

For her colleague Charles, this has not only generated more sophisticated ridership data, but also streamlined the labor it would take to analyze it. "It would be hours of data analysis, just to put all these pieces together" (Interview 7). Raina at Agency 5 also emphasized this spatial element when we discussed the sophisticated data provided by their NFC technology:

> We are able to capture more data in terms of our ridership patterns. We don't get that when someone is using a paper monthly pass. But when someone is using a digital device which they have their pass on, whether they take that device and it's a QR code and they activate it in the mobile phone, or validate it on the buses, we can capture that data. What that helps us do is that it gives us a little more insight on where customers are using our service, where potentially we could possibly add service between rail and buses. Maybe there's a transfer point that would really benefit our customers. It is the data piece. (Interview 5).

At Agency 7, John also noted how their NFC technology, which requires riders to tap onto and off of the transit system, allows them to accurately calculate fares along with capturing rider movements through their system.

> We can track the usage of that token - we're not actually tracking people, we're tracking tokens really - and we can see how that token moves through our system, when they transfer from bus to light rail. For example, we can see how, how long it takes them to get from point A to point B. And so, we're doing all this. This gives us the ability to not only control how the fare is calculated for the card, but how we can understand how that token flows through our system, how they use our service. So, it's a lot of fringe ridership data that we I don't think we would have otherwise. (Interview 10)

For Mike, the spatial information yielded by Agency 3's NFC technology helps illustrate how the agency integrates over 20 different services, all stitched together through a single smartcard. At Agency 3, the smartcard helps all these different services come together in a cohesive whole, which is borne out in the data:

> I think that the data from our card is really great for our agency's purposes, because we can actually see where the demand is for regional travel that involves multiple operators. Before we were implemented, I think the agencies just guessed, or, you know, like did rider surveys. But we actually have the data to have these numbers now. And we can see that there generally is a pretty robust market for people who ride in multiple agencies, that I don't think we would have been able to see before we had a smartcard. (Mike, Interview 4)

The card not only helps provide accurate data, it also simplifies and streamlines its collection, helping agencies move beyond guesswork and rider surveys. Mike noted that the data is strongest in the urban core, where adoption of their smartcard has been strongest, whereas data on more rural services is still limited. There are other aspects of transit and mobility service in Mike's region that also remain illegible:

> What we can't tell and we don't have visibility into is if you bus or your train stop out in the suburbs, and someone wants to take a Lyft, obviously, we don't have visibility for that. Other agencies in the region have been able to get Uber and Lyft data, and have been able to model it, but I don't think anybody's combined the data that we have from our card with Uber and Lyft data, to figure out what the overall thing is. (Interview 4)

The data provided by NFC technology would be incredibly laborious to collect manually. In a way, this resembles the automation of back-office accounting functions NFC also helps to automate. generating an image not just of revenue and numbers of riders, but of *where* those riders are.

This data makes ridership more legible, presenting an accurate spatio-temporal picture of who is in the system at a given time. This data also provides a sophisticated accounting picture, showing how much money is in the system at a given time. These different layers constitute "thick" data for agencies to draw on. By automating laborious tasks, it also extends the service capability of an agency. But, importantly, this data also reveals the way in which NFC stitches together transit agencies within a metropolitan region. By allowing agencies to "follow" a rider as they move through the system, even as they transfer between different service providers, NFC technology can generate data that shows links or gaps in their network that may not have been apparent before its introduction. However, this may risk reifying the primacy of services in the urban core at the expense of services in the periphery.

4. NFC technology and the shaping of fare policy

The relationship between NFC and fare policy is complex. While NFC helps make fare policy more legible to riders — by, for example, automating the collection of transfer fees paying for transfers and accounting for the various reciprocity agreements and various other "back office" tasks — it doesn't necessarily simplify the fare policy itself. That is, what the ride costs and why it costs that much. When I began this project, I thought that fare collection technology would be used to deliver a simplified fare structure that favors riders through policies like fare capping. I thought that the only thing that stood in the way of those things were lack of will or imagination, but I learned in my investigation that there's a lot more going on. It turns out that the *complexity* of fare policy isn't necessarily a problem - in fact more complex fare structure in some ways means

a fare structure that is more favorable to riders, if that complexity is due to various discounts. Most of the complexity of fare structure lies "backstage", hence the emphasis on simplifying and automating back office tasks discussed in Section 1. Still, complex fare structure is viewed as a barrier to ridership, as well as a barrier to MaaS. The actual cost of a ride is unclear with more complex fare policies that, for example, levy transfer fees or charge for peak hour travel. Fare structure and policy meanwhile is difficult to model in mobile applications, unlike schedules and fixed-route information.

Fares are harder to model in an API, which is why information about fares has been taken up more slowly by mobile applications than information about schedules and routes. Incorporating fare payment into different MaaS applications, such as MoveMent, "does tend to reveal in a stark light how complex sometimes those fare policies are" (Daniel, MoveMent, Interview 6). Christopher helps explain why this is the case. The nature of information about fares, the myriad exceptions that only exist in certain localities, are particularly problematic.

> I think with fares specifically, its complexity. This is true in North America but it is also true in Europe and in Japan and in most places. We've created a fare system which is incredibly complex. So, it's very hard to standardize, because, for instance, in Chicago, if you are an active military member in full uniform, you get to travel for free. But, that does not exist in that exact way anywhere else in the world...It's much harder to standardize all those exceptions, and the same goes for different fare mediums and transfer rules. There's just a lot of detail to say "this is how you should structure it." It's easier to do that for a single trip, and that's where GTFS started, but once you look at passes and all these different eligibility things and point of sale things, it's very complex. Which is very different than the schedule of the bus, which is much easier to summarize. (Interview 7)

Fare policy is localized and territorialized. As Christopher says, a fare which exists in one place "does not exist in that exact way anywhere else in the world." Exceptions which are available for certain classes of riders, like active duty service members, are not made everywhere. The territorialization of fare policy is due to social, political and institutional conditions on the ground and cannot be neatly redressed with the implementation of a new technology.

When asked if his organization has gone beyond merely trying to standardize the presentation of fare structure, to actually advising agencies on ways their fare policy should be structured and potentially more streamlined, Christopher replied:

> So as an organization we don't have a specific policy, in terms of what it should be, but… I studied urban planning, I've worked in this space for a long time. We do raise that point in a subtle way that… this [policy] is a lot of effort to maintain. There's also an efficiency in simplicity of things. Really is it worth making this special discount? In a lot of places, it's like, why don't you just have a 90-minute pass? It's way easier to model! That's already going to lower the costs of your fare collection but also the work that we're doing in terms of trying to build that model. It's going to be easier for us to represent that in the fare model, earlier on. We're not trying to do policy but we will...we start with what is most commonly used. If you have a crazy edge case, because you have a weird and overly detailed system, it's going to take us longer to get around to modelling that (Interview 7).

According to Christopher, maintaining an array of specialized discounts, exceptions and tiered-pricing is cumbersome, not unlike handling cash and paper media. In my participants' view, simplifying fare policy and paring it down to a single offering such a pass that grants the rider unlimited travel within a 90-minute window would simplify the work of transit provision, bringing potential cost-savings. Additionally, it would allow for fares to be more easily modelled and purchased within third-party apps alongside scheduling and route information.

Sam, speaking from experience working both at transit agencies and for fare payments solutions echoed this sentiment and talked about its impact on fare collection technology:

> Fare policy is incredibly complicated and very frustrating from an industry perspective because there's not that standard, a national or global standard around fare policy. It varies agency to agency, so you encounter these bizarre agency-specific rules that have been approved by their boards and are adopted by their riders, so the technology has to be nimble enough to kind of adopt these really agency specific rules across the states. (Interview 3)

At present, for a NFC technology solution to be successful, it must be able to accommodate an array of variegated fare policies alongside other particular needs of the agency. So, it is the job of the technology to reflect and carry out these policies, rather than to up-end the fare structure status

quo. Richard has worked at several agencies on deploying new fare collection technology, which has also accompanied conversations about simplifying fare structure at those agencies:

> I would say, at least from my own personal approach, I've looked at where fare policy should be and then figured out how to enact it. The idea is you're trying to make it as seamless as possible for the customer but because it is, because everyone has their own policy, it becomes complex…The technology allows you to enact the policies that are more customer friendly. However, you do just have to go beyond just having the technology to address the fare policy at least a little bit. (Interview 1)

According to Richard, simplifying fare structure has the potential to make transit more seamless not just for the riders, but for transit system workers. He recounted an experience he had while working for an agency on the West Coast:

> One day one of our drivers was complaining to me that our fare policy was very complex. I said "how is it too complex?" Thinking about our local fares. We have a local fare, a discount for seniors and a pass, so what's so hard about that? Well it was the fact that our fare policy was six pages long. About a half a page dealt with our local policy and the other pages dealt with our transfer arrangements with agencies in the metropolitan area. And, obviously, every system had a different arrangement, a different fare...it became very very complex. Yet, in an effort to try to make things work, we had to do these different policies. The idea is you're trying to make it as seamless as possible for the customer but because everyone has their own policy, it becomes complex. A smartcard or mobile payment is still complex but it can help simplify it — however, you do just have to go beyond just having the technology to addressing the fare policy at least a little bit. (Interview 1)

At Richard's former employer, multiple connecting and overlapping public transit agencies necessitated a complex fare policy. In his telling, NFC technology helps customers seamlessly transfer between public transit services without an overarching regional fare policy; instead, the technology stitches together a patchwork of distinct policies. The work of actually addressing fare policy is much more political and not easily resolved. This resembles the integrative power of NFC technology at Agency 4, which performs a similar stitching function.

Other participants I talked to have, like Richard, used new fare collection technology to enact more customer friendly fare policies. Sam's agency for example, is one of the first in the U.S. to implement a fare cap - a daily limit or weekly limit on how much a rider will pay for transit,

usually pegged to the price of a weekly pass. This policy was born out of a long internal research process at the agency: “The agency started with very methodically going through the fare policy and how the fare policy could change to support a new fare payment system” (Sam, Agency 2, Interview 3).

Curtis also discussed how Agency 1 is using NFC technology as an opportunity to experiment with new fare policies such as fare capping. He alluded to the potential social benefits often ascribed to fare capping; chiefly that it allows riders to take advantage of a weekly discount without requiring them to have the lump sum required to purchase a pass at the beginning of a given time period:

> So by allowing for things like fare capping on a daily/weekly/monthly basis with this type of technology, we can offer someone of limited means a way to take advantage of some of these discounts without them having to put up an amount of money in one lump sum, that they just can’t afford to do. (Interview 2)

He also discussed how the agency can now offer fares that are tailored to its particular network geography, where buses traverse long routes to connect with nearby metropolitan areas, showing how fare policy is to an extent shaped by network geography:

> And we’re also going to introduce distance-based [fares], because we’ve never tried that before and [this technology] gives us an opportunity to play around with that. Again, we travel very long distances. (Interview 2)

However, the possibilities offered by NFC technology outpace the movement of fare policies, which are typically set by the governing boards of U.S. transit agencies and sometimes require approval from the ridership or metropolitan governments in the regions they serve. This can contribute to cleavage between technology and policy. Raina described how, in spite of having a widely adopted NFC smartcard and growing mobile app, her agency has not experimented with “customer friendly policies,” as others have:

> I think at other transit agencies, it's a way to start experimenting with other fare policies, but not at this agency. It’s a lot of work to make changes to fare policies. The tech gets

> launched much more quickly. We may have had some discussions, but I'm not seeing any significant changes in the fare policy because of the implementation of these new systems. These new systems adapt and implement the old policy, the existing policy. It's kind of unfortunate. It'd be great if we could do fare capping but...yeah. (Interview 5)

Rebecca also alluded to the work that goes into changing fare policies at her agency:

> There's a lot... but fares and what you charge, when you charge and how you change fares, there's a lot that goes on to make sure that everything is ethical, legal. There's a lot you have to think about. (Interview 8)

Her agency's roll-out of a mobile ticketing app has at least started the conversation about updating their fare policy — which requires a robust study of "a million other questions" including setting a fair market price for transit — but, for now, as Raina said, their app will "adapt and implement the existing policy".

Mike at Agency 3 acknowledged they have been slow to move with changing their fare policy, despite having one of the first NFC systems deployed in the U.S:

> Of course, it's 2020. Now, I think the way that our system is implemented now, it definitely does need an upgrade to be able to support some of these newer policies, and kind of movements in fare policy and fare collection. (Interview 4)

Christine acknowledged the complexity of overhauling agency fare policy while also touting the flexibility of Agency 6's NFC technology:

> Certainly, there isn't a fare policy or a fare structure that our solution cannot support. And I think that's the beauty of the system because it is so agile and flexible and it can offer different changes and stuff. However, our solution doesn't set the fair policy or the structure. It just supports the implementation of it. The policy and structure is usually set by, you know, elected officials who serve on our board, you know, sometimes they want free fares, sometimes they want a different fare structure that...The great thing is that our NFC system can facilitate it all. (Interview 9)

In lieu of totally overhauling their fare structure, Christine has helped facilitate a number of discounts and partnerships detailed in prior sections. Daniel, who has integrated fare payment for multiple agencies within his company's mobile app also talked about how agencies have adapted fares to new technology without totally transforming their agency's policy.

> The other thing that we have seen is that some agencies in the global arena are using it to simplify the fare structure that they're offering on mobile. So not necessarily simplifying their whole fare structure, but saying that "we're not going to give everything for mobile, but we're going to have a monthly pass and a day pass" or "we're just going to have pay by and fare capping here. (Interview 6)

NFC technology has been slightly hamstrung by the requirements to accommodate different agencies' fare policies. Meanwhile, agencies can't just go ahead and simplify their fare policies, potentially enacting more customer friendly and attractive (and equitable) fares just because they have new technology. That being said, adopting NFC technology has been an opportunity to experiment with those policies — or at the very least begin the conversation on how to implement them. Meanwhile, some agencies have adapted the technology, circumventing the question of overhauling fares for the time being while still offering discounts tailored to and within their solution. At the end of the day, the tech adapts the agency's policies, not the other way around. The necessity of the technology to adapt is central to the future-imaginary of "one card for all transit." As Richard put it, "so anywhere you'd travel you could just have that one card that could adapt to the prices" (Interview 1). But fare collection technology has not always been able, whether through technological limits, the limits imposed by contracts, or even network geography, to adapt in this way.

5. NFC technology and the barrier of proprietary fare collection infrastructure

Over the course of my semi-structured interviews and archival analysis, the issue of proprietary hardware and information, usually as it relates to legacy fare collection systems, was presented as a major challenge. NFC technology both overcomes this challenge but is also limited by it. Already-existing fare collection technology has proven obdurate. Masabi, in their 2019 whitepaper which presents their software-as-a-service model of fare collection to transit agencies,

described agencies as “stuck” with older technologies because of restrictive and expensive contracts:

> However, this trend has not taken hold in the Fare Collection industry (mobile ticketing aside), which is still dominated by Automated Fare Collection (AFC) providers offering bespoke and customized solutions which agencies purchase and are stuck with for years (sometimes decades) using a Design, Build, Operate, Maintain (DBOM) model (2019 p. 3).

The “trend” Masabi speaks of is the “software-as-a-service” model, which is a hallmark of platform infrastructures. Rather than provide costly fixed infrastructure tailored to the needs of individual customers, platforms offer flexible software solutions. As opposed to a “bespoke” solution, companies subscribe to a service and can choose, on the fly, how feature-dense and extensive the services they need are. Daniel explained to me how the relationship between platform solutions and transit agencies fosters competition and incentives:

> Because they're getting paid a certain percentage on everything that they sell, they have an interest in increasing the adoption of selling more things. And because they have an interest in adoption and selling more things there's a very natural relationship we have between the two. (Interview 6)

According to Masabi and some of my participants, the hallmark of legacy fare collection systems, such as the ones provided by Cubic Systems, is inflexibility. Cubic was mentioned specifically by several participants. Cubic was cited as an “obstacle” (Interview 1) or “elephant in the room” (Interview 4) to a fully “open” token-agnostic fare collection system.

The participants I talked to who presently work with Cubic described Cubic as amenable to incorporating recent innovations in NFC technology such as account-based ticketing. Mike’s agency, for example, is rolling out an account feature developed by Cubic. Agency 6 brought in an outside contractor to develop and implement their accounts feature, and Christine described Cubic as a willing partner in this.

> ...the assumption is that Cubic is the only contractor that we work with. So, it's almost viewed as an unfair advantage that they have, when really the reason why they keep getting our business is because it just makes financial sense to continue to do business with them. It's not that we don't offer the opportunities, we go out with RFPs all the time for new business, but it's a competitive bid. And so Cubic has positioned themselves to dominate the fare equipment industry across the world (Interview 9).

According to these participants, Cubic isn't necessarily an obstacle for individual agencies who are looking to offer accounts or integrate with other services — both Agency 4 and 5 have been able to do these things while working with Cubic. Cubic, however, is said to stand in the way of a more open and competitive fare collection technology industry and payments ecosystem. Sam originally began working with her current agency (2) on helping to figure out how they could open up their fare collection system, not just to other modes of payment media, but to other fixed asset and hardware providers.

> So initially my work with them was building an embedded development kit for validating fares that we put onto third party validators...at the time that was pretty revolutionary because every fare collection system in the United states was essentially a closed system. In saying that what I mean is that for instance, Cubic, they own the back office, they own the card distribution, they own all of the hardware in the field, they own the contract for the website... what this agency did was kind of break that concept and say, "we want to have an open architecture" where the back office is owned by a system integrator but we want to choose the vendors we work with for each of these pieces to create the best end product for our riders… So, what that allows for is a disruption in the hardware space. So as an agency, you can look at having cheaper and cheaper hardware on your vehicles. There's a lot of low-cost hardware providers out there that have not traditionally been able to play in this place because the contracts are wholly owned by these very large organizations like Cubic. (Interview 3)

Daniel, drawing on an experience at a large transit agency prior to working for MoveMent, describes how the cost of proprietary fare collection infrastructure limited their ability to pursue a partnership with a private micromobility service:

> We went to go do this and what we learned was that it cost more to put a fare box on one of our microtransit vehicles than the vehicle cost. What that said was that transit agencies really weren't able to partner with sort of innovative start-ups in this way because of their legacy technology. (Interview 6)

Christopher implied proprietary information and fare collection infrastructure is holding the transit industry back, contrasting it with the willingness of tech companies to compete in an open environment.

> I think what's going to be interesting going forward is how do we bring all these payment companies around who are super interested in this. So, whether it's the vendors for the onboard payment systems, or the e-ticketing systems or whatever it is for agencies, as well as all these big payments companies, big credit card companies. How do we build that same attitude and environment that has managed to come out of Apple and Google and all the big tech companies? Like literally, Microsoft, Google, they're all members of our organization. How do we get that type of environment to also apply to fares? (Interview 7)

Curtis's agency is one of the first in the nation to experiment with an "open loop" mode of fare collection. He attributed the ability for Agency 1 to experiment in part due to their relative distance from other major metropolitan transit providers as well as the fact that they had never previously "locked in" to a legacy fare collection tech such as one provided by Cubic Systems.

> We're outside the major urban areas of San Francisco Bay area or the L.A. area where there are major investments in closed-loop contactless card or card reader technologies. Our region is outside of that. And we're not tied into a regional, political scheme that's supporting a particular technology at this point. (Interview 2)

Like the example of fare policy, fare collection systems are territorialized and shaped by regional politics.

Masabi and other "software-as-a-service" platform solutions for fare payment claim that the transit fare collection industry is uncompetitive. They are also unable to scale if transit agencies do not "open" their infrastructure to platform solutions. Thankfully for Masabi and their peers, agencies on the whole want to move beyond reliance on proprietary digital and physical infrastructure.

The results of my study highlight a number of benefits to adopting NFC technology. These benefits, as cited by my participants, can be attributed how NFC technology dematerializes or

digitizes fare collection, streamlining both the passenger experience and work of delivering transit service. Through digitization, multiple elements of fare collection are also automated, such as data collection and determining the cost of a journey. Even complex fair policies are automated and invisibilized. Transit service is also streamlined and extended by integrating payment across public and private mobility services. NFC technology has also disrupted fare collection infrastructure, allowing transit agencies to work with cheaper hardware providers while offering their riders a more convenient way to pay. However, these benefits might also be understood as infrastructure-light fixes for urban mobility, as well as downstream effects of the enclosure of the mobility commons.

Chapter 5: Towards a critical understanding of NFC technology

In this chapter, I will deploy key concepts from critical transportation scholarship to develop a critical understanding of NFC technology. In Chapter 4, I presented the results of my analysis of interview and archival data. My study sought to explain NFC technology through a lens informed by critical transportation scholarship. Drawing on critical transportation scholarship, as well as insights from policy mobilities and infrastructure studies, I developed three research questions:

- How does NFC technology serve as an urban mobility fix?
- How does the adoption of NFC technology reflect the logic of enclosure and commodification found in other low-carbon mobility infrastructures?
- How do the social infrastructures of the public transit industry shape NFC technology?

In Chapter 3, I provided a methodology to develop a critical understanding of NFC technology. This included a semi-structured interview protocol and development of an inductive coding structure drawn from my participants' responses as well as my review of critical transportation literature. Following my analysis of semi-structured interviews, I turned to an archive to supplement my interview data which I analyzed using my developed coding structure. The results of my interviews were consolidated into five themes. I detailed these themes extensively in Chapter 4 and have provided a summary table with examples:

Theme	Examples	Theoretical connections
Dematerializing cash and fare infrastructure	Convenient, cashless transactions for riders; efficiencies gained for transit agencies; on time performance gains; streamlined discounts	*The mobility fix*: infrastructure-light solutions which do not address broader conditions of urban mobility; *The mobility commons*: promotes capitalist ideal of consumer convenience, commodifies mobility
Integrating across public and private mobility services	Payment for public transit and micromobility or TNCs with single token or app; partnerships with TNCs; collapse and simplify all mobility options into one payment account	*The mobility fix*: transit service is extended via partnerships with private mobility, rather than expansion of public networks *The mobility commons*: a large swathe of the urban mobility ecosystem is enclosed within apps and banking technology *Policy mobilities*: integration isn't just digital, but requires work of actors within agencies
Customer awareness, awareness of customers	Customers have real time info about balances presented alongside journey planning; agencies have real time info about riders, able to follow journeys from a to b	*The mobility fix*: transit's capabilities extended through automation of data collection *The mobility commons*: incomplete data picture which reinforces the urban core over the periphery
NFC technology and fare policy	Technology simplifies fare payment but not the policy itself; technology is limited by political and institutional processes	*Policy mobilities*: technology is easily transferred, less-so successful adaption to local needs and conditions
NFC technology and the barrier of proprietary fare collection infrastructure	Agencies can choose hardware providers when they use flexible software solutions; learning from tech companies	*The mobility fix*: rather than use public capital to build public infrastructure, instead it is used to support a market for new, often unproven mobility technology

To answer my research questions, I will deploy three concepts in my discussion of NFC technology: urban mobility fix, governmental fix, and enclosure of mobility. I then devote the final section to discussing what I term "social infrastructures" (Peck and Theodore 2015) of NFC to show how NFC technology is more than just a digital and material form of infrastructure that arrives fully formed at U.S. transit agencies, and is instead territorialized and adopted by social actors within institutions.

NFC as a mobility fix

The embrace of NFC technology by public transit agencies in the U.S. must be situated in the context of two larger imperatives faced by transit in the 21st century. First fare collection secures an increasingly large share of operations funding in the form of fare revenue. At the same time, agencies are facing increased budget austerity – it's "an industry with not a lot of money to spend" according to one of my participants – alongside decreasing ridership. Second, transit agencies provide a critical infrastructure of low-carbon transportation, abating air pollution as well as congestion by conveying large amounts of people for a nominal fee. However, public transit now faces competition from private shared and micromobility services such as Uber, Lyft and Lime (scooters, bikeshare). While Uber and their ilk recognize they cannot necessarily compete with transit agencies on price, they do promise unmatched convenience by ferrying riders to their destinations with minimal interruptions.

NFC technology is one solution agencies have arrived at to address these imperatives; but it does so in a contradictory fashion, typical of "fast" infrastructure. The solution is to make paying for transit more efficient, and to use NFC technology to integrate with private mobility services. By emphasizing efficiency of payment, and relying on private mobility services as partners, NFC technology allows transit agencies to sidestep politics as well as having to contend with the auto-

centric built environment of American cities. Along the way, transit is opened up for private mobility services to piggyback (and profit off of) and transit agencies reproduce the logic of enclosure.

Extending transit's capabilities through NFC

NFC technology is an incomplete "fix" for public transit systems, extending their fixed-route service capabilities through quickly implemented software solutions, rather than a substantial investment in fixed assets and hard infrastructure. NFC technology extends the capabilities of transit agencies in three primary ways: dematerializing fare collection infrastructure, integrating payments for public transit with payments for private mobility services and by improving data collection. First, by "dematerializing" fare collection infrastructure and providing a digital alternative to cash, transit agencies anticipate on-time performance gains and administrative efficiencies with minimal fixed asset costs. Agency 5, for example, acknowledged that they "don't have a lot of room to grow." Their NFC technology then allows them to meet their high OTP standards on their BRT service without investing in a dedicated bus lane. However, this also undermines their service's ability to provide a substantial alternative to the automobile. Meanwhile, Visa's Cybersource solution promises increased passenger flows through stations, lowering lay-time without requiring an investment in more service.

But by "dematerializing" fare collection infrastructure and investing in digital alternatives to cash, agencies in this study have also extended their need-based fare offerings. By streamlining the delivery of need-based fares, like at Agency 3 and 6, NFC technology alongside *social* infrastructures of transit agencies may serve as more than just a mobility fix and help redress urban inequalities. However, without addressing spatial inequalities such as uneven access to reliable public transit – by, for example, expanding fixed route service to underserved areas — alongside

social inequalities like ability to pay for transit, the impact of need-based fares will be constrained. Transit agencies *are* interested in expanding service– but through partnerships and integration with private mobility services, rather than on their own vehicles.

By integrating payment for mobility across public and private modes, agencies are able to extend the network of transit available to a rider with minimal infrastructure investment by a public agency. With a platform solution like Masabi or Uber Transit, APIs serve as a digital infrastructure quickly "plugging" transit into the wider mobility ecosystem. Agency 6 noted how their newly implemented accounts-based platform helps them fill the "last-mile" service gap by allowing their riders to book TNC, e-scooter or bikeshare services without necessarily leaving their agency's system.

However, these private partnerships potentially enclose and fragment mobility infrastructure (Sheller 2018). For example, these last-mile services are effectively enclosed and inaccessible to anyone who opts-out of an account-based fare platform. Private shared mobility services remain strongest in the urban core, with longer wait-times, trip cancellations and discriminatory pricing algorithms experienced by riders in the periphery (Borowiak 2019, Ge et al. 2016, Pandy & Caliskan 2020); the geography of these services, then, along with their considerably higher cost-per-ride further divide transit into classed tiers (Grengs 2005). Additionally, the market capitalizations of these private services grow in part through these partnerships, from which they can expect a regular stream of riders to ferry over first or last mile journey segments. This isn't lost on Uber, who have pivoted from "competing" with transit in their IPO to "partnering" with transit by offering fare payment as well as fleet and demand management solutions to agencies (Uber 2021).

NFC technology generates granular data that would be laborious or impossible to collect manually. By automating data collection, agencies have a real-time picture of their system both in terms of riders and finances. However, the implications of this more lively, real-time data are unclear. While the data may be used to improve transit services, it may also introduce performance measures that put low-ridership – but nevertheless essential – services at risk of cuts. Additionally, this data may serve as another form of public capital that private mobility services profit. This is already evident in Agency 5's partnership with Uber, who at the time of this study had not agreed to share data with Agency 4.

Sheller (2018) includes "legal protection for data privacy" and open repositories for publicly funded data in her "Principles of Mobility Justice" (p. 286). Unfortunately, the question how agencies use the data generated through NFC technology was outside the scope of my study. In fact, I was pre-empted by several participants who noted they would not be able to discuss the substance of this data with me. However, in the case of Agency 4, it could be argued that the revelation, through their NFC technology data, of how their smartcard stitches together many different public transit providers might be harnessed in support of the mobility commons, rather than for an "extractive" data regime.

Opening up the walled garden: NFC as governmental fix

NFC helps transit occupy the "pump priming" role which Stehlin et al. note is emblematic of the governmental fix trajectory of mobility platformization (2020). In my study, agencies adopting NFC technology helped to foster the take-off conditions for various private mobility solutions. The most explicit way in which NFC served as a governmental fix for transit agencies was, via integrated payment, in allowing private mobility services to "piggyback" off their fixed-route infrastructure, providing TNCs and others with a stream of customers to ferry over the last-

mile. An advocate for TNCs might argue that transit agencies have a monopoly over fixed-route transit provision. By "opening up" the network to connect with other services, NFC technology fosters a more competitive market for mobility. In turn, presenting public transit service alongside private mobility alongside one another within a mode-agnostic mobility market, which MaaS apps represent, provide an individualized, rather than collective, solution to low-carbon mobility.

The revenue streams of transit agencies are also opened up when they adopt platform solutions for NFC technology. In lieu of legacy, multi-year DBOM contracts which services are paid for up front, platforms like Masabi take a percentage of each ticket sold. When Daniel explained this revenue model, he posited it as a "natural" relationship in which platforms are incentivized to help transit sell more fares. Fostering a more competitive market via NFC technology has also driven competition in the realm of fixed assets such as fare boxes. In contrast to the high fixed asset costs associated with legacy systems, agencies can now work with hardware providers "that haven't been able to traditionally play in this space," as Sam at Agency 2 noted. When Daniel drew on his experience with expensive, legacy hardware at a large transit agency, he noted it was a barrier to agency partnerships with innovative private sector actors.

This is also an area where transit agencies are most explicitly aligning themselves with technology companies. Technology companies are invoked as a model to follow, in part because of the apparent speed and ease at which they are able to move and in part because of their willingness to partner in an open, competitive marketplace. For example, Apple and Google are involved with standards-setting efforts related to fare collection. Uber may not share their data with all transit agencies openly, but they will sell transit tickets in their app or a subscription to their Uber Movement dashboard. While it can disrupt and challenge the dominance of legacy fare collection actors such as Cubic Systems, the governmental fix of NFC technology also extends

mobility infrastructure into new modes of accumulation. Transit is already understood to be "essential to the commodification of urban space" (Enright 2019 p. 13). By opening up its network infrastructure, and in turn markets for hardware and services, transit itself is turned into a commodity. Additionally, public transit networks themselves begin to resemble platforms, serving as "multi-sided markets" (Barns 2020) which connect rider/customers to private mobility services through carriage on public networks. This helps highly-capitalized mobility platforms proliferate as they are able to extract revenue and riders from transit agencies.

"The Freedom to Pay": commodifying mobility with NFC

> "It's a place where personal mobility is defined by freedom. The freedom to choose your preferred type of transportation. The freedom to choose your preferred mode of payment." (Cubic Systems, 2021, p. 3)

The imbrication of NFC technology and the commodification of mobility is most apparent when NFC technology promises to simplify the fare payment transaction. Typically, the complexity of paying for transit is contrasted with the ease with which one can buy a cup of coffee or an item of clothing. As Umo implies, transit riders lack options when it comes to fare payment. This is a barrier, not just to transit ridership, but freedom of personal mobility. This is an example of software working to advance the "enhanced ease and convenience of consumer capitalism" (Sheller 2018 p. 184) rather than fostering communal access to mobility. By equating payment for transit with payment for consumer goods demonstrates a critical misunderstanding of transit. Transit is a *medium* through which urban social reproduction takes place, *connecting* riders with, yes, coffee, but also countless other social needs from jobs, to cultural institutions, to family.

The implication that transit has a mandate to serve individual wants, rather than an expansive set of collective needs runs up against critical understandings of transit as a commons. In fact, in an Uber whitepaper, this mandate to serve everyone is framed as a burden by Uber,

rather than something that makes transit uniquely advantaged to foster a low-carbon mobility regime. What Uber — and by implication the agencies that partner with them — suggests is to enclose low-carbon mobility, with access granted only to smartphone holders who opt-in, rather than offer the highest level of service to everyone.

"Innovation is exhausting": the social infrastructure of NFC technology

NFC technology, particularly platform solutions like Masabi, can be implemented quickly, owing to their reliance on digital, rather than material, infrastructure. Like other examples of "fast policy" (Peck and Theodore 2015) and "fast infrastructure" (Stehlin 2019), the superficial elements of a model fare collection system such as TfL's OysterCard are easily adopted, while other elements integral to successful models, such as a region-wide fare policy, do not travel. In the case of NFC technology, the implementation of an account-based mode of payment that replaces cash and paper fare media with a digitally-enabled token is fairly consistent across each agency I studied. But rather than create a true "one card" fare collection environment, which would require standardizing fare policy across different municipalities and scales of governance — in the U.S. a complex political and institutional process – the result is a patchwork of different fare collection solutions, often reliant on private mobility services for a "seamless" mobility experience. By adopting a "fast" technical solution like NFC technology, public transit agencies appear to sidestep politics as much as they dodge investments in fixed transit infrastructure.

However, the policy mobilities approach to NFC technology reveals how rather than merely defer to technology, a social infrastructure of actors within transit agencies and in the private sector take part in the "political work of adaptation, mediation and translation that has to be done to move policies from one location to another" (Ward 2018b p. 277). So to understand NFC technology as discrete, fully formed upon arrival at a transit agency would be a mistake. In

this study, I run the risk of fetishizing NFC technology and granting it undue power it does not have outside of its relation with public transit infrastructure and the urban. In order to correct this, I want to conclude by discussing some of the social infrastructure that conditions NFC technology.

Though NFC technology in many ways widens the gulf between transit's social and economic goals, my participants tended to foreground the social goals of their work. Mobilizing NFC technology to serve social goals was among the foremost benefits cited by my participants, detailed in section 1 of Chapter 4. Along with delivering need-based fares, integration of payment for public mobility services could also serve as infrastructure for supporting the mobility commons. For example, at Agency 4 and 6, fare collection systems integrate payment for busy transit services in the urban core as well as "lifeline" services that connect regions at the periphery of the metro. By including smaller, lower-ridership but nonetheless essential, transit services within a larger fare revenue scheme, they help extend and thicken the capabilities of those services. The piggybacking of TNCs off of public infrastructure deserves critical scrutiny, but tying public infrastructures together through NFC technology as those agencies have demonstrated can serve mobility commoning.

Digital infrastructures like APIs and SDKs support integration with other mobility services, but it's internal work by people at transit agencies who ensure those partnerships cohere. This can contribute to fatigue; people are not as extensible as a transit network with an NFC mesh. As one participant put it, "innovation is exhausting" (Interview 5). As well, NFC technology ultimately enacts the policies of the networks in which it's deployed. While smartcards, for example, became "famous" in urbanist circles for rationalizing fares in London, there must be a policy in place to support a feature like fare capping first. As several of my participants noted, fare policy is beholden to political bodies like board chairs, municipal governments, and voters. This shows that despite

the well-founded critiques that digital and mobility infrastructures obscure politics, politics remains durable and, in some ways, require technologies to be designed around democratic institutions.

Code is the new turnstile

In the face of decreasing ridership and the proliferation of private mobility services, public transit agencies are adopting NFC technology, citing its convenience for customers and its operational efficiency. Agencies as well as providers of NFC technology look to retail as a model, positioning mobility as not unlike a retail or hospitality environment, offering customers convenience and flexibility of payment, Efficiency is gained through digitization and automation of fare payment, collection, and processing; by definition, "dematerializing" transit infrastructure, rather than materializing transit infrastructure. Code becomes the new turnstile, leading to more efficiencies and capabilities in operations downstream. Rather than devote money to capital projects that would guarantee transit's competitiveness with cars or shared modes, while growing its reliability and convenience, industry best practice has become instead to implement this form of fast infrastructure.

Chapter 6: Conclusion - Mobilizing a critical understanding of NFC technology

I have shown how an analysis of NFC technology through a lens informed by critical transportation studies in turn yields an understanding of NFC which is *critical*. By that, I mean it removes the layers of obfuscation from buzzwords like "convenience" and "seamless" to show how NFC is situated within a larger urban and mobility political economy. By understanding NFC technology as a mobility fix, it is possible to see how it may fail to redress systemic mobility issues, including climate change and urban inequality. At the same time, NFC technology serves as another engine of accumulation for the growing platform economy as well as for venture capital. This forecloses the possibility of public transit as a de-commodified common mode of social reproduction. However, my study also shows how digital infrastructures like platforms have not totally supplanted social infrastructures. Taking seriously the labor of adopting NFC technology shows many aspects of transit provision cannot be replaced by digital infrastructures nor de-politicized or de-territorialized.

This study was limited by the bounds of my M.A. studies, personal resources, as well as the Covid-19 pandemic. However, it provides a jumping off point for future critical studies of fare collection infrastructure. For example, there is a need to understand how riders have adapted to NFC technology. Future scholars could expand on Bissell's (2018) more-than-representational understanding of Sydney's Opal smartcard to explore rider adaptations. Scholars could also extend a critical transportation approach and link NFC technology transitions with activist contestations of fare policies and the policing of fares.

NFC technology might also be understood as a "carceral" mobility infrastructure, via its enhanced surveillance capabilities and its status as intellectual property (see McClain 2019 for the relationship between IP and the MTA MetroCard). The adaptation of transit workers to NFC technology also requires attention. For example, transit workers must now deal with the breakdown

of this new technology. Transit workers also serve as a social infrastructure, helping riders purchase fares or waving them on-board in lieu of payment in the event of a glitch or breakdown.

The FTA also serves as a governmental fix. Through the MaaS Sandbox and Integrated Mobility Innovation Project, the FTA is funding a number of experiments and supporting an open marketplace of mobility solutions. Future projects might explore how NFC technology has been rolled out alongside other mobility fixes, such as BRT or bus network redesign and the confluence of public and private capital that supports these projects.

Elsewhere in the city, new payments technology are shaping retail and hospitality environments. Customers as well as workers must adapt to the imperatives of these technologies, which are set far from the point of transaction. New payments technology has also shaped payments for public services beyond transit; for example, Von Schnitzler (2008) examines the techno politics of prepaid cards for water service. Future work might put NFC technology in the context of other payments for public services.

In the realm of practice as well as for the transit riding public, I hope this work shifts the imperative for transit to be "flexible" and "convenient" for individual riders, to transit planning which foregrounds collective imperatives. Public transit should not be subject to capitalist imperatives, taking cues from private mobility firms while also allowing them to profit off of public infrastructure. A radical, collective transformation of transit planning would aim beyond quantifiable service improvements or revenue growth, or reliance on any one particular technology or infrastructure fix. Instead, it would break the neoliberal frame of revenue neutrality, entrepreneurialism and flexibility that conditions "successful" infrastructure projects, thus allowing public transit agencies to go beyond "sustainable" transit to supporting "transformative" urban life.

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Appendix A: Overview of participants

Agency Code	Agency type^	Role	Region	Participant*	NFC Technology	Interview
Agency 1	Small public transit	CEO	West Coast	"Curtis"	Contactless, open loop payment	2
Agency 2	Large public transit	Systems analyst	West Coast	"Sam"	Account-based mobile ticketing, contactless, open loop payment	3
Agency 3	Large public transit	Program coordinator	West Coast	"Mike"	Smartcard	4
Agency 4	Large public transit	Senior Product Manager	Southwest	"Raina"	Smartcard, Account-based mobile ticketing	5
Agency 5	Small public transit	CAO, Planner, GIS	Midwest	"Rebecca" "Greg" "Mark"	Mobile ticketing	8
Agency 6	Large public transit	Special Projects director, coordinator	West Coast	"Christine" "Sandy"	Smartcard, account-based ticketing	9
Agency 7	Mid-size public transit	IT Manager, Fare Collection	Southwest	"John"	Smartcard	10
"Move ment App"	MaaS Start-up	CTO	Global	"Daniel"	Mobile ticketing	6
Movemtnt Info	Standards-setting org	Product manager	North America	"Christopher"	Mobile ticketing	7
Seamless Metro	Advocacy org	Policy consultant	West Coast	"Richard"		1

*^Based on APTA typology;*Participants are pseudonyms*

Appendix B: Interview Protocol

THEMES/KEY CONCEPTS

How benefits of smartcards are framed - economic vs. social; how the smartcard was adapted for needs of particular agencies; from whom was the smartcard "learned" (model cases); contractors and developers of NPT and their relationship to the agency; benefits of NPT to transit agencies - data for planners, improved revenue capture; the limitations of legacy payment media; devices NPT interacts with; the limitations of NPT; the potential of NPT to impact "new" mobility. Will people provide new insights or will they repeat what is already out in whitepapers and promotional materials for the technology? Develop questions that address gaps in whitepapers/other gray lit: broader visions of mobility and the city, what paradigms are they following.

Broad questions for all interviewees;

Tell me about your organization and its main goals. What is your role there?

- Transit agency that provides transportation/mobility to a metropolitan region
- Technology officer/engineer/chief planner/fare payment manager

I am interested in new fare payment technology such as smartcards and mobile payment apps. Can you tell me a bit more about why NPT is so important for public transit providers?

- Streamlines fare collection
- Integrates fare payment with multiple other payment media (cash, debit/credit, NFC)
- Improves revenue/farebox recovery

What do you see as the future of urban mobility? What is the role of smartcards in it?

- Many choices that encompasses needs of diverse ridership
- Robust service not just in CBD but through the last mile, via partnerships with mobility providers
- Simplified way to pay for those multiple modes

How does your fare payment connect with larger MaaS Ecosystem? Why is it important that fare payment connect with MaaS? - how to word...teasing out connection between ticketing and MaaS, following "platformization as governmental fix".

How do you see fare payment working in 10 or 20 years?

- Fully automated fare collection, akin to i.e. Amazon store
- Biometric fare collection
- NFC-only fare collection

What does [Agency] look like in that time?

- Ridership growth
- Zero emissions
- Less-reliant on state

- Partnered with other mobility services

Do you see rideshare/other MAAS platforms as competitors or as peers/fellow stakeholders?

- Yes, MAAS platforms such as scooter and rideshare companies have been important partners for us, helping to fill gaps in service and connect our riders with their destinations.

What do you see as the main benefits of your agency's choice of NPT?

- Our NPT not only provides our riders with a simple way to pay for transit but also was tailored to particular needs and requirements of our agency. For example it provides us with unique data that informs planning decisions, like increasing capacity in certain areas of the system.

I'd like to know more about the process of planning NPT.

In the early stages of planning NPT, was there hope that NPT might attract new riders? In what ways?

- [benefits of NPT]
- Expected answers has something to do with capturing fares and increasing ridership to save public transit and make it appealing to choice riders (not necessarily those who ride based on need)

How did you balance the needs of existing ridership while considering features of NPT that would attract new riders?

- [benefits of NPT] [adaptation of NPT]

How has adopting your NPT impacted the structure of your fares? Has it led to changes in your fare structure? In what ways?

Were there any particular experiences in your career as engineer/planner in this agency or elsewhere that you drew on in adopting NPT?

Appendix C: Recruitment Email

Dear [participant]

My name is Joe Gallagher and I am a graduate student in the Department of Geography and Environmental Sustainability at the University of Oklahoma. I am conducting research on the use of new fare payment technologies by transit agencies in the United States.
I am looking to speak with someone at [agency] involved with [fare product]. With the recent launch of [product] for services in [region], the [product] is poised to become a major player in the fare payment and trip planning landscape. I would greatly appreciate the chance to talk with someone [agency[involved with the process of planning and implementing the [product[as well as the future of transit fare payment and public transit as a whole.

Contactless payment is an under-researched area in urban geography and this project has the potential to make a large impact in and beyond my field. Please let me know if someone at [agency]would be able to talk to me for my research.

Thank you for your help!
Best,

Joe

Joseph Gallagher
M.A. Geography Student
University of Oklahoma
Dept. Geography and Environmental Sustainability

Glossary[1]

Account-based: a transit fare payment system in which the fare medium serves as to associate the rider with information held in a separate account. No fare value is carried on the fare medium itself. (TCRP)

Fare - All income received directly from passengers, paid either in cash or through pre-paid tickets, passes, etc. It includes donations from those passengers who donate money on the vehicle. It includes the reduced fares paid by passengers in a user-side subsidy arrangement. (FTA)

Fare collection system - Any equipment used in collecting passenger fares including turnstiles, fare boxes automated fare boxesand fare dispensing kiosks. (FTA)

Fare media - any means of payment or proof of payment distributed by the agency either directly or through agents under private contract, and includes smartcards, mobile tickets, tokens, and passes. (FTA)

First/last mile - The distance between a traveller's origin/destination and a transit station/stop. (APTA)

Fixed-route service - Services provided on a repetitive, fixed schedule basis along a specific route with vehicles stopping to pick up and deliver passengers to specific locations; each fixed route trip serves the same origins and destinations, such as rail and bus.(FTA)

Interoperability - the capability of a transit fare payment system and its components (such as fare media, card readers, etc.) to work with or use the parts or equipment of another system. Interoperability includes the capacity to exchange information. (TCRP)

Micromobility - Transportation using lightweight vehicles such as bicycles or scooters, especially electric ones that may be borrowed as part of a self-service rental program in which people rent vehicles for short-term use within a town or city. (FTA)

[1] Sources: APTA Mobility Innovation Hub Glossary, https://www.apta.com/research-technical-resources/mobility-innovation-hub/glossary/; FTA National Transit Database Glossary, https://www.transit.dot.gov/ntd/national-transit-database-ntd-glossary; FTA Shared Mobility Definitions, https://www.transit.dot.gov/regulations-and-guidance/shared-mobility-definitions; TCRP Report 177, "Preliminary Strategic Analysis of Next Generation Fare Payment Systems for Public Transportation"

Mobile ticketing: a process whereby a transit rider can order, pay for, obtain and validate a transit ticket using a mobile device such as a smartphone, “smart watch”, or other mobile device. (TCRP)

On-time performance -The proportion of the time that a transit system adheres to its published schedule times within stated tolerances; for example, a transit unit (vehicle or train) arriving, passing, or leaving a predetermined point (time point) along its route or line within a time period that is no more than x minutes earlier and no more than y minutes later than a published schedule time. (APTA)

Open payment system: an account-based transit fare payment system that is able to accept third-party payment media such as bank cards and mobile device as its fare media. All open payment systems are both standards- and account-based systems. Also known as an open loop system. (TCRP)

Public transit agency – A public entity that provides public transportation services. It may be a state or local government, or any department, special purpose district (e.g. transit or transportation district), authority or other instrumentality of one or more state or local governments. (FTA)

Public transit - transportation by a conveyance that provides regular and continuing general or special transportation to the public, but does not include school bus, charter, or intercity bus transportation or intercity passenger rail transportation. (FTA)

Shared mobility - Transportation services that are shared among users, including public transit; taxis and limos; bikesharing; and car sharing. (FTA)

Smartcard: a transit fare card, bankcard, or identification card or other credential that includes an embedded computer chip and antenna. (TCRP)
Private mobility service - A non-public, for-profit entity that provides public transportation services.

Transportation network company - Use of online platforms to connect passengers with drivers and automate reservations, payments, and customer feedback. Riders can choose from a variety of service classes, including drivers who use personal, non-commercial vehicles. Examples include Uber and Lyft. (FTA)