Getting There: Barriers and Facilitators to Transportation Access in Underserved Communities

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Advances in Information and Communication Technologies (ICTs) offer new opportunities for addressing transportation needs; however, past research suggests that opportunities are not equally shared by millions of low-income Americans. We draw from four empirical studies and two case studies to contribute descriptions of the 11 everyday transportation models currently used by residents of low-income and underserved communities to enhance their access to health-enhancing resources. These models fell into personal, private, public, and interpersonal categories. We contribute insights regarding the following barriers and facilitators associated with these models: (1) affordability; (2) individual capabilities; (3) interpersonal trust, care and/or reciprocity; (4) trust in technology; (5) service availability/eligibility; (6) spatial and temporal matches; (7) match between transportation mode and physical needs; (8) service reliability and quality; and (9) infrastructure access. To address these barriers and build on these facilitators, we contribute six supportive policy and design principles. Operationalizing these principles, we propose four new ICT-enhanced models: (1) smart jitneys; (2) generalized, favor-based models; (3) expanded resource pooling; and (4) transportation clubs. The focus of these models on socio-technical integration with current capabilities and resources holds promise for enhancing access to jobs, food, and health care for residents of low-income communities.

CCS Concepts: • **Human-centered computing** → *Human computer interaction (HCI)*; *Empirical studies in HCI*;

Additional Key Words and Phrases: Transportation, social determinants of health (SDOH), low-income communities

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1 INTRODUCTION

Millions of Americans cannot provide or pay for their own transportation. Many of these individuals live in underserved communities and have low incomes and/or disabilities [1]. Lack of transportation contributes to social inequality and exclusion [2–4] as well as health-related disparities in the United States (US) [2]. Thus, transportation access and its associated mobility is central to people's health and economic wellbeing [5].

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A lack of transportation often limits access to health-enhancing resources such as employment [6], healthy food [7], and health care [8]. As such, transportation options influence access to the "social determinants of health" (SDOH). The SDOH are environmental conditions in which people are born, work, play, live, worship, and age [9]. These conditions include economic stability, education, social and community context, health care and the neighborhood/built environment, and they affect a variety of health, functioning, and quality-of-life outcomes and risks. They include, for example, disparities in rates of obesity, diabetes, hypertension, cardiovascular disease and kidney disease in low-income and African American communities in the US [10, 11].

While owning a car provides greater accessibility to health-enhancing resources [5], alternative transport modes for those without vehicles may include carpooling, bicycling, getting rides from friends and family, using public transit (where available), walking, borrowing cars from others, and having others manage their transportation needs, a concept referred to as "substitution." These transit modes, however, are not barrier free [5]. In addition to these more traditional transportation approaches, advances in ubiquitous information and communication technologies (ICTs) have transformed mobility. Real-time ridesharing systems such as Uber and Lyft, car rental services such as Zipcar and Turo, and bicycle-sharing services have emerged as part of the "sharing economy" and have reduced the need for vehicle ownership in some circumstances [12] (see Table 1 for available transportation models and their definitions). However, past research shows that underserved and low-income communities do not benefit from these services in the same way as others due to barriers such as racial discrimination [13], financial limitations, and a lack of digital skills often required because of these technological advances [14, 15].

We argue that there is a need for new, computing-enabled, shared transportation models that specifically meet the needs of low-income people living in underserved communities. Such services should address both individual and collective problems and needs, including access to health-enhancing resources. To develop novel transportation models, it is critical to first understand existing transportation models used in underserved communities, and the barriers and facilitators associated with them. To generate this empirical insight, we integrate analyses of findings from four empirical qualitative studies and two case studies, all conducted in Metropolitan Detroit. These findings specifically address transportation-related access to the aforementioned health-enhancing resources: (1) *employment*, (2) *healthy food,* and (3) *health care*. We primarily contribute empirical findings concerning transportation models used in these areas, as well as barriers and facilitators associated with these models.

Next, building on these barriers and facilitators, we contribute a set of policy and design principles to which new ICT-enabled models for underserved communities should adhere. We conclude by proposing four transportation models that embody these principles and achieve socio-technical integration with communities' current capabilities and resources. This research advances the field's ability to design ICT-enhanced transportation models that address the needs of low-income individuals and underserved communities.

2 BACKGROUND AND RELATED WORK

As we outline below, lack of transportation has a significant, negative impact on access to health-enhancing resources; thus, there is an urgent need to develop transportation models that can advance such access. We further show the failures of personal, private, and institutional transportation models for low-income individuals or the underserved communities to which they typically belong. We conclude by suggesting that research in the Computer-Supported Collaborative Work and Social Computing (CSCW) and Human-Computer Interaction (HCI) traditions may assist in developing models that truly work for these individuals and their communities.

2.1 Transportation and the Social Determinants of Health

As we explain below, lack of transportation is an important barrier to health-enhancing resources. Accordingly, access to these resources form a motivating use case for the present article.

2.1.1 Access to Employment and Employment Opportunities. Job insecurity, unemployment and low-wages—three factors emblematic of the global shift to "precarious employment"—have important negative impacts on health. For example, unemployed people and people with insecure employment have worse self-rated health, experience more illness, and have increased risk of death [16–18]. Additionally, experiences of precarious employment and unemployment are linked to mental health challenges, such as depression and anxiety [16, 19, 20]. People who have precarious employment may also experience worse working conditions, poverty, and income insecurity [16, 21].

Precarious employment and unemployment are unevenly distributed both socially and spatially. In the US, there is often a "spatial mismatch" between available jobs and the location of potential employees; this is driven in part by long-term migrations of available jobs from cities to suburbs, while low-income people often remain in cities [22]. In particular, due to the history of racial residential segregation in the US, low-income African Americans are likely to live in low-income communities with little access to jobs [23]. Limited access to reliable transportation is often cited as a key reason why individuals, particularly African Americans, experience poor employment outcomes [22].

2.1.2 Access to Health Food. Food choices are related to the geographic accessibility of healthy food sources such as grocery stores. Easier access is associated with greater consumption of healthy foods such as fresh fruits and vegetables ("produce") [24–26], and it is particularly important for people without a car [27]. However, many low-income neighborhoods across the US lack easy access to grocery stores, a phenomenon sometimes referred to as "food deserts" [7]. Additionally, stores that are located in these low-income neighborhoods may offer lower-quality produce than suburban grocery stores [28].

Access to transportation is thus an important resource for overcoming the limitations of the local food environment [29–32] and for facilitating a healthy diet [33]. Lack of transportation is also a documented barrier to consumption of healthy food [34]. At a population level, greater access to grocery stores is associated with reductions in community obesity rates [35]. People with access to a vehicle eat a wider variety of foods [36], shop for food more frequently, and consume more produce [37].

2.1.3 Access to Health Care. Timely use of high-quality health care services is also an important determinant of health. Yet approximately 3.6 million Americans forego medical care each year due to a lack of non-emergency transportation [38]. A 2013 systematic review found that 25 separate studies showed that transportation was a barrier to healthcare access among people with lower incomes [8]. Additionally, people who are racial or ethnic minorities, who are older, and who have disabilities or multiple chronic conditions are more likely to face transportation barriers when seeking care [39]. Exacerbating these issues is the fact that low-income communities often lack healthcare providers within their borders.

In such contexts, limited transportation access has been associated with lack of regular medical care, uncompleted referrals or follow-up appointments, appointment cancellations, and missed appointments [11, 40–42].

While prior research has done much to establish that lack of transportation is a barrier to the aforementioned resources, there has been little attention accorded to existing transportation

models used by low-income people. The development of new transportation models would profit from understanding such current approaches.

2.2 Failures of Existing Transportation Models for Low-Income People

In addition to the long distances that many low-income people must travel to obtain health- enhancing resources, they may face barriers in using various transportation models. Such barriers have been identified in a fragmented set of literatures, which we integrate below. In addition, we draw from the real-time ridesharing barriers that low-income and transportation-scarce individuals faced as identified in past CSCW and HCI literature. We identify three categories—personal, private, and public—to characterize the transportation models used based on ownership of the means of transportation, and the identity of those using the transportation. In personal transportation models, the means of transportation are owned and operated by individuals/families, who are also its primary users. Personal means of transportation include walking, biking, and driving. Private models of transportation involve vehicles and/or platforms owned by individual entrepreneurs or for-profit businesses, which provide transportation as a service for a fee. They include bicycle sharing, car rental, driver-as-employee, peer-to-peer car sharing, real-time ridesharing, shuttling services, and taxis. Finally, public models of transportation typically involve vehicles owned by a public or non-profit organization; they are also typically funded or subsidized by tax dollars, accompanied by paid fares. See Table 1 for a summary of documented barriers based on the extant literature.

2.2.1 Personal. Though walking, biking, and driving are models of transportation that an individual can perform independently, there are several external dependencies that must be met for transportation to be managed successfully. Conditions in underserved communities may thus create barriers through unmet external dependencies. Walking, for example, may be difficult in low-income neighborhoods as they often lack sidewalks, sufficient road crossings for pedestrians [43], and adequate lighting [43]. High crime rates and vacant housing may also impede walking [44]. African-American pedestrians, who are more likely to live in low-income neighborhoods, experience racial biases from drivers, including drivers taking longer times before yielding [45, 46]. African Americans and Native Americans have significantly higher rates of pedestrian fatalities than Whites in 42 states and Washington, DC [47], and more bicyclists choose to ride in areas that feature slower traffic speeds, dedicated bicycle lanes, and separation from other traffic [48–52].

Barriers to bicycling in low-income neighborhoods include diminished road safety [53, 54] and higher rates of cycling-related crashes [55]. Low-income neighborhoods may also have fewer elements of bicycling infrastructure such as bike racks or bike trails [54, 56, 57]. Low-income people may perceive personal barriers to bicycling such as physical safety, physical discomfort, incompatibility of biking in work attire, poor health or disability, and the difficulty of carrying bulky items.

Walking and biking are the least expensive personal transportation options. In contrast, driving one's own car is very expensive: the cost of a vehicle, including insurance, maintenance, fuel and depreciation, is estimated to be $8,558 per year for an average sedan [58]. When one considers that the income threshold for living in poverty for a family of four is $24,447 [59], it is clear that the costs of a vehicle could be prohibitive for the 43.1 million Americans living in poverty [59].

2.2.2 Private. To address the desire for car access without the financial burdens of ownership, private forms of transportation, such as car sharing and car rental services, and taxis are options. Bicycle sharing is also a private form of transportation that is often characterized by previously identified barriers. A 2013 member survey of a bike sharing service in Washington, DC showed that the sharing service was primarily used by socio-economically advantaged people [60].

Table 1. Transportation Models, Characteristics and Barriers for Low-Income People, as Described in the Literature

Transportation models		Definitions	Barriers for low-income people identified in related work
Personal	Bicycling	Transport by bicycle	• Less access to bike lanes and racks [48] • Worse road safety [50] • Health or comfort barriers [54] • Unsuitability for carrying of parcels or wearing work attire [54]
	Walking	Transport by foot	• Insufficient infrastructure [43] • Traffic-related safety concerns for African and Native Americans [46]
	Driving	Transport via automobile	• High cost of ongoing car ownership [59] • Difficulty paying for repairs [59] • Higher auto insurance [58]
Private	Bicycle sharing*	A system consisting of bike-stations that enable individuals to share bicycles	• Perceived lack of diversity among users • Safety concerns • Lack of convenient stations • Unaffordable membership costs [61]
	Real-time ridesharing*	A system that relies on ICTs to provide rides on demand to riders.	• Cost and Reliance upon credit cards [15, 63] • Lack of reliable mobile Internet access and digital literacy skills [15] • Limited trust in strangers and in online payment methods • Racial discrimination, longer wait times [13, 64]
	Car rental/Zipcar*	A system enabling individuals to rent available vehicles from a company for short periods of time	High costs of usage [62]
	Taxis*	A system in which companies dispatch drivers to take passengers to their specified destinations.	• Less service availability [64] • Slow and unreliable services [66]
Institutional	Public transportation*	A city- or county-sponsored system in which fleets of vehicles follow specified routes to provide ride services to citizens.	• Lack of public transit • Unreliable service [71]

Note: *coordination required between and among individuals.

Lower-income people experienced the following barriers: (1) a perceived lack of diversity in the ethnicities and ages of users, (2) a sense of less safety, (3) a lack of accessible and convenient stations, and (4) unaffordable membership costs [61].

In contrast to traditional services requiring at least a day-long rental, services such as Zipcar are promising for low-income people since they offer short-term rentals for as little time as an hour. A 2015 study found that the demand for Zipcar was the same between relatively low-income neighborhoods and typical car-sharing locations in New York City, but the cost for these shared vehicles was too high, impeding its adoption [62]. Past CSCW and HCI research revealed barriers to real-time ridesharing and shared-mobility services such as cost, and reliance upon resources to which low-income potential riders may have limited access, such as credit cards, reliable mobile Internet access, and digital literacy [15]. Such services assume a fabric of trust among strangers, which may be lacking in low-income community contexts [63]. Furthermore, low-income residents may distrust online payment methods that are used by these services [63]. Services such as Uber are also sites of racial discrimination against African-American passengers [13]; this is a barrier for low-income people since African Americans are more likely to have lower incomes than Whites in the US. Further, the real-time ridesharing service UberX was shown to have significantly shorter wait times (under 3 minutes) in dense, wealthy neighborhoods than in low-income areas (over 10 minutes) [64].

Taxis are a regulated system of transportation in which companies dispatch drivers to take passengers to their destinations for a payment. While they are widely available across the US, they tend to provide less service to low-income than high-income neighborhoods [65]. Furthermore, taxi services to low-income communities are typically slower and less reliable than those in wealthier areas [66–68].

2.2.3 Public. Public transportation options typically include buses and rail service. The past few decades have been a period of disinvestment in public transportation in the US (e.g., [69, 70]), and many poor African-American communities lack access to it (e.g., [71]). Where service exists, coverage and reliability may suffer.

While the foregoing outlines a useful set of transportation models and barriers, these examples are not geared toward our use cases of employment, healthy food, and healthcare access, all of which warrant further examination. Furthermore, some specialized types of transportation options may be available in some locations; however, these have not been examined systematically. These include: shuttling services that have been piloted for grocery stores in a few locations [72–74] and situations in which an organization purchases a vehicle and offers rides to clients/customers ("driver-as-employee"), which has been used by some healthcare organizations [75, 76]. In addition, there is a need to better understand the use and applicability of informal models that are not well-described in the literature, such as carpooling, getting rides from friends and family, or borrowing cars from others. Therefore, we examine the full range of transportation models identified across multiple studies conducted in low-income communities. We also consider their application in the context of our health-related use cases. Additionally, previous work, while considering barriers, does not necessarily address facilitators of existing models among low-income individuals and underserved communities. Therefore, in this article, we focus on this question since knowledge of such facilitators is important for the design of transportation models that will achieve sociotechnical integration with existing community resources.

2.3 Addressing Transportation Needs: A Role for CSCW and HCI

All non-personal transportation models require some form of coordination (see * in Table 1). Coordination is a key point of interest in CSCW and HCI research and given its centrality to emerging

transportation models, transportation research has been a growing focus in the fields of CSCW and HCI. For example, researchers have examined factors that motivate transportation modality and ridesharing (e.g., [77, 78]) and transportation is often a popular task in timebanking activities [79]. Researchers have also examined ways to support mobility among older adults and their need for "mobile independence" [80]. More recently, researchers have explored new real-time ridesharing services in the context of the sharing economy [14, 81, 82].

We build on this prior work by identifying barriers and facilitators to transportation models for low-income people, and their oft-underserved communities, for the particular use case of access to health-enhancing resources. Given the highly social nature of transportation and the complexity required to coordinate transportation among individuals in underserved communities, HCI and CSCW research can offer promising insights and solutions toward our ultimate goal of generating policy and design principles, as well as new transportation models for low-income individuals and underserved communities.

3 METHOD

We begin the section by first providing regional context of our studies. All studies took place in Metropolitan Detroit, where transportation access is scarce. We then draw from four empirical studies and two case studies as they relate to transportation needs for health-enhancing resources (see Table 2 for an overview of our studies). Three of the four empirical studies identify design implications for future ICTs to address issues related to economic mobility; the fourth study uncovers user requirements for individuals with chronic health conditions. The two case studies focus on access to healthy food for low-income communities. The original research questions and findings for these studies are shown in Table 2. In the present article, we re-analyze data from these studies to address the following new research questions, which were not the focus of the original studies:

RQ1. What transportation models do residents of low-income communities use to gain access to jobs, food, and health care?

RQ2. What barriers and facilitators are encountered in use of each of these transportation models for these purposes?

All empirical studies received ethical approval from the University of Michigan's Health Sciences and Behavioral Sciences; the case studies were not considered human subjects research, and thus were not regulated by the IRB.

3.1 Regional Focus

This research was conducted in Metropolitan Detroit, including the City of Detroit, and two other low-income and underserved urban areas in the region: Flint and Inkster. This region offers a rich opportunity for studying transportation issues; while a challenge in many US cities (e.g., [83]), transportation is particularly scarce in Metropolitan Detroit. The City of Detroit itself is vast, spanning 138.8 square miles; in fact, the cities of Boston (48.4 square miles), Miami (35.7 square miles), and San Francisco (46.69 square miles) could all fit within Detroit's borders.

With regard to access to health-enhancing resources, the Metropolitan Detroit area poses many challenges. There is a spatial mismatch in employment: more than 10,000 Detroiters travel each day to low-paying jobs in suburban communities [84]. Food access is a challenge: there are 108 (out of 297 total) census tracts in Metropolitan Detroit that have been designated as "food deserts" by the US government [85]. Food deserts have low access to grocery stores (e.g., at least 500 people or 33% of the population lives >0.5 miles from the nearest grocery store in an urban area) and are typically found in low-income areas [85]. Access to health care is also uneven: in the Metropolitan Detroit region, 228 census tracts have been designated as "medically underserved" areas, which

Table 2. Overview of Studies and Data Sources Used in this Article

No	Study theme, name and year	Research questions/objective	Data sources	Study results
1	Economic mobility: Detroit and economic mobility (DET1), 2013	What are the key challenges of populations facing economic hardship? What strategies and key resources are used to get ahead?	In-depth interviews: 30 participants Workshop: 12 participants (Detroit)	Challenges include a shortage of resources, limited education, poor political climate, and not having strong social connections. Finding employment to gain economic mobility requires networking and having the right connections [91].
2	Economic mobility: Detroit and economic mobility (DET2), 2014	What opportunities, if any, are there for technology, specifically the sharing economy, to support financially constrained individuals?	Workshop: 20 participants (Detroit)	The sharing economy applications could help with employment and/or saving money. Access to spare resources was not identified as a major concern; however, issues related to privacy and security, trust in the sharing economy and balanced reciprocity arose. There are opportunities to strengthen social connections to those in authority to provide further benefits [63].
3	Transportation: Uber as an alternative to transportation (DET3), 2015–2016	What is the feasibility of real-time ridesharing services to address transportation scarcity in Detroit?	Survey: 12 participants; Diary study and interview: 13 participants (Detroit)	The uptake of Uber led to positive experiences and, reliable transportation to work, interviews, and other appointments among participants. Barriers included costs and limited digital literacy [15].
4	Chronic Illness Management: Community Health Information Infrastructure Project (CHII), 2012–2014	How do residents of Inkster, Northwest Detroit, and Flint acquire, share, and use health information and other health enhancing resources? What do they see as community assets and barriers to their ability to do so?	Interviews: 71 participants (Flint, Inkster, and Detroit)	Patients engaged in "adherence work," which addressed external contingencies present in these communities [93]; patients "translated" health information into local strategies for chronic illness management [92]
5	Transportation: Prince Valley market case study, 2016	Does providing free rides home to customers who spend $50 or more sustain revenue and alleviate transportation deficiencies to healthy food?	A total of 4 newspaper or magazine articles; Interview: 1 participant (Detroit)	Description of service; description of uptake [94]
6	Transportation: Cartrides transportation case study, 2017	Does providing $10 roundtrip rides to the grocery store sustain revenue and alleviate transportation deficiencies to healthy food?	A total of 3 newspaper articles/TV interviews (Detroit); Interview: 1 participant (Detroit); Final report from pilot study	Description of service; description of uptake and stakeholder perspectives

means there is a shortage of primary healthcare providers in relation to the needs of the population within that area.

Despite these spatial challenges in resource access, 40% of Detroit residents do not own cars [86], and the city has reduced and eliminated much of its public bus service [87]. This has led to limited and unreliable service. Public transportation is also a challenge in smaller cities within Metropolitan Detroit such as Flint, which has recently experienced deep cuts in public transportation funding [88]. Additionally, the municipality of Inkster (5 square miles of land), located in Metropolitan Detroit, lacks local public transportation, relying instead upon a patchwork system of regional transit that does not provide direct routes to many needed resources. Illustratively, 49 communities in Metropolitan Detroit have opted out of regional transit [84], and a recent ballot measure for regional transit was defeated [89].

Walking as a mode of transport can also be a challenge in cities in the Metropolitan Detroit area; Flint and Inkster have been identified as having low walkability scores, while Detroit is identified as somewhat walkable [90]. Walkability, however, varies in different parts of the city. The city of Detroit has been identified as somewhat bikeable, with scores unavailable for Flint and Inkster [90]. However, poor road repair and potholes can make biking difficult in some locations; issues of safety and high crime rates can make biking and walking difficult as well.

3.2 Data Collection

3.2.1 Empirical Studies: Employment and Economic Mobility. Three empirical studies, DET1–DET3, were conducted to address issues related to employment and economic mobility in the City of Detroit. We leveraged data collected from these studies because transportation is a significant barrier to employment and hence economic mobility, and it is a very specific issue for Detroit. Though only one of these studies focused on transportation directly, the issue was pervasive among all studies.

The first study (DET1), which was conducted in 2013, incorporated in-depth interviews from 30 Detroiters, 25 of whom completed participant surveys to inform a design-scenario exercise. The goal of the 1–2 hour interview was to understand what challenges populations experiencing economic hardship face; the strategies used and key resources accessed to overcome these challenges; and aspects of social capital such as trust, reciprocity and community engagement [91]. We captured a set of concrete challenges and key resources used to overcome these challenges to inform a scenario-based design workshop for which we recruited 12 of our interview participants. One aim of the workshop was to identify how groups used the resources and their social networks to work through the challenges identified in interviews. Another aim of the workshop session was to investigate whether there were opportunities for technology to address the challenges that were uncovered such as limited access to information, resources, and jobs. We provided food and compensated interview and workshop participants $30 for their time.

To further explore opportunities for technology to address challenges faced by individuals who were financially constrained, we conducted a second study (DET2). Whereas DET1 was a scenario-based workshop, DET2 was a qualitative study inspired by participatory-design methods such as cultural probes, user profiles, role-play, and scenarios to help characterize four sharing economy applications: Lyft, TaskRabbit, Neighborgoods, and Airbnb. The goal of the study was to assess the feasibility of using these sharing economy services and what benefits, if any, such services provided to individuals living in low-income communities [63]. A secondary goal of the study was to understand if the sharing economy could support employment for active job seekers. We also provided food and compensated these participants $30 for their time.

After identifying real-time ridesharing services in DET2 as a potential solution to address transportation needs, the third study (DET3), involved onboarding participants to Uber and providing

them with credits to use the service. The goal was to explore the feasibility of real-time ridesharing services among individuals living in Detroit who faced transportation difficulties [15]. We analyzed survey and interview data and short diary entries of 13 participants to capture their existing transportation methods and experience using the service. Interview data also provided information about access to drivers' licenses, alternative transportation methods, and the advantages and shortcomings of each. Participants in this study were compensated $75 in Uber ride credits and $25 to complete a survey and interview.

All interviews and workshop sessions were audio recorded and transcribed verbatim. We employed a variety of recruitment strategies such as leveraging USA Data, a service offering targeted mailing lists to consumers (DET1); using Craigslist; and going to locations such as barbershops, hair salons, employment centers, bus stops, and non-profits. We also relied on word of mouth. We focused our recruitment efforts in low-income areas of Detroit based on US Census data to target specific areas based on zip code. Additional study and recruitment details about all studies are described in [15, 63, 91].

3.2.2 Empirical Studies: Access to Healthy Food and Health Care. In this qualitative cross-sectional study, called "Enhancing the Community Health Information Infrastructure (CHII)", participants were purposively sampled to represent the gender, age, and racial composition of three high-poverty cities: Flint, Inkster, and the Northwestern region of Detroit. Participants were recruited through health care and service provider referrals, in-person visits to an exercise program for people with chronic disease, flyers posted in housing developments, clinics, and community centers, and snowball sampling. Though income was not a factor used for recruitment, all participants lived in high-poverty areas. Individual factors suggesting low income included participant employment status and health insurance providers (see Table 3). Many participants were retired, disabled, or unemployed; very few had full-time employment. In addition, several participants were on Medicaid, a federally-sponsored assistance program offered to individuals with limited income and resources. Researchers conducted in depth, individual semi-structured interviews with people with diabetes, hypertension and/or chronic kidney disease. As part of a larger study concerning health information [92, 93], participants were asked about their eating behavior and health care utilization, their transportation modes for acquiring these resources, and their experiences with those transportation modes.

Participants received $20, and the interviews, conducted between February 2012 and July 2014, were audio recorded and transcribed verbatim.

3.2.3 Case Studies 1–2: Access to Healthy Food. The two case studies describe experiences with implementing services designed to address deficiencies in transportation for healthy food access in Metropolitan Detroit. To describe these case studies, we conducted searches for articles and stories about the projects in all Metropolitan Detroit media outlets (Crain's Detroit Business, Detroit Metro Times, the Detroit Free Press, and the Detroit News; Detroit Public Radio: WDET; NBC and CNN affiliate WDIV, Fox affiliate WJBK, CBS affiliate WWJ, and ABC affiliate WXYZ). The search involved the names of the businesses involved, and then an examination of the relevant articles to determine whether they discussed the relevant projects. Additionally, we contacted business representatives, conducted interviews, and obtained documents from one of them, as reported below.

Prince Valley Market: Prince Valley Market is a grocery store located in Southwest Detroit. In September of 2015, the owner piloted a seven-month program to provide free rides home to shoppers living within a five-mile radius of the store and who spent more than $50 on groceries. The store acted as a broker to transportation services, and used Uber to provide that transportation. The program was advertised via the store website, newsletter, and word of mouth [94]; the first

author and a research assistant conducted an in-person informal interview with the store owner to learn more about the pilot. The author and the store owner continued communication via email and exchanged six emails specifically about the pilot. The source of our data analysis includes the informal interview, four published newspaper/magazine articles about the service, and email exchanges regarding the progress of the service.

Cart Rides: Cart was a start-up in Detroit that focused on provision of transportation to grocery stores in the city of Detroit. In a 10-week pilot study, Cart acted as a transportation broker, partnering with Lyft to provide roundtrip rides to grocery store locations in Detroit. As part of this, Cart partnered with a grocery chain, which helped subsidize these rides. Individuals who lived within a 5-mile radius paid $10 for a roundtrip ride to the grocery store using any preferred payment methods (e.g., cash, credit card, check).

Cart advertised on buses and via flyers at local organizations and programs such as Head Start and WIC clinics. Several news channels and local radio and television channels also advertised the pilot; we located three newspaper articles/TV segments that were also used as data for the study. Cart's CEO participated in informal interviews and provided a report [95] describing the results, which became a source for our data analysis.

3.3 Data Analysis

Our analyses focused on finding patterns across all of the empirical and case studies using a common codebook to answer the research questions asked in this study. We initially developed the codebook using the extant literature to identify transportation models, including all of the transportation models in Table 1, as well as others not yet studied in low-income communities, such as peer-to-peer ridesharing and shuttle services. We used provisional coding [96] to deductively assign these codes to transcripts and related documents for all studies, along with deductive codes for (1) purpose of travel (employment, obtaining food or attending healthcare appointments), (2) facilitating conditions for using the transportation model, and (3) barriers in using this transportation model. Additionally, we conducted open coding [97] in which we inductively developed codes as we analyzed our data, creating codes for new models not described in the literature, such as "paratransit," "interpersonal," and "jitneys." As part of our analyses, we created a construct table [98] (see Table 4 for the final transportation models included in the codebook) that summarizes facilitators and barriers associated with each model. Data regarding these case studies were analyzed using the same codebook as for the empirical studies.

4 RESULTS

4.1 Characteristics of Participants

Table 3 outlines the demographics of participants across the four empirical qualitative studies. Across the four studies, there were 116 participants, of whom the majority (104, 89%) were African American and female (71, 61%). In two studies (CHII and DET1), the average age of participants was over 50; participants in the other two studies were younger on average. A minority of participants across all studies were employed (29, 25%) or had a college degree (30, 26%). Participants in the CHII project all had at least one chronic illness; this information was unavailable for other studies.

4.2 Transportation Models Used

In the following section, we describe the results of our participants' existing methods of travel to access employment, healthy food and health care (see Table 5). Several travel methods identified in the literature were not used by our participants. These are as follows: (1) bike sharing, which

Table 3. Demographics of Participants in Empirical Studies

		Detroit transportation studies (n = 45)			Enhancing the Community Health Information infrastructure (CHII) (n = 71)		
		Detroit and Economic Mobility (DET1) (n = 12)	Detroit and Economic Mobility (DET2) (n = 20)	Uber as an Alternative to Transportation (DET3) (n = 13)	Flint (n = 22)	Inkster (n = 24)	Detroit Northwest (n = 25)
Age (Mean, SD)		53.1 (10.8)	40 (12.81)	34.07 (12.03)	54.6 (10.3)	56.2 (14.9)	53.1 (10.8)
Gender (#/%)	Female	9 (75%)	8 (40%)	5 (38.5%)	13 (60.1%)	17 (70.8%)	16 (64.0%)
Race (#/%)	African American	12 (100%)	18 (90%)	11 (84.6%)	17 (77.3%)	21 (87.5%)	25 (100%)
	European American	0 (0%)	1 (5%)	2 (15.4%)	3 (13.6%)	3 (12.5%)	0(0.0%)
	Native American/ Alaska Native	0 (0%)	0 (0%)	0 (0.0%)	2 (9.1%)	0 (0.0%)	4 (16.0%)
	Other	0 (0.0%)	1 (5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Ethnicity (#/%)	Hispanic/Latino	0 (0%)	0 (0%)	0 (0.0%)	2 (9.1%)	0 (0.0%)	0 (0.0%)
Education level (#/%)	High school or less	1 (10%)	7 (35%)	7 (53.8%)	10 (45.5%)	13 (54.0%)	9 (36.0%)
	Some college	4 (33.3%)	10 (50%)	5 (38.5%)	2 (9.1%)	5 (21.0%)	10 (40.0%)
	College degree or higher	4 (33.3%)	3 (15)	1 (7.7%)	10 (45.5%)	6 (25.0%)	6 (24.0%)
Total household income (#/%)	$0–$20,000	3 (25%)	17 (85%)	13 (100%)	–	–	–
	$20,001–$50,000	4 (33.3%)	0 (0%)	0 (0%)	–	–	–
	$50,001+	3 (25%)	2 (10%)	0 (0%)	–	–	–
Employment status (#/%)	Full-time work	8 (66.7%)	4 (20%)	3 (23%)	3 (13.6%)	1 (4.2%)	1 (4.2%)
	Part-time work	0 (0%)	0 (0%)	1 (7.7%)	1 (4.5%)	1 (4.2%)	4 (16.0%)
	Unemployed	1 (8.3%)	13 (65%)	5 (38.5%)	2 (9.1%)	8 (33%)	6 (24.0%)
	Retired or Disability	0 (0%)	0 (0%)	0 (0.0%)	14 (18.2%)	14 (58.0%)	11 (44.0%)
	Self-employed	1 (8.3%)	1 (5%)	1 (7.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Student or Other	2 (16.7%)	2 (10%)	3 (23%)	2 (9.1%)	1 (4.0%)	3 (12.0%)
Health insurance (#/%) (multiple responses possible)	Medicare	–	–	–	13 (59.1%)	12 (50.0%)	11 (44.0%)
	Medicaid	–	–	–	10 (45.5%)	8 (33%)	5 (20.0%)
	Veteran's Affairs	–	–	–	3 (13.6%)	0 (0.0%)	0 (0.0%)
	Private	–	–	–	4 (18.1%)	13 (54.2%)	12 (48.0%)
	Other (Country plans, COBRA, etc.)	–	–	–	4 (18.1%)	0 (0.0%)	2 (8.0%)
	No health insurance	–	–	–	0 (0.0%)	1 (4.1%)	4 (16.0%)
Health status (#/%)	Hypertension	–	–	–	22 (100.0%)	24 (100.0%)	25 (100.0%)
	Diabetes	–	–	–	15 (68.2%)	18 (75.0%)	18 (72.0%)
	Chronic Kidney Disease	–	–	–	8 (36.4%)	9 (38.0%)	7 (28.0%)

was unavailable in the areas studied and (2) car rentals (including Zipcar). Other transportation methods such as shuttling and driver-as-employee services were also not widely available. Furthermore, our findings show new transportation models that participants used or offered that were not identified in the literature. Specifically, we found new private (jitneys, brokers) and public transportation models (paratransit) in use. Additionally, findings revealed use of several interpersonal models: carpooling, favors, and maintaining transportation as a collective resource. Driving, public transit, and favors were the most widely used transportation methods, perhaps because they were used for all use cases (Table 5).

Table 4. Transportation Models Used, Facilitating Conditions, and Barriers Identified

Transportation models		Number of occurrences: CHII	Number of occurrences: DET1–3	Facilitators	Barriers
Personal	Biking	2	2	• Individual capabilities: health sufficient for biking • Spatial matches: distance to resources • Infrastructure access: vehicles	Barriers identified (also in prior research): • Physical needs: Unsuitability for carrying of parcels [54] New Barriers identified: • Interpersonal trust: personal safety fears • Infrastructure access: vehicles • Physical need for comfort: weather
	Driving	33	3	• Affordability: ability to afford gas, insurance, and repairs • Individual capabilities: ability to drive • Infrastructure access: vehicles	Barriers identified (also in prior research): • Affordability: cost of repairs and insurance [58, 59] • Infrastructure access: vehicles [86] New barriers identified: • Affordability: cost of fuel • Individual capabilities: lack of driver's license, inability to drive due to health
	Walking	9	5	• Individual capabilities: health sufficient for walking • Spatial matches: distance to resources	Barriers identified (also in prior research): • Spatial matches: distance to health-enhancing resources [84] New barriers identified: • Individual capabilities: inability to walk due to health • Interpersonal trust: personal safety fears • Spatial matches: proximity to less-healthy food sources • Physical need for comfort: weather
Private	Broker	–	–	• Interpersonal trust: an invested and trusted organization to broker rides • Infrastructure access: Real-time ridesharing for ride management and scheduling	New barriers identified: • Affordability: cost of rides for consumers, cost of service provision for organizations, cost of providing service for drivers • Individual capabilities: digital literacy skills • Interpersonal trust: slow uptake, need for high-touch advertisement • Trust in technology • Service availability
	Jitney	3	3	• Affordability: predictable, low-cost rides; some non-monetary payment accepted • Interpersonal trust: knowledge of driver, reputation-based referrals • Technological trust: cash payment accepted • Spatial matches: a known gathering place • Driver's infrastructure access (vehicle) and individual capabilities (ability to drive)	New barriers identified: • Interpersonal trust: knowledge of driver • Service availability: only used in Detroit

(Continued)

Table 4. Continued

Transportation models		Number of occurrences: CHII	Number of occurrences: DET1–3	Facilitators	Barriers
	Real-time ridesharing	0	3 prior DET3; 82 during DET3	• Service availability • Service reliability	Barriers identified (also in prior research): • Affordability [15] • Individual capabilities: digital literacy skills [15] • Interpersonal trust [63] • Trust in technology [15] • Infrastructure access: smartphones, data plans [15] New barrier identified: • Infrastructure access: for potential drivers, vehicles that met age requirements
	Taxi	1	4	• Affordability: financial subsidy for taxi	Barriers identified (also in prior research): • Service availability [64, 65] • Service reliability [66, 67, 68] New barrier identified: • Affordability • Service quality: driver professionalism, vehicle quality, and cleanliness
Public	Paratransit	13	1	• Affordability: free or discounted access • Spatial and temporal matches: common destinations, routes planned in advance	New barriers identified: • Service eligibility • Service reliability
	Public transit	20	10	• Affordability: discounted access • Technological trust: cash payment accepted • Service availability • Spatial matches: common starting places and destinations	Barriers identified (also in prior research): • Service availability [71] • Spatial and temporal matches [84, 87] • Service reliability [71] New barrier identified: • Affordability: transfers to reach healthcare providers in different municipalities • Interpersonal trust: personal safety fears • Physical needs: Unsuitability for carrying of parcels
Interpersonal	Favors	20	8	• Affordability • Interpersonal care • Infrastructure access: vehicles • Service reliability	New barriers identified: • Interpersonal reciprocity • Temporal matches
	Resource pooling	3	0	• Affordability • Interpersonal care • Spatial and temporal matches: common starting places and destinations • Infrastructure access: vehicles	• Interpersonal care

Table 5. Transportation Models Used for Activities Related to the SDOH

Transportation models		Employment and employment opportunities	Healthcare appointments	Healthy food
Personal	Biking	X		X
	Driving	X	X	X
	Walking	X	X	X
Private	Brokers			X
	Jitneys			X
	Real-time Ridesharing	X		X
	Taxi	X		X
Public	Paratransit		X	X*
	Public transit	X	X	X
Interpersonal	Favors	X	X	X
	Resource pooling		X	X

Note: *Indicates that only one instance of this model was mentioned among our participants.

4.2.1 Personal. Our participants used all forms of personal transportation to access health-related resources. Driving was popular among some participants, particularly in the CHII study, despite prevalent barriers such as lack of access to a car and inability to drive. Walking was relatively common, but biking was uncommon. Barriers such as interpersonal trust rooted in fears of crime and inclement weather prevented some participants from biking and walking. Given that CHII participants had chronic illnesses, the need to be healthy and able-bodied was also a barrier for driving, walking, and biking.

4.2.1.1 Biking.

Use cases. Biking was not a commonly used form of transportation. When it was used, it was for employment reasons (Detroit only) and for accessing healthy food (Flint only). No participants discussed biking to healthcare appointments. Two DET3 survey respondents reported riding their bicycles for transportation to work among other places they needed to travel to on a regular basis.

Facilitators. Biking was facilitated by the spatial match of destinations within a manageable distance, as well as infrastructure access through bicycle (vehicle) ownership. Only two participants in the CHII study used bicycles for transportation, and in one case, a bicycle was used for grocery shopping by the participant's healthier friend or family member who was capable of biking. As this Flint participant said: "My boyfriend rides a bike to the store and carries the bags back…He'll have them tied to the handlebars…"

Barriers. Participants identified several barriers to biking as a mode of transportation for any purpose. The aforementioned participant whose partner biked to the grocery store reported that carrying items on bike handlebars was challenging but possible. Lack of interpersonal trust was also a barrier in that personal safety was a concern: one of the DET3 participants who had a disability feared the risk of harm while riding his bike: "I'm constantly afraid because I'm disabled that someone's going to run up, knock me off my bike and take it." Another Flint participant said that he did not bicycle for groceries due to his concerns about safety: "...they had a little trail where they will go through the woods to go through the school and go to the store…and it was safe. But later…they had found people being killed and thrown out there and being attacked on the bicycle trails…" For one Flint woman, the barrier was simply lack of bike ownership: "I used to have a bike.

I need to get one. I'm going to get another bike for the next summer." As previously mentioned, physical needs also served as a barrier, and winter weather limited bicycle use.

4.2.1.2 Driving.

Use cases. Participants who owned cars or had access to them preferred to drive for employment, grocery shopping, and healthcare appointments. Three DET3 participants with driver's licenses relied on cars for transportation to work or to find work. The 33 CHII participants (46%) that had cars preferred using them for grocery shopping as it was easier to carry items; driving to healthcare appointments was preferred partly due to the distant locations of many providers.

Facilitators. As might be expected, facilitators included the ability to drive; affordability of car-related expenses such as gas, insurance, and maintenance; and infrastructure access (through car ownership).

Barriers. Across all studies, the greatest barrier to driving was lack of access to a car or to a driver's license. In terms of individual capabilities, only three of the 13 participants in the DET3 study had an active driver's license. Due to an accumulation of traffic violations, another participant's driver's license had been suspended.

Health-related individual capabilities such as visual or cognitive impairments also impeded driving among CHII participants. (With medical procedures such as dialysis or eye exams that left participants unable to drive, this was a temporary impediment.) Some CHII participants feared future loss of their ability to drive due to their advanced ages.

Affordability was also a barrier for some who possessed vehicles and driver's licenses. Vehicle repairs, the cost of fuel, and as one participant noted, the cost of insurance could all stand in the way of actually using one's car. At least one DET3 participant and two CHII participants had a vehicle in need of unaffordable repairs: "I don't have any brakes" said one participant. Gas costs were a barrier for CHII participants. Those who drove frequented a larger number of grocery stores than those who did not; this was motivated by a search for better-quality food at lower prices. However, such comparison shopping could be difficult due to gas-related expenses. One Detroit man who preferred to go to a reasonably-priced store far away reported: "...if there ain't no gas, we can't go..." Finally, one participant from the Cart case study stated, "I need to get insurance for my car, my car [tire] is flat and my battery is dead…insurance is almost $400."

4.2.1.3 Walking.

Use cases. Walking is the simplest form of transportation in that it requires the fewest dependencies. Five DET3 survey respondents reported walking when necessary. When asked what form of transportation he uses most frequently, one participant responded, "The transportation that God gave me: my feet." Participants reported walking to work if their job was close enough. Some also walked to visit family or to go shopping. Eight CHII participants in total walked to grocery stores on a regular basis because the store was close to them. Some enjoyed the activity, as this Flint participant said: "I like to walk … I do it every day… I walk here and there... Go to the store…" One CHII participant reported walking to healthcare appointments.

Facilitators. Individual capabilities for walking facilitated use of this model. Spatial matches, or the location of jobs, grocery stores, and healthcare providers close to one's residence were a key facilitator of walking. Only one person, who lived close to a federally-qualified health center in Inkster, mentioned walking to her appointments: "Sometimes I walk because it's not that far away."

Barriers. In terms of individual capabilities, CHII participants mentioned that their health status stood in the way of walking long distances, or at all. This Flint man had limited mobility due to foot ulcers from his diabetes: "You don't get to do what you use to like…I have ulcers under my feet… I've had four operations now on my feet…"

Spatial matches also served as a barrier. Although close proximity made it easier to walk to grocery stores if one was nearby, it also had downsides since CHII participants were often surrounded by sources of less-healthy food; therefore, walking for food often meant walking to fast-food restaurants or convenience stores. As this Detroit woman with diabetes and hypertension opined: "…if you drive around Detroit, you'll come to some intersections and there's four fast food places on every intersection." It is perhaps unsurprising, then, that some participants described unhealthy food purchases from walkable locations. This Inkster woman explains that she may obtain food from a gas station, partly due to ease of access: "…we don't live that close to the grocery store. Sometimes, I walk to the gas station or something…"

Lack of interpersonal trust and/or fears of crime also served as a barrier to walking for some. In the DET1 discussion mentioned earlier, the group brainstormed walking as another method of transport despite living in an unsafe neighborhood:

Female 6: If she lives three or four blocks away from work, she needs to put on her gym shoes and start walking.

Male 3: She in a bad neighborhood though.

Female 6: She's got to put on a pair of shoes darling. (laughter) She's got a car to fix, she got bills to pay, she got to walk. She's got to work. Start working days or something, sorry but you got to walk. Whatever it takes.

Finally, physical needs were a barrier in that weather was problematic for three CHII participants, with a stated preference for not walking either on the hottest days of summer or during the winter. As this Flint hemodialysis patient said: "I don't go outside. I ain't doing too much walking in the cold."

4.2.2 Private. Study participants used taxis, real-time ridesharing, broker services, and jitneys. Jitneys are informal, unregulated taxis that are often cheaper than a regulated taxi. We also describe two case studies of the broker model, in which an organization arranges transportation for others using existing services (e.g., real-time ridesharing services) for a fee or in return for spending money at a business.

Participants reported using taxis and real-time ridesharing services for employment-related reasons. Jitneys and the broker model were only used to access grocery stores. While all private forms of transportation were limited by their availability, participants reported the most barriers and limitations with taxis. Taxis were less affordable and more unreliable than real-time ridesharing services and jitneys. Broker models also struggled with affordability for both riders and the providers of rides.

4.2.2.1 Broker.

Use cases. The broker model required an organization to handle ride management/scheduling. Our two case studies involved third parties who offered services to access healthy food; these services were offered for a fee and/or for customers who spent a certain amount at the store. Both involved connecting potential grocery store consumers with rides provided via a real-time ride sharing service (Lyft and Uber, respectively). These services were available only to customers within a five-mile radius of two grocery stores in Detroit: Prince Valley Market and Meijer.

Facilitators. The facilitators of this model included interpersonal trust, where an invested and trusted organization provided services as a broker. Infrastructure access in the form of real-time ridesharing systems to manage and schedule rides was also a facilitator.

Barriers. The case studies reveal several challenges with the broker model. First, both services faced affordability-related barriers. For Cart, the price of $10 was affordable for most customers; however, seniors on fixed incomes had a less favorable response to the price. Furthermore, the

participating grocery chain (Meijer) also described $10 as being too expensive per transaction to sustain the program. The Prince Valley owner did not discuss $50 in grocery purchases as being too expensive for customers; however, he described inconsistent price fluctuations with Uber, which made the service less financially viable for the market. He also described customer complaints that stemmed from drivers' financial concerns for providing short rides from the grocery store. For example, drivers complained to riders that it was a waste of money for them to drive ten miles only to take a customer two miles from their current destination. Concerned about whether customer complaints would negatively impact customer perceptions of the store, the owner ultimately terminated the pilot.

In terms of individual capabilities, the Cart service encountered a mismatch between the technical demands of the service and the digital literacy skills of the target audience. According to the Cart report, half of the customers required technology assistance or were confused about the process to initiate a ride, which led to Cart providing direct support to some customers. This was not a difficulty encountered at the Prince Valley Market, where staff members handled booking and payment on behalf of the customer while the customer waited.

Additionally, both broker services faced interpersonal trust barriers that manifested in poor uptake. A related issue was finding successful methods for advertising these new services. Cart reported having the highest success with high-touch or face-to-face experiences with potential customers and through purchased city bus advertisements. The Cart report also described limited success with a referral program in which Cart provided a small monetary incentive to referring customers. While the Cart report suggests that housing and branding the service through community organizations might increase trust, there were initial issues with Prince Valley Market's brokering service. As the Prince Valley store owner stated: "At first, there were no takers. I think because people didn't believe it [that he was offering free rides home]…But in the last couple weeks we've had 20 or so take advantage of it. I'm sure as winter comes, it will become very popular."

In the Cart pilot, trust in technology was a barrier, particularly in relation to online payment. This led to the creation of a bar-code-based payment system that facilitated cash payment. Furthermore, service availability was an obvious barrier since the broker model was only available to people in Detroit for the purpose of grocery shopping at one of three specific grocery stores.

4.2.2.2 Jitneys.

Use cases. Jitneys tend to come from the community that they serve, and drivers usually provide the service to supplement their income, and thus might be thought of as individual entrepreneurs in some cases. Jitneys were used by three CHII study participants primarily for access to healthy foods. In Detroit, CHII participants who walked to the grocery store occasionally purchased the services of jitneys for the return trip when carrying their purchases. As this Detroit woman said: "…if I do walk there, then I can catch a jitney back…Somebody who'll bring you home." This was a time when people were typically carrying groceries that would be more difficult to manage on a walk home. Similarly, one DET3 interviewee reported using jitneys or other unregulated taxi services for longer trips that required multiple stops. She would take a single trip to pick up groceries, medication prescriptions, and her pay check. Though participants reported using jitneys for other reasons, no one reported relying on jitneys to go to places related to employment or to healthcare appointments.

Facilitators. Affordability was a facilitator, since jitneys charged predictable amounts that were typically less than taxis. As the aforementioned Detroit woman said: "You pay 'em. They might charge you $6 or $7 from up there to here…" There was also evidence of informal jitney-like services among friends, particularly when friends felt that they had done too many favors for

one another. One DET3 interviewee stated that she has given her friends rides to various places including work when she has a working vehicle and she started accepting payments after two years: "I would say the first two years when I was here, no [she would not accept payments]. But this last year, yeah, it's been about like, 'I need gas money.' Yeah, just because I'm realizing the more damage is being done to my car, I'm running people where they need to go, and I'm footing the bill. At the end of the day, they don't help. So yeah, I've taken a little bit more initiative in asking for funds to take them." Another DET3 resident would pay his friend "maybe 10 to 15 [dollars]" for a 10 to 15-mile distance.

Varieties of payment types were also described, which may have assisted in affordability. In a DET3 interview, one participant self-identified as being a part-time jitney driver over a decade ago and who did not always accept cash payments during that time. She reported accepting food and company instead: "…he says, 'How much are you going to charge me?' '…I'll fill the full tank. When we leave, when we come back, you fill it back… and you buy lunch, and that's what we did'." "I says, 'It won't be anything expensive…It could be fast food'. We found this nice little buffet."

Interpersonal trust, when present, was also a facilitator, as evidenced by informal jitney services among friends. Trust also facilitated more formal jitney services: "You just know who to get in the car with and who not to get in the car with…" Indeed, since jitneys are not dispatched via telephone or smartphone as with other services, they rely on reputation-based referrals or prior relationships. Spatial matches were also facilitators, with grocery stores serving as a known gathering place from which vehicles could be accessed. For the driver, it is also clear that facilitating conditions included having access to a vehicle and an individual capability to drive.

Technological trust was also a facilitator in that riders did not have to use online payment modes they distrusted; rather, they typically pay jitney drivers in cash, or perhaps, as described above, non-monetary payment.

Barriers. Lack of interpersonal trust could also be a barrier. One participant explained that for safety reasons, the use of jitneys required knowledge of the driver. Therefore, the use of these services also relies upon accessing the known networks.

Service availability was a barrier to jitneys, with more people discussing the use of them in the City of Detroit than in Flint and Inkster.

4.2.2.3 Real-Time Ridesharing.

Use cases. Overall, participants anticipated and reported positive experiences with this transportation model, which they used to access employment and make trips to grocery stores. One reason this model was only used and mentioned in the DET1–3 studies may have been because the CHII study was conducted before widespread availability of real-time ridesharing in the study areas. Although there were a total of 82 trips made among our 12 DET3 participants, only three participants reported using real-time ridesharing services before enrolling into the study.

Facilitators. Service availability was an identified facilitator. One participant interviewed in DET3 described how he was able to get a ride with Uber despite his location: "I'm in a messed-up neighborhood, they still come. No matter what's in this neighborhood…They come pick you up from wherever you at, but your destination is all that matter."

Service reliability was also a facilitator. Another DET3 participant spoke highly of the service's reliability and professionalism: "Basically I believe Uber is really effective. I'm really behind them. I have not been disappointed…They on time, they very professional, they courtesy [sic], and they make you feel right at home."

Barriers. As anticipated, barriers to real-time ridesharing included affordability, and the need for credit cards. While the DET3 study aimed to eliminate many of these barriers—i.e., the use of Uber

business to remove the credit card requirement, results suggest that financial barriers remained significant [15]. A related issue with affordability was a lack of smart phones with reliable data access.

Individual capabilities in the form of digital literacy skills and computer self-efficacy prevented individuals from participating in the DET3 study as reported in [15].

Lack of interpersonal trust was also a barrier to use of this model; participants who signed up for the DET3 study did so via referrals, or through a trusted local non-profit, which lowered this barrier. Trust in the technology platform, including online payment, was also a barrier.

Access to infrastructure was also a barrier; this included a lack of smart phones with reliable data access. From the point of view of potential drivers, most had access to older vehicles that did not meet vehicle requirements for participating in real-time ridesharing. Only one participant in the DET2 group had access to a vehicle that met Lyft's car requirements.

4.2.2.4 Taxis.

Use cases. Taxis are local companies that dispatch drivers in the area in which transportation is needed. In total, five participants reported using taxis to access employment and/or grocery shopping. No one mentioned using them for healthcare appointments.

Facilitators. While taxis are costly, one Flint resident received discount services and used a cab to get to her job if her usual transportation fell through: "I'm…blessed to be on a list of people that have the luxury of booking a cab at a very reduced fare due to a grant through the Visually Impaired Center. And that's cab service…I'll book a cab and…I'm going to get to work on time."

Barriers. Affordability was a factor underlying infrequent use of taxis. Service availability was also a barrier; DET2 group members complained about a lack of availability in certain low-income neighborhoods. Unreliable service, manifested in long wait times, was also a major barrier, as voiced by DET1-DET3 participants. This DET3 participant complained: "I waited 6 hours on a cab. There is no storm…No snow on the ground and it's six hours on a Sunday morning." Similarly, a DET1 participant said: "Cab takes all day to get … and some cabs don't even come to certain areas, depending on where you live at. They sure ask you that … Depending on what cab company you dealing with."

Service quality in terms of professionalism of the service provided by the drivers was also a barrier. One DET1 participant opined: "Cabs take too long… drivers go out their way to try and get more money. Go and take the wrong route." A DET3 participant experienced bad attitudes from drivers, and another DET3 participant was unhappy with a dispatcher: "…the old dispatcher that they fired … I won't go into that one…"

Service quality in terms of taxi company vehicles also served as a barrier, according to several DET3 study participants. One said: "Shammy (pseudonym for a local cab company) has crappy cabs but they're good. Three-Star's (pseudonym) got newer cabs…" Another DET3 participant described taxis as smelling of cigarette smoke and being unclean—he avoided them when scheduling transportation to get to interviews: "Some cabs, they don't take the time to detail their vehicle."

4.2.3 Public. Public forms of transportation included public transit and paratransit. Participants used public transit frequently, and for all of our use cases: employment, healthy food and health care appointments. However, paratransit is a service primarily limited to health care appointments though it was used in one instance for grocery store access.

4.2.3.1 Paratransit.

Use cases. Thirteen CHII participants and one DET3 participants used paratransit, which is a specialized transportation service that is usually offered free of charge for seniors and people with

certain health conditions or disabilities. It is usually subsidized by tax dollars. It may be offered as an extension of an existing public transportation service as in Flint, or through a contracted organization as in Inkster and in Detroit. Paratransit is often offered through vehicles meant to transport multiple people, such as vans or buses. Paratransit use was concentrated on healthcare appointments and in one case, food access; no employment-related travel was noted.

Facilitators. Affordability was a facilitator as CHII participants with Medicaid insurance had access to free medical-appointment transportation. In Flint, many used a free or discounted public transit van service for older adults and people with disabilities living in the area. As this participant explained: "This is my monthly bus pass right here. Yeah, it costs $25 for the whole month…Your Ride takes you door-to-door. It's a van that picks you up…"

Spatial and temporal matches were also facilitators. Spatially, the services provided door-to-door service by planning and combining routes with multiple starting points and multiple destinations. Temporal matches were also achieved by requiring that rides be booked in advance; the minimum advance time period in Inkster and Detroit was three days. This was made possible by the fact that healthcare appointments are often booked well in advance.

Barriers. Lack of service eligibility was a barrier to use of paratransit since in Detroit and Inkster it was only available for healthcare appointments, and only for those on Medicaid. In Flint, somewhat wider eligibility requirements and usages allowed one person to use paratransit for groceries.

Lack of service reliability was also a barrier to paratransit. Long wait times and lateness were concerns among participants in all of the cities. For these reasons, this Inkster woman was not happy with the service: "It's okay. I just don't like when I'm done and I'm ready to go, I have to wait on them. It has taken them up to an hour to pick me up, so...I call them and tell them, or either I will say, my appointment's going to take an hour…because they have like a schedule." A Flint dialysis patient who used the service three times a week complained: "They're not always the most punctual of drivers so sometimes you have to wait a little while to get a ride home……[t]hat could be problematic because sometimes I don't feel that well getting off the [dialysis] machine. So, I'm stuck there in the chair until they come pick me up." Similarly, another DET3 participant complained about: "Drivers being extremely late…driving all over the city and the suburbs, and still dropping me off late."

Relatedly, non-arrival of rides was a concern. One DET3 participant complained: **"**I use Medicaid transportation. My insurance transports me to medical appointments…There's just been issues with that, big time**…**Drivers not showing up." This Inkster man reported a similar issue and claimed that not all of his appointments were met by the service: "…sometimes they come, sometimes they don't come."

4.2.3.2 Public Transit.

Use Cases. Where available, public transit was used for purposes of employment, access to healthy food, and access to health care appointments. Via surveys, ten DET3 participants reported using the bus, with some using it to get to work and others using it to visit family and shop for groceries. In the CHII study, 20 participants reported using public transit at least some of the time for employment or job-seeking, grocery shopping and/or healthcare appointments.

Facilitators. Affordability could be a facilitator of use, especially if a person qualified for a discount fare due to disability or age. Technological trust was also a facilitator in that the option to pay in cash was embraced by our participants as was service availability. Furthermore, spatial matches drove use, as when both home and destination were close to bus lines. For two Inkster participants, travel for groceries via the regional bus service was straightforward for this reason: "Kroger is on a bus line. There's a Kroger on Michigan Avenue, you can get there on a bus." Buses

also worked well for attending healthcare appointments in Flint, where physicians were typically closer to them and more accessible by bus. As this Flint resident said, "Most of my doctors are on the bus line."

Barriers. Affordability could also serve as a barrier for those on limited incomes, primarily due to the long distances traveled to healthcare appointments, sometimes across multiple municipalities. For instance, CHII participants from Inkster and Detroit noted that travel to their healthcare providers located in the suburbs could be expensive. As this Inkster woman said: "I took the SMART[1] bus…It will be better when I turn 65 and it's $2 instead of $4. It costs $4 each way." Similarly, a Detroit participant who had many different doctors similarly complained: "…me borrowing money or saving a few dollars I got to catch buses all to these places…"

Interpersonal trust issues in relation to safety concerns were also a barrier to use of public transit. This Flint woman complained: "As I get older, the kids, they don't know how to respect people. They cuss on the bus, all indifferent… They just don't care. And I hate getting on the bus and then sometimes I'll be kind of paranoid. I don't know what's going to happen. They got cameras on the bus here." This young man from Detroit avoided public transit because: "…people on the bus made me feel uncomfortable a few times and drama on the bus."

Spatial matches in the form of limited bus routes could also serve as barriers. Bus routes were challenging for the urban-dwelling CHII participants in Detroit and Inkster, who often had to travel to healthcare appointments in the suburbs. Consequently, this Inkster woman described a patchwork of transportation methods to reach one of her healthcare providers: "I also would take the SmartBus, and then, I'll take the real bus back, and then, I would walk from the bus station home." A CHII participant from Detroit corroborated the complexity of this process: "I'm not just catching on one bus, two or three buses sometimes. And there's time I caught three or four or five buses." An Inkster woman also expressed concerns about the fact that the bus did not run to her doctor's office at all, thus making her car-dependent: "…if I had to depend on the bus for Main Street I never would've made it to where my doctor is located…Because my doctor is in Livonia and the bus stops right there on… My doctor's office is on Middlebelt but the bus stops at Warren. It used to go straight down, but it doesn't do that anymore. So, if you're trying to get anywhere past that, good luck."

Bus schedules also posed a temporal match barrier. This DET1 man faced challenges coordinating work hours with bus availability: "I've worked at McDonald's…We can't get these buses to run 2 or 3 o'clock in the morning. Buses [sic] get off work at 12 midnight, and you can't even get a bus home 'cause it's stopped…" A related problem was that low-income participants might have little control over their working hours, making alternative transportation methods difficult. As this DET1 participant said: "…they can actually call you the day before you go into work or tell you… Or a day that you are off, they can call you a day before and actually tell you, 'Oh, you got work today.'" Bus schedules were also difficult for grocery shoppers. A CHII participant in Detroit complained about her previous difficulty of shopping due to the bus schedule: "…it runs like every hour, hour and a half… on the weekends it's extremely slow… I don't think it runs at all on Sunday…[to get to the grocery store, it took] anywhere from 45 minutes to a little better than an hour." Consequently, she was relieved to have since obtained a car.

Lack of service reliability was also a barrier. With regard to employment, one DET3 woman stated, "Buses are not on time. They don't have as many buses on the routes like they used to. They have shut down routes at a certain time, where they had routes that would run all night. I have known people to have actually lost their jobs due to the public transportation failure." This

[1]SMART is the only regional public transportation provider in Southeast Michigan. It is a federally and state-funded fixed-route bus service that connects people to educational and employment institutions.

participant had not ridden public transit for seven years due to its unreliability. There were also complaints about the reliability of buses for healthcare appointments, as this CHII participant from Flint said: "The bus is late every day. It's kind of frustrating…sometimes you can be 15 minutes late to an appointment, and they will cancel you and tell you got to come back." Finally, physical needs created a barrier when, due to the difficulty of carrying items on the bus, public transit was viewed as unsuitable for grocery shopping.

4.2.4 Interpersonal. In interpersonal transportation models, private ownership was extended to use by people other than the primary owner(s), with access provided through social relationships—typically between family and friends. Interpersonal models include favors and resource pooling. Facilitators involved affordability, interpersonal care between car-owners and non-car-owners, spatial and temporal matches, and access to infrastructure in the form of vehicles.

Key barriers included temporal mismatches in the form of conflicting schedules, issues in balancing interpersonal reciprocity, and not having access to caring social networks.

4.2.4.1 Favors. We define favors as an informal system in which individuals received rides or transportation-enabled assistance from people in their social networks, without an expectation of monetary payment or other direct exchange of goods or services.

Use cases. Twenty CHII participants used favors at least some of the time. Fifteen CHII participants had relatives, friends, or neighbors who took them to the grocery store. Three participants with limited mobility also reported that younger relatives, like their children or a niece, went shopping for them. As this Flint participant said: "…the kids go for me. I'll [tell] them what I want and they go for it." Favors for healthcare appointments were also common. For some participants, reliance upon family members was temporary, such as when they had a recent medical procedure or a temporary health issue such as an injury. As this Detroit woman with diabetes and hypertension noted: "…when I had a problem with my back, my daughter had to take me." For employment-related purposes, a total of eight DET3 survey respondents reported asking family members and/or friends for rides.

Facilitators. Affordability was a facilitator of this model in that recipients typically did not pay for the rides. Interpersonal care was also a key facilitator, as participants obtained rides from spouses, parents, adult children, nieces, in-laws, cousins, and friends who owned cars. Access to infrastructure in the form of cars and service reliability were also facilitators. One DET3 participant, for example, stated that he asks friends for rides specifically for job interviews to increase his chances of arriving on time.

Barriers. Interpersonal reciprocity was a barrier to favors. Interviews from DET3 revealed that concerns about "asking too much" of others made participants reluctant to rely heavily on the favor model for employment. By its very nature, such frequent travel requests risked "asking too much." Additionally, two participants also described a reliance on favors as in conflict with a desire for independence; this prevented them from asking friends or families for rides. One of these individuals, stated: "I don't believe in asking anybody because, when you ask, you always get let down. I learned to do things for myself." Nevertheless, the perceived limits could be expanded by reciprocating with non-transportation-related resources.

Temporal matches in the form of conflicting schedules were a barrier to providing favors. For example, drivers' schedules did not always mesh with the scheduling needs of the passenger. This was a particular problem for employed relatives who had to miss work during regular business hours; consequently, relatives were not always available to provide transportation to healthcare appointments. Providing favors was also not conducive to employment schedules or for

activities that occurred more often than once per week. This was exacerbated when participants had unpredictable work hours.

4.2.4.2 Resource Pooling. Resource pooling involves sharing vehicles, rides and/or vehicle upkeep with others. One CHII participant from Detroit shared a car owned by his mother. Another CHII participant carpooled with another person on a regular basis. In the CHII study, there was also a single instance of what we define as an upkeep-sharing approach whereby individuals in a community contribute to keeping a privately owned vehicle in operating condition. In exchange, contributors were able to use the vehicle.

Use cases. Resource pooling was used for food and healthcare access, but not for employment. With regard to carpooling, just one CHII participant, a Detroit man, described sharing a weekly ride to the grocery store with the mother of his child: "I go with her. She got a ride with her son, uses her son's ride, go to the grocery store…"

Facilitators. Resource pooling was affordable as it involved sharing expenses. Furthermore, as suggested above, interpersonal care with someone with vehicle access was a facilitator to carpooling. Interpersonal care was also a facilitator to upkeep-sharing. In Flint, via an informal arrangement, a woman's friend maintained her vehicle and helped pay for gas in exchange for occasional transportation. As the car owner said, "…I can't afford gas… this lady I'm going to pick up, she's very good at like if some things break down, she'll fix it for me. She'll keep gas in the ride …she's been a good friend in my life, so if I can do something to help her I don't mind".

Spatial and temporal matches were also a facilitator of ride sharing, as in proximate starting places and a shared destination; this was evident in carpooling to grocery stores.

Barriers. Interpersonal care could also serve as a barrier when it was lacking. DET1 involved a small group discussion of a problem scenario describing community issues that researchers asked them to solve. The group's goal was to work through the problems and share their solutions with a larger group. Respondents' primary concern was that the city had very limited medical transportation available. Due to significant lack of community and trust, they *suggested* building a strong, trusting personal network to enable carpooling as an option to address such problems. This implies that lack of a caring social network with car owners may be a barrier to resource sharing in the form of carpooling.

5 DISCUSSION

Through examination of the results of four qualitative studies and two case studies, we have identified which transportation models low-income individuals used to access health-enhancing resources—and which they did not. Personal, public and interpersonal forms of transportation were most widely used (see Table 4; this excludes the real-time ridesharing trips paid for by DET3). However, per Table 4, interpersonal forms of transportation posed the fewest barriers. We found that driving, walking, public transit and favors were used for all three SDOH-related activities: employment, healthcare appointments, and food shopping (see Table 5).

Walking, broker, real-time ridesharing and public transportation posed the largest number of different challenges. We categorize the barriers and facilitators to transportation usage that emerged in our results as follows: (1) affordability; (2) individual capabilities; (3) interpersonal trust, care, and/or reciprocity; (4) trust in technology; (5) service availability and eligibility criteria; (6) spatial and temporal matches; (7) matches between physical needs and transportation mode; (8) service reliability and quality; and (9) infrastructure access in terms of vehicles, smartphones, and data plans. Affordability and service availability were the most pervasive challenges our participants experienced. We discuss our findings in light of the literature.

5.1 Affordability

Financial barriers identified included the high costs of vehicle insurance, upkeep, and fuel. This is in line with previous work outlining the high costs of vehicle ownership [58, 59, 99–102]. As stated earlier, driving one's own car is very expensive, and for many, reliable access to a vehicle can also be unpredictable. For example, 33% of US drivers could not pay for a vehicle repair without going into debt [99]. Not surprisingly, some of our participants reported the high cost of auto repairs as a problem. The need for affordable repairs is of particular concern given that there may be more car crashes in low-income neighborhoods [100]. Moreover, the financial difficulty of owning a car is compounded in the State of Michigan [101], which has the highest auto insurance rates in the country [102]. On average, drivers in Detroit pay 165% more than the national average for car insurance. To date, this issue has received little attention in the scholarly literature.

For some of our participants, payments for other forms of travel, such as taxis, could also strain resources. The only regular user of taxis was a person who had discounted service provided through governmental programs. Surprisingly, public transit was also mentioned as being too expensive, although higher fares may have been due to the need to travel between municipalities to visit healthcare providers. The broker model was also seen to be expensive by some Cart users. To our knowledge, though somewhat intuitive, financial concerns regarding taxis have not been previously described in the literature, nor have cost issues related to public transit been addressed. Notably, some models not used in our studies, including car rental/Zipcar and bicycle sharing have been identified previously as cost-prohibitive for low-income people [61, 62].

Affordability from the point of view of the ride provider also emerged in the case studies as a finding in this research. Echoing prior work [72–74], our two broker case studies involving grocery store access identified difficulties related to making or sustaining revenue. Nevertheless, paratransit worked for healthcare because insurers saw a financial case for providing it to healthcare appointments.

Some models did not have affordability as a barrier. These included biking, walking, paratransit, jitneys, and both interpersonal models. Representing different financial arrangements, interpersonal favors and resource pooling worked when someone could share their resources with others. The extent and functioning of such informal interpersonal and jitney transportation models in low-income communities have not been discussed extensively, particularly in HCI. These informal methods show promise to address much-needed access to health-enhancing resources in underserved and low-income communities.

5.2 Lack of Individual Capacities

Barriers and facilitators to use of existing transportation models include the inability or ability to drive. A number of participants in our studies, most of whom were African-American, did not possess valid drivers' licenses. This is in line with national trends; individuals without driver's licenses are, by and large, people of color. People of color are also disproportionally affected by being unemployed as a result of not having a driver's license [103]. Individuals who are poor often have their licenses revoked for minor infractions such as failure to pay a traffic ticket or driving with non-working taillights. While a speeding violation in excess of the speed limit by 25-miles per hour could lead to a half-month license suspension, failing to pay a ticket for a burnt-out taillight could lead to a 12-month license suspension. In fact, two legal justice groups filed a lawsuit in Detroit arguing that the State of Michigan is in violation of the Equal Protection Clause of the 14th Amendment by making it unfeasible for poor people to drive [104].

Chronic illness also limited the participants' walking, driving, and biking capabilities. The prominence of this issue differed from previous work on low-income communities, primarily due to the CHII study's focus on chronically ill people.

Lack of digital literacy skills was an identified barrier for the broker model [95] and the real-time ridesharing model, which were the only used models that relied upon ICTs.

5.3 Interpersonal Trust, Care and/or Reciprocity

According to Möllering, trust is "…a state of favorable expectation regarding other people's actions and intentions" [105]. As has been described in the case of shared-mobility services, transportation models for low-income people may be less successful when trust is lacking among unacquainted people [15]. Distrust of strangers manifested commonly in fear of crime, which served as a barrier for some participants in relation to biking, walking, and public transit models. This also extended to distrust in potential drivers, as evidenced in the broker, jitney, and real-time ridesharing models. Notably, interpersonal trust could become a facilitator, as when knowledge of a driver and referrals facilitated use of jitneys, and when high-touch outreach stimulated trust in the Cart organization's broker model. This supports a recent article that calls attention to the creative ways in which Detroiters set up ride-share networks in trusted communities without technology [Vande Panne, 2017].Given its importance, we advocate use of a trust-centered design framework for potential transportation interventions in underserved communities [106].

Interpersonal care was an important facilitator of informal transportation models, and its lack served as a barrier to them. In particular, our findings newly highlight the importance of the favor model in low-income communities. Previous quantitative research has shown that it is common for chronically ill people to obtain rides from others to attend healthcare appointments (e.g., [5, 107]), we demonstrate its use for access to employment and grocery stores. Moreover, we show several forms of resource pooling which, though rare, have not yet been well-documented.

We also build on prior research by identifying lack of interpersonal reciprocity as a barrier to use of interpersonal transportation models. Specifically for favors, people in need of rides from others were wary of "asking too much" of others, which has also been reported in [63]. Due to the risk of "asking too much," some people responded by seeking opportunities to give back, or avoided situations in which they would have to depend upon others. Past research equates this avoidance with "withdrawal" or a "self-imposed restriction" from participating in or accepting help from one's social networks when one is unable or unwilling to reciprocate [108].

5.4 Trust in Technology

Lack of trust in technology emerged as a barrier in broker and real-time ridesharing models, with online payment systems provoking suspicion. Consequently, cash payment was preferred in some cases. This is in line with previous work showing that low-income residents may distrust online payment methods used by real-time ridesharing services [15, 63]. Accordingly, acceptance of cash was a facilitator for use for jitneys and public transit. Additionally, as mentioned, creators of the Cart version of the broker model addressed this barrier by accepting cash payments.

5.5 Service availability or Eligibility Criteria

Our studies revealed several transportation models that are available only to some people, or in some locations, or for some reasons. Paratransit was typically available only for people with specific health insurance (Medicaid), and for one purpose: healthcare visits. Broker models were available only for grocery shopping, and for clients of two grocery stores in the Detroit area (Prince Valley and Meijer). The Cart rides to Meijer were limited to zip codes within a 5-mile radius of the grocery store. Jitneys were primarily available in the city of Detroit, and were most accessible for grocery shopping. Notably, the availability of jitneys in some areas may have been reflective of the reduced service of licensed taxis in low-income areas [65].

Furthermore, the services with the most flexibility for use, such as driving, taxis, walking, biking, and public transit all had limitations for some people (e.g., poor health, lack of a vehicle, or unreliable service). Public transportation, for example, was not conducive to carrying groceries, and biking and walking in cold or hot weather were undesirable activities. The result was a complex patchwork of transportation solutions that required considerable effort to navigate; for low-income people with chronic illnesses or disabilities, this must be understood in the context of the significant burden of effort that is already required to manage their conditions [93]. Together, such burdens may make adherence to chronic disease management recommendations exceedingly difficult [93].

As stated earlier, some options, such as bike sharing services were unavailable to all participants and others, such as Zipcar, were not used or mentioned. It is possible that these services, if available and combined with social networks, might have been cheaper to use. This could be a research opportunity to explore in the future. Nevertheless, to meet the needs of low-income communities, we contend that an ideal transportation model would reduce the complexity surrounding finding and accessing transportation services. Such complexity reduction requires broad availability and eligibility requirements, as well as transportation modalities that are suitable for a wider range of purposes.

5.6 Spatial and Temporal Matches

With regard to spatial matches, some transportation models, such as carpooling and shuttling services (not used in this study), require that people share a common starting location and/or destination. Indeed, previous pilot projects such as supermarket shuttles gathered participants from densely populated areas (e.g., [74]). We found that models with this requirement were not widely used by participants in our studies. For employment and healthcare appointments, this may have been due to a lack of common employers or healthcare providers located in the same neighborhood. With more sparsely populated neighborhoods as a result of depopulation over the past decades, transport to and from grocery stores in Detroit has also become more difficult.

Public transit also operates with common starting places and destinations, though presumably a larger number of both exist along a system of bus and train routes. Participants in our studies noted that there were gaps in service to potential employers and their specialist physicians, some of whom were located outside of the City of Detroit. Another factor was the length of the trip; clearly, very long trips (such as those required for many jobs and healthcare appointments) were not suited to walking or biking.

There were also temporal mismatches between service timing and scheduling needs. As our three DET studies showed, low-income people often find themselves working in service-oriented jobs that require them to work evenings, nights, or weekends, outside of a typical nine-to-five schedule. At the same time, people may need to work more than one job to get by, leaving little time in which to undertake tasks such as grocery shopping. The result of these temporal demands may be the need for transportation availability outside of typical hours for public transportation. Conflicting schedules also stood in the way of the favor model, including requirements for people to take time off of work to take participants to healthcare appointments. Additionally, for low-income people, work hours may also be unpredictable, making it more difficult to gain access to favors. Our work is unique in identifying these temporal challenges in facilitating transportation for low-income people.

These findings demonstrated a need to improve the match between service/driver locations and rider destinations. Based on our studies, there appears to be a need to allow for the pooling of trips with proximate starting points and destinations, for a wide range of purposes, while permitting travel to locations which go beyond municipal boundaries. Furthermore, there is a need to improve

the match between low-income peoples' scheduling needs and the transportation models available to them.

5.7 Match between Physical Needs and Transportation Mode

Our studies revealed difficulties in the match between available vehicles and the needs of potential drivers and riders. Carrying groceries was difficult while walking, biking, or taking public transportation. Because many low-income people have older vehicles, they may not qualify to act as drivers in shared-mobility services, such as Lyft and Uber. Yet, such vehicles might be sufficient for some types of trips, and it may be that jitney drivers were already providing such services using older vehicles. While not a part of our study, the need for car seats could also serve as a barrier for those with small children.

Additionally, as might be expected, our studies revealed greater physical challenges in using some modes of transportation depending on the weather. Specifically, the discomfort of walking and biking on very cold or hot days creates a mismatch between transportation availability and basic human needs. This aligns with previous research showing that older adults may walk less often in their neighborhoods when there is snow on the ground [109]. Previous work has also indicated that adults of any age may avoid or delay outdoor exercise during adverse weather conditions [110].

5.8 Service Reliability and Quality

Some trips, including arrivals at jobs and healthcare appointments, require adherence to a strict schedule. Consequently, late service, long wait times, and no-shows were major concerns mentioned across our studies, most prominently with public transit and paratransit. Such difficulties with public transit have received little prior attention in the literature. The lack of service reliability is a well-recognized problem in paratransit services funded by Medicaid; this recognition led to recent pilot projects using Uber for healthcare purposes [111, 112]. In addition, efforts such as OneBusAway provide real-time arrival information for public transportation. While this project does not guarantee reliability, access to arrival information has been shown previously to help to reduce wait times and alleviate safety concerns [113].

While real-time ridesharing may not be a panacea for low-income communities [64], long wait times were not reported as an issue with this model [15]. In comparison to other models such as public transportation and taxis, participants were satisfied knowing that their ride was on the way. Participants also complained about the unreliability of licensed taxi services. Such findings align with studies of low-income communities in other geographic areas [66–68]. Notably, favors were viewed as a reliable form of transportation.

5.9 Infrastructure Access: Vehicles, Smartphones, Data Plans

Personal access to a vehicle, whether a car or a bicycle, was a major facilitator to personal transportation models. Additionally, the availability of vehicles among people who were willing to serve as drivers was a facilitator, whether through private models such as real-time ridesharing and jitneys or through interpersonal models. Given the importance of car-owners in facilitating transportation access to those without vehicles, we contend that transportation models for underserved communities should strive to achieve socio-technical integration with this resource.

Because of the fact that smartphone and data plan access were uneven, it also appears that if needed, access to this form of infrastructure may profitably be provided via an intermediary (such as a store, as in the Prince Valley Case Study) or through a non-profit organization, as in DET3.

6 IMPLICATIONS FOR POLICY, DESIGN, AND NEW TRANSPORTATION MODELS

We conclude by outlining new policy and design principles based on the aforementioned barriers and facilitators. We propose principles that address the most pervasive and critical challenges to transportation per our participants, while also building on existing facilitators of transportation. These principles are geared toward creating greater access to health-enhancing resources for low-income people and their communities. We then propose new transportation models that integrate these principles, while promoting access to resources that address the SDOH. We first present our principles.

6.1 Policy Principle 1: Reduce Transportation Costs via External Funding and by Leveraging Current Practices of Favors and Resource Pooling

Per Table 5, affordability was the most significant barrier identified in our studies. Therefore, a viable transportation model for low-income people must minimize out-of-pocket costs through financial strategies and build on the existing strengths of the communities. Employer-based transportation-demand management programs, for example, incentivize carpooling and encourage consideration of alternative modes of employee travel to and from work. The goal of such programs is to reduce expenses and improve air quality [114]. Such efforts include providing free or subsidized bus passes and adjustable work hours; offering employee shuttles; and starting employee carpool campaigns. None of our participants mentioned these types of initiatives. However, this type of funding by an invested stakeholder such as an employer could help decrease the cost of transportation while reducing congestion and improving overall air quality. An effort to build on and strengthen the existing financial arrangements such as favors and resource pooling is another option. This would require coordination or management between those with access to vehicles and those without them. Furthermore, some financial arrangements involved cash, such as the use of jitneys—credit cards were not required. Therefore, a service must permit use of cash and/or trading of services, rather than credit cards alone—real-time rideshare services such as Uber offer cash-based options though this option is unavailable in Detroit. The use of a kiosk to accept multiple payment types was proposed in prior work [15], and Cart provided a system that enabled various payment types [95]; however, Cart's overall technology was still too difficult for many to use. Future models could allow for costs to be bundled into existing payment infrastructures, such as an individual's mobile phone bill. Maintaining manual ledgers or spreadsheets is a common practice among micro-finance institutions serving low-resourced communities in developing regions [115, 116].

6.2 Policy Principle 2: Ensure Flexible Eligibility and Use Criteria

Service availability and eligibility criteria, per Table 5, was the second most pervasive barrier identified among our participants. As discussed earlier, not all individuals were able to use the various transportation models offered via insurance providers, local jitney drivers, and brokers. In addition, except for jitneys, some of these models had starting place or destination restrictions. Accordingly, these models provided only partial solutions for meeting transportation needs.

Given this, transportation models should have flexible eligibility and use criteria. Health insurance providers, for example, could extend transportation coverage that currently covers healthcare appointments to local grocery stores with pharmacies. Notably, paratransit services in Flint already extend to grocery store visits. Broker models could extend beyond grocery stores to provide rides to and from work, with employer-provided subsidies. As was promoted in the Cart case study, to take advantage of idling capacity, or extra seats within vehicles, individuals who are eligible for the service could, for a small fee, increase the number of people who could then share costs.

Notably, flexible eligibility requirements are important because lack of transportation was often a transient state (e.g., a car suddenly breaks down and cannot be repaired, or a family member is called in to work and can no longer drive a person to a healthcare appointment). In cases of transportation loss, the barriers to entry that go along with flexible eligibility criteria could facilitate speedy access to transportation.

6.3 Policy Principle 3: Ensure Reliable Service and Strict Arrival Times for Some Trips, While Allowing More Flexibility for Others

Service reliability is perhaps the most critical barrier and most important facilitator to transportation for employment and healthcare appointments. A successful transportation model would ensure that participants who use the service would never (or very rarely) be late for these use cases. However, this is not necessary for most grocery-related trips. The ability to treat different types of rides differently may permit slack in ride planning and scheduling systems.

Many participants complained about the unreliability of government-funded transportation such as paratransit and public buses. States and cities must hold these services accountable for providing reliable service. Real-time ridesharing services such as Uber and Lyft have ratings for riders and drivers. This approach could be extended to vendors who provide transportation on behalf of insurance companies, particularly with the entry of these services into the healthcare market. These vendors and others who provide transportation could be assessed yearly by mandate to ensure the best quality service.

6.4 Design Principle 1: Enhance, and Broaden Access to, the Capabilities of Low-Income Community Members

A viable transportation service would not assume the user capabilities outlined earlier (e.g., drivers are licensed, riders are healthy and digitally literate), but would instead build upon and coordinate access to those capabilities. A viable transportation model would match a car owner who is unable to drive with an able driver. A model would also match vehicle owners with community-dwelling mechanics with whom it would be possible to trade services to enhance transportation access. At the same time, capabilities that can be learned, such as digital skills, should be enhanced [117]. As we have argued elsewhere [14, 15], a transportation service requiring digital skills could be implemented alongside a training and technical support program—preferably delivered via trusted people and/or organizations such as non-profits.

Some of our participants showed resilience by overcoming limitations to existing modes of transit (e.g., tying grocery bags to bicycle handlebars). Transportation models and/or incentives should specifically build on these resiliencies whenever possible. Providing access to add-on baskets and cargo racks are options.

6.5 Design Principle 2: Facilitate Matching Based on Available Vehicles and Trip Characteristics

Along with individual and family resources, health conditions and employment status influence the types of trips people need to make. Transportation models should take this dynamic into account to best facilitate matching. There may be a need to match vehicles with users based on the capacity of the vehicle (e.g., space for a walker) and the characteristics, or requirements of the trip (e.g., carrying parcels), for example. Accordingly, transportation services should match an individual's destination and length of trip based on the individual's real-time needs. Services such

as UberPOOL[2] and Lyft Line[3] begin to address such need through options such as carpooling. Researchers have proposed matching carpooling algorithms based on activity instead of location [118]; a person's flexibility [119]; or their willingness to modify their destination while maintaining their primary activity [120]. However, there is a need for capabilities not present in such models, such as combination of trips and the ability to request specific vehicle types. One such matching algorithm was used in the broader context of timebanking, or matches based on an individual's complementary abilities and needs [121].

While recent efforts to use social media to improve public transportation routes hold promise for improving the match between riders and destinations [122], fragmented municipal funding models may work against implementation of individual-level approaches in public transit. Improved matching algorithms for the context of transportation should enable individuals who need rides to provide details of their trip to the most appropriate vehicles nearby. Ideally, these algorithms would not necessarily be applied to real-time ridesharing services. Such algorithms could be applied to other transportation models such as the shuttle model and even peer-to-peer car sharing, to encourage or incentivize drivers to drive for individuals who have similar needs.

6.6 Design Principle 3: Facilitate Reciprocity in Existing Trusting and Caring Relationships

Successful transportation models for low-income people and their underserved communities would build upon the trusting and caring relationships outlined in 5.3. A viable transportation model must also encourage reciprocity between drivers and riders; for example, an ICT-enabled system could facilitate trading or bartering. In addition to transportation and money, as in the informal jitney model, goods and services could include other forms of exchange as well, such as a home-cooked meal for a ride.

However, facilitation of exchange should be designed in a way that prevents individuals from withdrawing from the network due to concerns about inability to reciprocate or "asking too much." One strategy to minimize network withdrawal might allow for acquisition of support from outside of current social networks [108, 123]. Recipients could turn to social service agencies or volunteer networks if they were temporarily or permanently unable to provide assistance [108].

6.7 Proposed Transportation Models

Our policy and design principles support the selection of four promising models for low-income individuals and underserved communities for enhancing access to employment, healthy food, and healthcare. Accordingly, these models could be viewed as strategies for addressing the SDOH. These models also extend informal arrangements and diverse exchanges [124] that already function well for some people in some situations. As such, they build on existing community strengths, while highlighting rich areas for HCI and CSCW contributions.

6.7.1 Smart Jitneys. Building on Design Principles 1 and 2, we suggest a transportation model that expands on the jitney model, which already had the benefit of affordability. Notably, this model supports those with cars who are seeking employment and could further support existing jitney drivers to expand their customer base. Real-time ridesharing services such as Uber and Lyft already support unregulated taxis, but driving is restricted to individuals whose cars meet specific requirements (e.g., at least a certain year and four doors). In line with Policy Principle 2, some

[2]A type of Uber service that pairs an individual with other riders who are headed in the same direct. The service allows passengers to split the cost between riders.
[3]A type of Lyft service that enables carpooling, or "ride sharing" with passengers headed in the same direction. Passengers using this service are able to view each other's profile information.

restrictions could be lowered to support local jitney drivers (i.e., allowing two-door in addition to four-door cars, or cars older than the mandated requirements). Additionally, this service could be expanded to include small tasks for payment, such as a person who makes runs to the grocery store via a bicycle as part of the "gig economy" [125].

Technology could help expand the scope and scale of jitney-type services by improving spatial and temporal matches between services and needs. This would broaden the service beyond jitneys that wait for people needing a ride home from the grocery store. Matching could also allow people to choose a favorite driver, and to specify their vehicle requirements, such as a car seat or room for a walker. Such enhanced matching via preferences could help ensure greater satisfaction among drivers and passengers alike. According to Policy Principle 3, it should also be possible to designate trips as either firm or flexible in terms of timing.

6.7.2 Generalized Favor-Based Model. Taking Policy Principle 1 and Design Principle 3 into close consideration, we advocate the creation of a generalized, favor-based model that can expand the reach and improve the sustainability of this approach. With regard to reach, an ICT-enabled model could allow people to volunteer to provide rides for people in need of them, or to exchange rides for other valued resources. For example, one individual may own a vehicle but not be able to drive it for lack of a driver's license; however, she may be willing to allow a licensed community member to use her car to take her to her medical appointments. In return, she may allow the driver to use the car for personal errands. Without an ICT-enabled matching service, two people might have difficulty meeting and negotiating such an exchange. As such, a generalized, favor-based model, similar to concepts proposed in [Carroll, 2016] and [Suhonen, 2010] could improve the ability to identify community resources and people willing to assist others. Moreover, it is possible that the model, which facilitates volunteerism, might reduce the stigma associated with being a recipient of "too much" help from others by distributing the help across a larger number of pairs of people.

In terms of sustainability, and in line with Policy Principle 1, a generalized, favor-based model could enhance participants' abilities to track, and keep account of, favors and trades in which they have participated. This could potentially be used to identify when it is time to "give back," and provide opportunities for doing so. Sustainability could also be enhanced through reputation-enhancing designs. Members who provide favors to others could be recognized as highly active community members, which could encourage both them and others to provide similar favors. This service could be hosted by a non-profit organization as a community economic development program; if so, Policy Principle 2 should be in force such that barriers to entry are low, and a wide variety of transportation services can be provided.

6.7.3 Expanded Resource Pooling Model. We propose an expanded resource pooling model that adheres to Policy Principle 1 and Design Principle 3. In an upkeep-sharing model, individuals in a community contribute to keeping a vehicle in operating condition. In return, along with the auto's owner, a driver can benefit from use of the vehicle. While only one participant from our empirical studies used this model, another stated that she had been a part-time jitney driver in 2002 and described a similar approach. That is, she negotiated a meal for compensation and gas reimbursement. Vehicle sharing, seen in one CHII participant with a family member, could also be expanded.

While real-time ridesharing applications support individuals' connections to resources for payment, the platform does not allow any forms of payment other than money. It also assumes that a vehicle "belongs" to an organization or individual rather than a group or non-profit and fails to take into account the overhead that goes into auto maintenance.

In contrast, we propose an expanded resource pooling model in which people can contribute skills, work, and/or money to maintaining a safe and reliable means of transportation for a group of people, either as a network or as part of a non-profit. As found in our empirical studies, those who have available cars and require gas or other maintenance of their vehicle could seek others requiring a ride to help them maintain their vehicle. If there are unused bicycles that require maintenance, community members who have the skills to fix them could do so, and use them in return. Existing frameworks of motivational differences in the context of timebanks [126] and peer-to-peer economy systems could be used to support this model [127]. Alternatively, a non-profit organization such as a church or voluntary organization could purchase cars or bikes for use by a group who contribute to their purchase and then collectively "own" them. As a part of ownership, overhead costs could be distributed among the members of the group. This model requires underutilized assets, individuals' time, and some skill depending on which transportation mode is required.

6.7.4 Transportation Clubs. Following Policy Principle 1 and Design Principles 2 and 3, we propose a model in which individuals can form clubs or groups on a temporary or ongoing basis to pursue modes of travel for which safety concerns served as a barrier. Specifically, walking or biking clubs, or group trips on public transportation, could be planned for travel related to our use cases, as a type of extension of a resource pooling model. This would be facilitated by ICT-based matching of individuals. We imagine that matching would be based on those who know one another already, available vehicles (e.g., both have a bicycle or current bus schedules) and trip characteristics, such as a shared destination. Notably, local community health centers could assist with this model if they allow patients to book adjacent appointments if they desire to do so. Support for this model is suggested by public health interventions that have involved the creation of walking groups; notably, this intervention model has been shown to be effective in both underserved and more advantaged communities [128].

6.8 Limitations

Our studies have several limitations that should be kept in mind. First, although transportation issues in Metropolitan Detroit are acute, our investigation was limited to studies conducted in this area, which could limit how well our findings generalize. It is possible that usage, facilitators, and barriers could differ in other regions. Factors that may make Metropolitan Detroit unique include its comparatively large geographic area; this may make spatial mismatches based on distance more acute than in other areas. Furthermore, insurance rates and relatively punitive handling of traffic violations [104] may create more barriers to driving than elsewhere. A particularly under-resourced and fragmented public transit system may also intensify related barriers. In comparison to other cities, Detroit also has low educational attainment compared to other US cities [129], which may make digital literacy skills more of an issue than elsewhere. In addition 60% of Detroit households have no broadband Internet connection and 40% of those have no Internet connection at all, either fixed or mobile [130].

Despite these unique characteristics which may intensify transportation barriers, we believe that many of these issues may be present in other underserved communities. For example, spatial issues such as food deserts [7] and medically-underserved areas are national phenomena in the US. Driving has been identified as out of reach to low-income people on a national scale [1]. Funding for public transportation has been reduced across the US [69, 70]. Furthermore, national studies repeatedly show that a cohort of people remains unconnected to the Internet, many of whom have low incomes [131]. A further limitation is that we derive our proposed models based on our

findings and have not yet designed, implemented, or evaluated said models—we aim to address this limitation in the future.

No CHII participants mentioned the use of real-time ridesharing services, perhaps because the project began before these services became popular. Similarly, some unused services such as bike sharing, shuttles, and driver-as-employee were not available at all in these areas at the time of the studies. Therefore, we are unable to contribute to an empirical understanding of the feasibility of these services in low-income and underserved communities.

7 CONCLUSION AND FUTURE WORK

Drawing from four empirical studies and two case studies, this article showed how low-income people from three underserved communities in Metropolitan Detroit secured transportation in their efforts to obtain health-enhancing resources. In so doing, we identified facilitators and unexpected barriers to existing transportation models, as well as previously-underemphasized methods that worked well for at least some of the participants in some situations. Building on these insights, we developed novel policy and design principles. We used these principles to suggest four transportation models that focus on socio-technical integration with communities' current capabilities, resources, and involved actors. The resulting models include the following: (1) Smart jitneys; (2) a generalized, favor-based model; (3) an expanded resource pooling model; and (4) transportation clubs. Notably, underserved communities could adopt each of these models as approaches to health enhancement for their residents. Critical next steps involve testing the feasibility, acceptability, and impact of these transportation models in underserved communities. Ultimately, if successful, such models could expand access to resources that are critical SDOH.

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