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Understanding Access to Grocery Stores in Food Deserts in Baltimore City

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16. Abstract

As American cities have seen a change in land uses in urban areas, with stores moving to suburban areas increasing the reliance on cars, many urban areas are left with a lack of accessible quality food options. These food insecure areas, commonly known as food deserts, where residents lack both access and sufficient economic resources to purchase healthy food, result in health disparities for residents in these communities. Though the existence of food deserts are well known among researchers, there is a lack of consensus on how food deserts are defined and identified. Through a survey of 573 Baltimore City residents, this study provides an in-depth analysis of individual grocery store choice and travel decisions. The study found that most people grocery shopped 2-4 times in a given month and at 2-3 different grocery stores; the choice of the store depends on the items purchased. In evaluating food desert metrics, two common assumptions are made: (1) trips originate from home and (2) people shop at the nearest store. This study found that the second assumption does not hold as an overwhelming percentage of those surveyed (77%) do not shop at their nearest grocery store.

By using the survey data, the authors of this study identified user-generated data-driven indicators with statistical significance for developing a novel food desert metric using CHAID decision trees. A new healthy food priority area measure was developed for Baltimore that deemed all residential areas where the median income of the census block group is less than $35,000 as food insecure. A prioritization matrix was developed based on the secondary factors of proximity to the nearest grocery store (at the half-mile threshold) and the number of stores within 3 miles. This measure found a significant difference in the frequency of grocery store visits as well as the quality of food for those who live in a food desert as opposed to those who do not. The results of this study showed that people value choice of stores when grocery shopping. Limiting food desert measures to the distance to the nearest supermarket undervalues the importance of choice and variety in food selection. The data-driven yet simplistic methodology presented can be replicated to other municipalities as developing an accurate method of prioritizing areas for investments to reduce food disparities is vital to addressing the prevailing systemic divestiture of resources on communities.

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LIST OF ACRONYMS

ACS	American Community Survey
BG	Block Group
HFAI	Healthy Food Availability Index
LILA	Low Income and Low Access
LSA	Limited Supermarket Access
USDA	United States Department of Agriculture

EXECUTIVE SUMMARY

As American cities have seen a change in land uses in urban areas, with stores moving to suburban areas increasing the reliance on cars, many urban areas are left with a lack of accessible quality food options. These food insecure areas, commonly known as food deserts, where residents lack both access and sufficient economic resources to purchase healthy food, result in health disparities for residents of these communities. Though the existence of food deserts is well known among researchers, there is a lack of consensus on how food deserts are defined and identified. Most food desert metrics contain income, vehicle ownership, and proximity to nearest grocery store thresholds. A recent study by the Johns Hopkins Center for a Livable Future (CLF) and the Baltimore Food Policy Initiative (BFPI) found that one in every four resident in the City lives in a food desert which covers 12% land area of the city. In contrast, by the USDA definition, 50% of the city is deemed as food desert and 42% of the residents reside in a food desert, and according to the Reinvestment Fund's Limited Supermarket Access metric, 33% of the city area is and 36% of the residents live in a food desert.

Through a survey of 573 Baltimore City residents, this study provides an in-depth analysis of individual grocery store choice and travel decisions. The survey was divided into five sections: sociodemographic information, household information, perception of modes and willingness to pay, grocery shopping habits, and trip characteristics for their preferred grocery store. The survey found that carless residents of Baltimore City rely on many forms of transportation to get to the grocery store, including the informal taxi mode known as hacks. Reserachers surveyed 30 hack drivers to better understand the role and customers of this unsanctioned mode. Longstanding customers patronize hack drivers for roundtrip service to the grocery store; other customers flag awaiting hack drivers for the return trip home. Though ride-hailing systems have had a slight impact on the hacking industry, hacks customer service, availability, and affordability make them a preferred option for many carless households in Baltimore.

Most survey respondents (59%) preferred to shop at a supermarket; however, those with lower incomes more readily shopped at discount grocery stores (e.g., Save-A-Lot) and those with incomes over $100,000 preferred specialty grocery stores (e.g., Whole Foods). Location and affordability were the two primary reasons for selecting preferred stores. Most people shopped 2-4 times in a given month and at 2-3 different grocery stores; the choice of the store depends on the items purchased. For example, 37% of people shop at a farmers market for fresh produce, whereas only 25% shop at a superstore (e.g. Walmart) for fresh produce. Approximately three out of every four people surveyed do not shop at the grocery store nearest to their home.

Food desert metrics aim to identify geographic areas with a high concentration of households with limited grocery access. By using the survey data, the authors of this study identified user-generated data-driven indicators with statistical significance for developing a novel food desert metric. Chi-Square Automatic Interaction Detector (CHAID) decision trees determined the factors that best predict the following accessibility factors: frequency of grocery store trips, number of different stores

visited, quality of preferred grocery store, and whether the preferred grocery store is the store nearest to home. Though transportation plays an important role in accessibility, the CHAID decision tree analysis of the accessibility indicators found that vehicle ownership was not a predictor of grocery store accessibility and that income was the primary factor. Highlighting the importance of choice, the number of stores available within 3 miles was a secondary predictor of some of the accessibility metrics. Proximity to the grocery store was important in determining the likelihood of shopping at the nearest grocery store only. The study found that using a network distance of half a mile was the most significant. Additionally, using Euclidean or straight-line distance over estimates access to stores by nearly a factor of 2.

The New Food Prioritization Area is defined as an area zoned residential where the median household income of the census block group is less than $35,000. A prioritization score was defined to address choice and proximity, where 1 = high priority and 4 = low priority. The prioritization index is based on network distance to the grocery store where:

- Priority #1 = 7 or fewer grocery stores within 3 miles and the nearest store is more than 0.5 miles away
- Priority #2 = 8-10 grocery stores within 3 miles and the nearest store is more than 0.5 miles away or 7 OR fewer stores within 3 miles and the nearest store is within 0.5 miles
- Priority #3 = More than 10 grocery stores within 3 miles and the nearest store is more than 0.5 miles away OR 8-10 grocery stores within 3 miles and the nearest store is within 0.5 miles
- Priority #4 = More than 10 grocery stores within 3 miles and the nearest grocery store is within 0.5 miles.

The new food desert metric found a significant difference in the frequency of grocery store visits as well as the quality of food for those who live in a food desert as opposed to those who do not. Those living in priority areas 1-3 were less likely to shop at the nearest grocery store compared to those in priority area #4 and non-food deserts. The quality of food was the only metric that differed significantly from all of the previous food desert metrics for those liing in food deserts.

The results of this study showed that people value choice of stores when grocery shopping. Limiting food desert measures to the distance to the nearest supermarket undervalues the importance of choice and variety in food selection. For residents of Baltimore City, income was the dominant factor in determining grocery store accessibility. The data-driven yet simplistic methodology presented can be replicated to other municipalities since developing an accurate method of prioritizing areas for investments to reduce food disparities is vital to addressing the prevailing systemic divestiture of resources on communities.

1. INTRODUCTION

Food is the cornerstone of health and a basic human need. To maintain a healthy and functioning lifestyle, access to nutritious and sufficient food is necessary (Battersby, 2013). The Food and Agricultural Organization (FAO) of the United Nations describes the concept of "Food Security" as "when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (Food and Agriculture Organization, 1996). However, a growing body of research shows that there are disparities in access to healthy food based on income, ethnicity, and social status, resulting in these people living in food-deficient areas. Generally, the regions with restricted access to healthy foods as well as other nutritious options are commonly known as food deserts (Apparicio et al., 2007).

Limited access to food endangers people's well-being. Equitable and convenient access to healthy food is vital to our shared health. The most common options for healthy food are grocery stores, as they provide access to a wide variety of nutritionally dense and affordable food options. Local food systems within neighborhoods have been a key focus for both researchers and political decision makers (Apparicio et al., 2007; Bader et al., 2010; Caspi et al., 2012; Taylor, 2015; Yeager and Gatrell, 2014; Zhang et al., 2014). Researchers and stakeholders are primarily interested in the quantity and types of food stores and their spatial variability. Access to healthy food locations is associated with location, travel time, and socio-economic attributes for an individual. Studies have analyzed socio-economic factors that may contribute to the social injustice of low food availability in many jurisdictions. The geographic access to healthy foods has been allied with lower morbidity and mortality (Caspi et al., 2012). Physical access to healthy food significantly improves nutrition intake and health in general (Kent and Thompson, 2014; Smoyer-Tomic et al., 2006; Taylor, 2015). Thus, accessibility to food stores is key and, in this nexus, the accessibility to healthy foods is dependent on various factors, i.e., socioeconomic characteristics, time available, the quality of the nearest food vendor, and the mode of transportation available (Preston and Rajé, 2007; Smoyer-Tomic et al., 2006; Widener et al., 2013). Numerous studies have linked access to healthy food stores with public health, neighborhood socioeconomics, and society as a whole (Barnes et al., 2016; Black et al., 2014; Caspi et al., 2012; Ravensbergen et al., 2016; Wang et al., 2016). Studies from the Baltimore City Food Environment Report and Johns Hopkins Bloomberg School of Public Health note that another major issue concerning access to nutritious foods is that the food settings change often. This is due to market competition, consumer choices, and the economy (Buczynski et al., 2015). Cities have seen a change in land uses, with stores moving to suburban areas, increasing the reliance on cars and leaving many urban areas without accessible quality food options. Many grocery store outlets left the low-income, inner-city areas for the wealthier suburbs, creating an underserved gap area or food desert (Winne, 2019). Nevertheless, cities are complex dynamic systems where people move throughout the day and night. The movement of the people depends on their spatial, economic, social, and transportation settings. Thus, when an individual shops can impact their accessibility to healthy food locations (Widener et al., 2013).

The absence of geographic access to grocery stores can adversely impact people's health. Ideally, individuals should have the spatial access, economic means, and satisfactory knowledge to truly have "access to healthy foods" (Widener et al., 2013). Food deserts are fundamentally a geographical paradigm, where spatial data and mapping technologies are applied to classify food accessibility based on (1) access to supermarkets; (2) racial/ethnic disparities; (3) income/socioeconomic status; and (4) cost, availability of food items and store type. The common practice in most food desert studies uses census demographics and considers the urban environment to be static (Horner and Wood, 2014; Salze et al., 2011; Widener et al., 2013, 2011).

Numerous studies have been conducted to identify food deserts in urban and rural areas. While there is agreement on the primary factors – vehicle access, income, and proximity to the grocery store – there is a lack of consensus on how to combine these and other factors into a metric. For example, a commonly used measure of food insecurity in the United States is the definition from the U.S. Department of Agriculture (USDA) which defines a food desert "as not having consistent access to adequate food because of lack of money or limited resources at points during the year" (Economic Research Service, 2015). According to the USDA Low Income and Low Access measures, "a food desert is a low-income census tract in which a significant number – at least 500 people – or share – at least 33 % – of the population is greater than ½ mile (or 1 mile depending on definition) from the nearest supermarket, supercenter, or large grocery store for an urban area" (Economic Research Service, 2015). Conversely, in Baltimore City "an area is considered a food desert if each of the following holds: (1) More than a ¼ mi radius from a grocery store, (2) 30% or more of residents are without a vehicle in the census tract, (3) median income of the census tract is at or below 185% federal poverty level (SNAP definition), and (4) Average Healthy Food Availability Index (HFAI) score by block group <= 9.5" (Buczynski et al., 2015).

Using food access metrics to identify geographic areas where residents lack healthy food options allows jurisdictions to systematically determine where policies and interventions are needed. Several works have established that food accessibility is correlated to income, vehicle access, and distance to grocery stores. The vast majority of food desert definitions include aggregate vehicle ownership rates and a Euclidean distance from a grocery store – usually in the range of ¼ - 1 mile, indicating the distance that people are willing to walk. As food desert work is typically conducted in the public health arena, there is a lack of information as to how people who live in food deserts access grocery stores. Spatial accessibility to grocery stores can be determined with the help of GIS analysis for different travel cost thresholds.

This study examines how these two often neglected dynamics – grocery store location and mode of transportation – affect healthy food accessibility in Baltimore, Maryland. In Baltimore, observation shows a reliance on informal taxis known as hacks for the return trip from the grocery store. These vehicles queue at grocery and retail stores waiting for customers who have too many items to return home by transit or foot. This study will explore the trip patterns, modes used, and choice in grocery store locations for residents of Baltimore. By better understanding how people make travel choices to and from the grocery store, we can better determine the geographic areas in need of intervention.

2. LITERATURE REVIEW

Demarcation of food deserts is complex as the indicators and metrics used to model the food environment vary widely. The results from Rose et al. (2009) and Kowaleski-Jones et al. (2009) illustrate that the location of food deserts varied across the study areas subject to dataset and indicators used. This chapter will discuss in detail the most common food desert methodologies, indicators, and metrics used in food desert research.

Food insecurity is based on several factors. Food deserts are geographic areas with limited physical access to food. However, individual attributes also factor into the demarcation of a food desert, such as income and vehicle availability. A study on diabetes found that when determining glycemic control, based on HbA1c in patients with diabetes, individual factors related to food security were more significant than living in an area with low physical access to food (Berkowitz et al., 2018). At its simplest, the term 'food desert' is a geographic area where inhabitants need or do not have satisfactory access to healthy food locations. In the absence of any standard definition, researchers explore newer novel approaches to address that issue. The ambiguity and inconsistency from these variations in definition or approach often result in contradictory opinions about the scope of the food desert problem and the actual demarcation of it.

Most previous studies have tried to answer who suffers from the absence of healthy foods but were less concerned about why such foods are not available in those areas. Car-centric infrastructure planning expands the city boundaries to suburbs as predominantly affluent and white residents move in that direction and the large grocery stores follow them (Larsen and Gilliland, 2008). The lowest-income neighborhoods had approximately 30% fewer supermarkets than the highest income neighborhoods (Walker et al., 2010) and these stores have less selection with steeper prices than the chain supermarkets (Kaufman et al., 1997). Using a household travel survey in Atlanta, it was found that people traveled an average of 6.3 miles to get to the grocery store; however, lower-income groups travelled farther (Kerr et al., 2012). The prospect of selling healthier foods at corner stores is limited. Fast food locations and convenience stores are more likely to be found in these poorer areas. There is a positive association between the number and density of fast food locations to state-level obesity rates in the United States (Smoyer-Tomic et al., 2006). Often residents prefer fast foods or rely on corner stores for their dietary needs due to the absence of grocery stores or their mobility obstacles (Fraser et al., 2010).

In general, 'food deserts' are defined as areas with limited access to healthy and inexpensive foods with a range of other nutritious choices (Apparicio et al., 2007; Economic Research Service, 2015). For urban areas, food deserts are largely located in inner-city areas with higher poverty rates (Dutko et al., 2012) and predominantly African American or Hispanic neighborhoods (Smoyer-Tomic et al., 2006). Healthy foods in minority and poor neighborhoods are typically less accessible (Buczynski et al., 2015). Areas with higher poverty rates, minorities, and less educated residents are the more likely candidates for food deserts. Decreasing population and business moving to suburbs has resulted in one in four residents in Baltimore living in food deserts (Behrens et al., 2015). The highest poverty

proportion in Maryland belongs to Baltimore City (McLeod et al., 2017). Furthermore, the incidence of diet-related diseases such as obesity, diabetes, and high blood pressure is high in Baltimore City. Neighborhood disparities across Baltimore City significantly affect the health status of Baltimore's residents (Baltimore City Health Department, 2014). One way to reduce food insecurity and provide healthy foods for residents is to improve their access to healthy food locations. Generally, the chain supermarkets and large food stores are more likely to stock fresh produce and healthy foods at a reasonable price (Powell et al., 2007). Thus, most studies evaluate accessibility, comparing access to large and chain grocery stores that provide healthy food choices (Duran et al., 2013; Gould et al., 2012; Smoyer-Tomic et al., 2006).

Socioeconomic Indicators of Food Insecurity

Limited access to healthy food is considered an environmental justice issue. The correlation between minimal food access and residents' socioeconomic status has been extensively examined. Poverty is a significant barrier to acquiring healthy food, and in low-income neighborhoods there are also fewer stores with healthy food options (Hendrickson et al., 2006). Corner stores that have higher food prices with poorer quality are abundant in higher poverty areas. Financial limitation restrains the ability of residents in disadvantaged neighborhoods to afford cars or shared ride services to travel to healthy food stores of their choice. In food desert access studies, socioeconomic and demographic variables – i.e., income, vehicle ownership, education level, employment, ethnicity, and age – are vital factors. Blanchard (2007) suggested that the socio-demographic characteristics of food deserts are imperative for developing any specific policy that alleviates the problems of the disadvantaged populations affected by living in the food deserts.

Accessibility Indicators

Accessibility to food is a measure of the ease of finding healthy food options in a given geographic area. In food desert studies, the physical constraints hinder the accessibility to food stores. In this regard, the inherent characteristic of 'food deserts' is spatial, and the physical absence of grocery stores within administrative units (i.e., census tract, neighborhood, community) is accentuated in urban planning. For example, many local governments in the USA, Canada, and Australia have adopted and developed analytical tools to identify the food deserts with limited geographic access to healthy food within a given administrative unit (Couzin-Frankel, 2012; Wehunt, 2009). These analytical tools mostly apply geographic information systems (GIS) to evaluate the accessibility of the grocery stores. The key focus of spatial food desert studies is distance-based measurements. But the question of acceptable walking or driving distance to get to a food outlet has yet to be standardized. Researchers have articulated and applied many different time-based distance measurements for walking, driving, and public transportation methods. For walking the threshold is 15 minutes or a quarter mile and for driving it is 10 miles (Ver Ploeg et al., 2009). Identifying realistic thresholds for walking or driving distances is imperative because more food desert metrics define a time- or distance-based buffer around food stores. The density or number of food stores within a buffer may also be used to estimate a household's accessibility to food stores (Thornton et al., 2010). A more accurate illustration of people's movement is network distance, which measures the distance between origin and destination along streets using the shortest path (Levinson et al., 2004).

Access to healthy food locations, distance, and travel cost is studied by many researchers to comprehend the level of access for people across various regions (Bertrand et al., 2008; Lee and Lim, 2009; Widener et al., 2013). Studies often measure accessibility from home but do not consider the spatial variability in commuting behaviors (Salze et al., 2011). Travel behavior, mode of choice, and available time can affect individuals' access to healthy food locations. Individual-level accessibility can provide valuable insight regarding spatially disaggregate data to delineate individual food environments. But mapping areas with limited access to food opportunities and aggregating them to the community level remains a challenge. For food desert research, accessibility can be defined as the proximity between residents' address and healthy food locations (Apparicio et al., 2007; Widener et al., 2013). Early studies conceptualized accessibility as the number of food opportunities in a given administrative unit, or within a given distance of a place, or the minimum distance to the nearest food locations (Preston and Rajé, 2007; Ravensbergen et al., 2016). These studies did not consider the transportation network but only focused on the Euclidean or straight-line distance between the resident and the food opportunities. Generally, the disadvantaged population may reside in food deserts but may not choose to shop locally, instead travelling relatively longer distances to reach their desired food store (Walker et al., 2010).

Spatial distribution of accessibility can be categorized into place-based and people-based categories (Dijst et al., 2002; Handy and Niemeier, 1997). For the place-based metrics, accessibility levels considered at the census geographical unit use gravity models (Páez et al., 2012). But this metric simplifies accessibility at the same level for all the people within a geographic unit, which is not true when personal mode choice and time window are considered. Personal constraints and individual accessibility are considered in people-based metrics. It has proven difficult to aggregate or generalize an individual's accessibility and how these can be combined. Studies like the analysis of space-time travel paths of individuals in Portland or the use of potential path area estimations to delineate people's possible shopping destination choice in Louisville, Kentucky, (Páez et al., 2012) have tried to address the issue. From a food accessibility standpoint, both people- and place-based metrics offer valuable insights. There have been few studies fusing people- and place-based accessibility approaches (Páez et al., 2012). Widener et al. (2013) examined accessibility in relation to people's fixed journey-to-work commutes, and with constraints for the time to travel to shopping after work. This method aggregates individuals' travel origins and destinations at traffic analysis zones, and everyone is expected to have an equal travel budget. However, a novel approach is needed that considers place-based variability of food accessibility and is derived from the travel constraints of individuals.

Availability of public transit and automobile ownership play a vital role in food desert demarcation. Not everyone can afford a personal vehicle; public transportation provides alternative transportation for people to go to supermarkets and grocery stores. Areas with the fewest supermarkets are also areas with the lowest vehicle ownership; however, most vulnerable populations lived within a 10-minute drive or 30-minute bus ride of an affordable grocery store (Jiao et al., 2012). Vehicle ownership makes spatial accessibility more comparable than any other socioeconomic indicators and since many people with low incomes cannot afford to own a vehicle, the availability of public transit may be crucial in accessing food resources. For the town of London, Ontario, Canada, 35.1% of the urban residents

lived within 1 kilometer of a supermarket, while 86.5% had accessibility by bus (Larsen and Gilliland, 2008). Even though public transit may offer an equitable and affordable option, its efficiency and effectiveness remain a concern. Public transit is an inexpensive mode of transportation and subject to spatial restrictions such as the number of bus stops and transfers available. If people are required to walk for quite a distance from the bus stop to their house, the problem of carrying the goods arises. In one low-income neighborhood in South Central Los Angeles, one-third of the residents surveyed reported difficulties carrying their groceries home, roughly the same number of persons without access to a vehicle (Widener et al., 2013). The difficulty in carrying groceries also leads to limiting the amount of groceries purchased (Widener et al., 2011). Fewer items purchased increases the frequency of store visits (Apparicio et al., 2007; Bader et al., 2010). These problems augment the amount of time dedicated to provisioning activities and travel. Accessibility by public transit depends on whether the route operates in peak time or off peak (Widener et al., 2013). Generally, in big cities most grocery stores are usually served by multiple routes, and thus the frequency is also fairly high. But in the suburbs, the transit service is typically limited; hence the low frequency. Even if the transit system is efficient and cost is significantly lower than personal vehicles, ride shares or taxis, it can still be expensive for low-income residents as they have to shop more frequently (Walker et al., 2010).

Food Desert Measures and Limitations

Food desert literature summarizes four key indicators: (1) access to supermarkets; (2) racial/ethnic disparities; (3) socio-economic status; and (4) availability of food items and store type (Walker et al., 2010); see Table 1. Travel cost and time considerations are imperative for residents (Blanchard and Matthews, 2007) and access to healthy foods also correlates to race and poverty (Galvez et al., 2009). Proximity to a supermarket is the main criterion for access to healthy food (Coveney et al., 2006) as it is nearly 30% less in disadvantaged neighborhoods than in affluent ones (Weinberg, 1995). Since residents of the low-income area struggle financially, the primary obstacle to reaching healthy food is to afford the transportation cost (Rose et al., 2009). Accessibility of healthy food facilities affects people's food selection (Wrigley et al., 2003), and, generally, unhealthy foods are more easily reached than healthy foods are (Donkin et al., 1999). Low-income and older adults without automobiles most need nearby supermarkets to avoid long transit commutes, expensive cab fares, or dependence on family, friends, or social services for transportation (Smoyer-Tomic et al., 2006), and about 40% of residents who do not have an automobile do not have access to healthy food (Bertrand et al., 2008).

Table 1. Select Food Desert Measures

Metric / Study	Distance to Store	Low Income	Vehicle Access	Other Measures
Bertrand et al. (2008) *Montreal, Canada*	Euclidean distance of 500 m (0.3 mi) for carless or 3 km (1.87 mi) for those who own vehicle from centroid of dissemination area (DA)		Motorization rate was considered when determining average availability of fresh fruits and vegetables for a DA	Total square foot of fresh fruits and vegetables within a certain distance of DA
Clarke et al. (2002) *Leeds/Bradford and Cardiff, England*	Buffer of 500 m (0.3 mi) around food outlets; Proximity to and density of stores by type		No car availability	Carstairs index of deprivation
Economic Research Service (2015) USDA LILA *United States*	Tracts where at least 500 people or 33% of population is greater than 0.5 miles (or 1 mile) Euclidean	Tracts with a poverty rate ≥ 20%; or median family income ≤ 80% of the state or metropolitan area's median family income		
Economic Research Service (2015) USDA Veh Access *United States*	Tracts where at least 100 households are greater than 0.5 mi Euclidean	Tracts with a poverty rate ≥ 20%; or median family income ≤ 80% of the state or metropolitan area's median family income	Those same 100 households do not have access to a vehicle	
Larsen and Gillilan (2008) *London, Ontario, Canada*	Percent of population within 1000 m (0.6 miles) network distance of store			Percent of population a bus ride 10 min or less without transfers, combined with 500-meter or less walk to and/or from bus journey
Misiaszek et al (2018) *Baltimore, MD*	Greater than 0.25 miles Euclidean	Tracts with median household income less than or equal to 185% of the Federal Poverty Level	Tracts where greater than 30% of households have no vehicle available	Block Groups where Healthy Food Availability Index (HFAI) for all food stores is low (0 – 9.5)
Reinvestment Fund (2018) Limited Supermarket Access (LSA) *United States*	Reference Distance (Euclidean) to store ranges from 0.3 to 12.9 mi dependent on block group class	Block group median household incomes at or above 120% of area median income (AMI) considered when determining reference distance for each class.	Only considered percent without vehicles for high population density block groups classes	Population density is used to determine the reference distance for each class

Most studies consider driving and walking as the primary transportation modes to access healthy food (Algert et al., 2006), while others also explore public transit (Larsen and Gilliland, 2008) (Larsen and Gilliland, 2008; Pearson et al., 2005). Public transit accessibility relates to the frequency of service (Al Mamun et al., 2011; Ryus et al., 2000), station access (Moniruzzaman and Páez, 2012), and travel times (Lei and Church, 2010; O'Sullivan et al., 2000). Widener et al. (2017) studied the influence of time of day on food accessibility in Toronto, Ontario, and concluded that in the late night and early morning access to grocery stores decreased; also travel times via public transit in the early morning are higher than the other times of day (Widener et al., 2017). Widener et al. (2015) analyzed commute data from Cincinnati, Ohio, and concluded that most of the residents improved their access to the supermarket by grocery shopping on the way home from work.

The geographic area denoted by various food desert measures varies widely, leading many jurisdictions to adopt their own methodology of demarcating food insecure areas. In Baltimore City, almost one-third (29.4%) of city residents do not have access to a car, which also aligns with 23.0% of population living below 100% poverty level (ACS, 2018). The Baltimore City Department of Planning in conjunction with Johns Hopkins University developed a food desert metric known as healthy food priority areas that accounts for the quality of food as measured through the Healthy Food Availability Index (HFAI), income, vehicle ownership and land use (Misiaszek et al., 2018); see Figure 1. Using the Baltimore City definition, 12% of Baltimore is and 24% of its residents live in food insecure areas.

Nationally, the United States Department of Agriculture (USDA) has four food desert metrics; see Figure 2. However, since Baltimore City is entirely urban these metrics collapse to three applicable definitions: tracts which are (1) low-income census tracts where a significant number (at least 500 people) or share (at least 33 percent) of the population is greater than ½ mile from the nearest supermarket, supercenter, or large grocery store; (2) low-income census tracts where a significant number (at least 500 people) or share (at least 33 percent) of the population is greater than 1.0 mile from the nearest supermarket, supercenter, or large grocery store; and (3) low-income tracts in which a significant number of households are located far from a supermarket and do not have access to a vehicle. A tract is considered low access if at least 100 households are more than ½ mile from the nearest supermarket and have no access to a vehicle (Economic Research Service, 2015). According to the USDA vehicle access definition, 50% of Baltimore City is and 42% of residents live in a food desert.

2018 BALTIMORE CITY

Misiaszek et al. (2018)

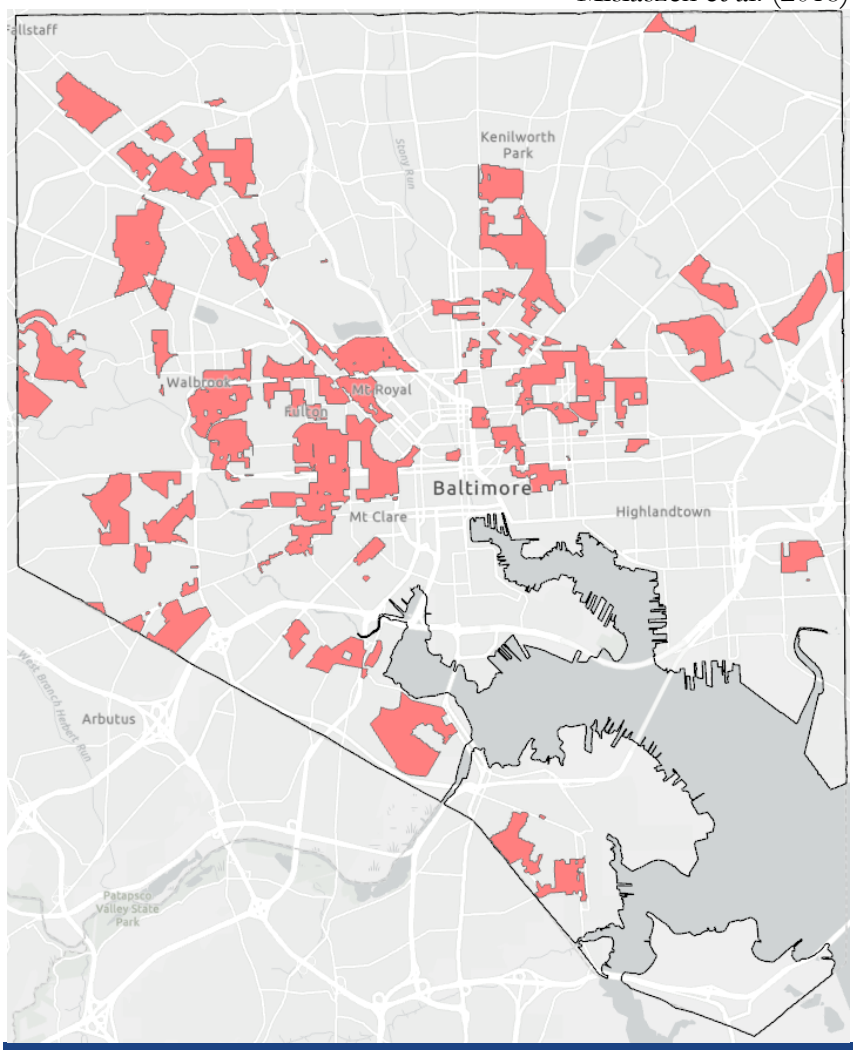


Figure 1. 2018 Baltimore City Healthy Food Priority Areas

12% OF CITY DEEMED A FOOD DESERT
24% OF RESIDENTS LIVE IN A FOOD DESERT

Geographic Units:
Tracts & Block Groups

Definition

Block Groups with average Healthy Food Availability Index (HFAI) less than 9.5[1]

Median household income of census tract is at or below 185% of the Federal Poverty Level for family of 4 ($44,862[2])

Census tracts where over 30 percent of households have no vehicle available[3]

The distance to a supermarket is more than a quarter of a mile.

Residential land use

Drawbacks
Uses Euclidean distance around each grocery store which does not consider geographic boundaries such as highways and waterways

Strengths
Considers quality of store, residential land use

[1] HFAI Scores range from 0 to 28.5 in Baltimore City
[2] 2011-15 American Community Survey (ACS)
[3] Citywide, approximately 30% of Baltimore City households do not have a vehicle available at home

2015 USDA

Economic Research Service (2015)

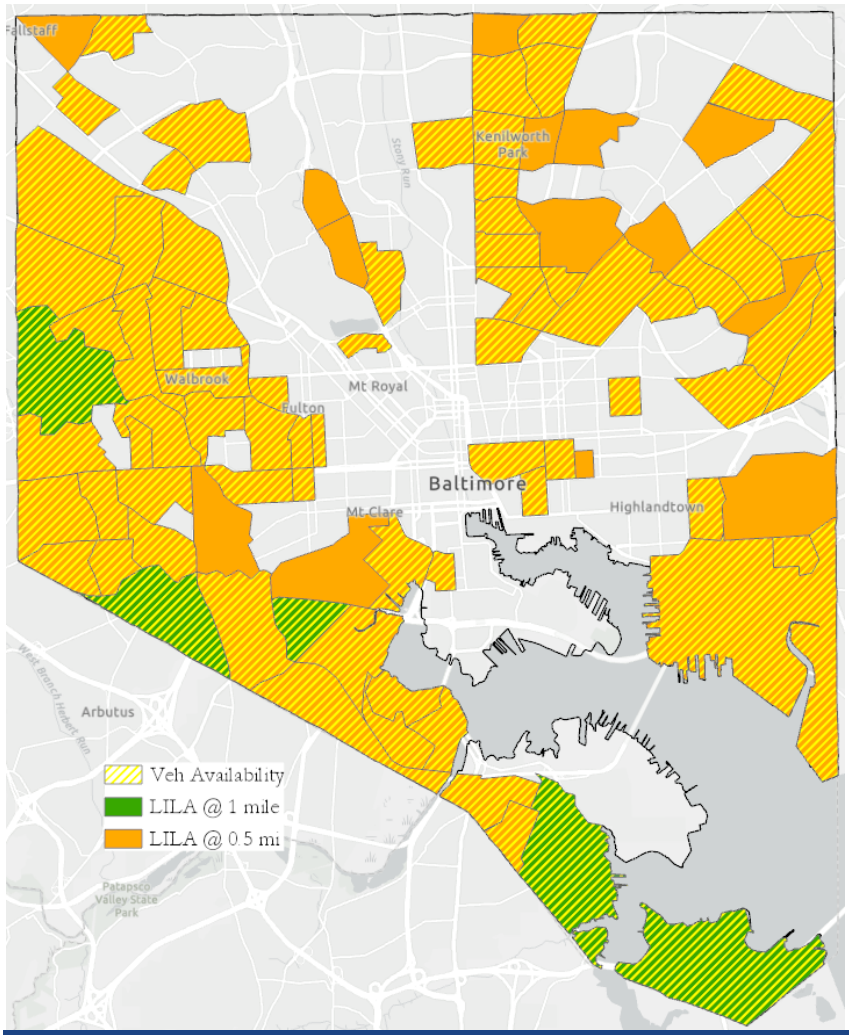


Figure 2. 2015 U.S. Department of Agriculture Food Desert Areas

Note: USDA has three food desert area definitions pertinent to Baltimore City: (1) low income and low access at 0.5 miles, (2) low income and low access at 1 mile and (3) low income and low vehicle availability

50% OF CITY DEEMED A FOOD DESERT
42% OF RESIDENTS LIVE IN A FOOD DESERT BASED ON VEHICLE ACCESS

Geographic Unit: Tracts

Definitions

Low Income[4]

- Poverty rate greater than 20% OR
- Median income ≤ 80% statewide ($55,146) or metropolitan median income ($56,749)

Low Access @ 0.5 or 1 Mile
A low-income tract with at least 500 people, or 33% of the population, living more than 0.5 or 1 mile (urban areas) from the nearest supermarket, supercenter, or large grocery store.

Vehicle Availability
At least 100 households are located more than ½ mile from the nearest supermarket and have no vehicle access

Drawbacks
Unpopulated areas are included in metric.

One-mile distance is too long if walk is considered the primary alternative mode.

Strengths
Nationwide definition

[4] Source: 2010-14 ACS. The Baltimore Metropolitan Statistical Area includes Baltimore City, Towson, and Columbia. The Federal Poverty rate for 2015 was $24,250.

2018 LIMITED SUPERMARKET ACCESS (LSA)

Reinvestment Fund (2018)

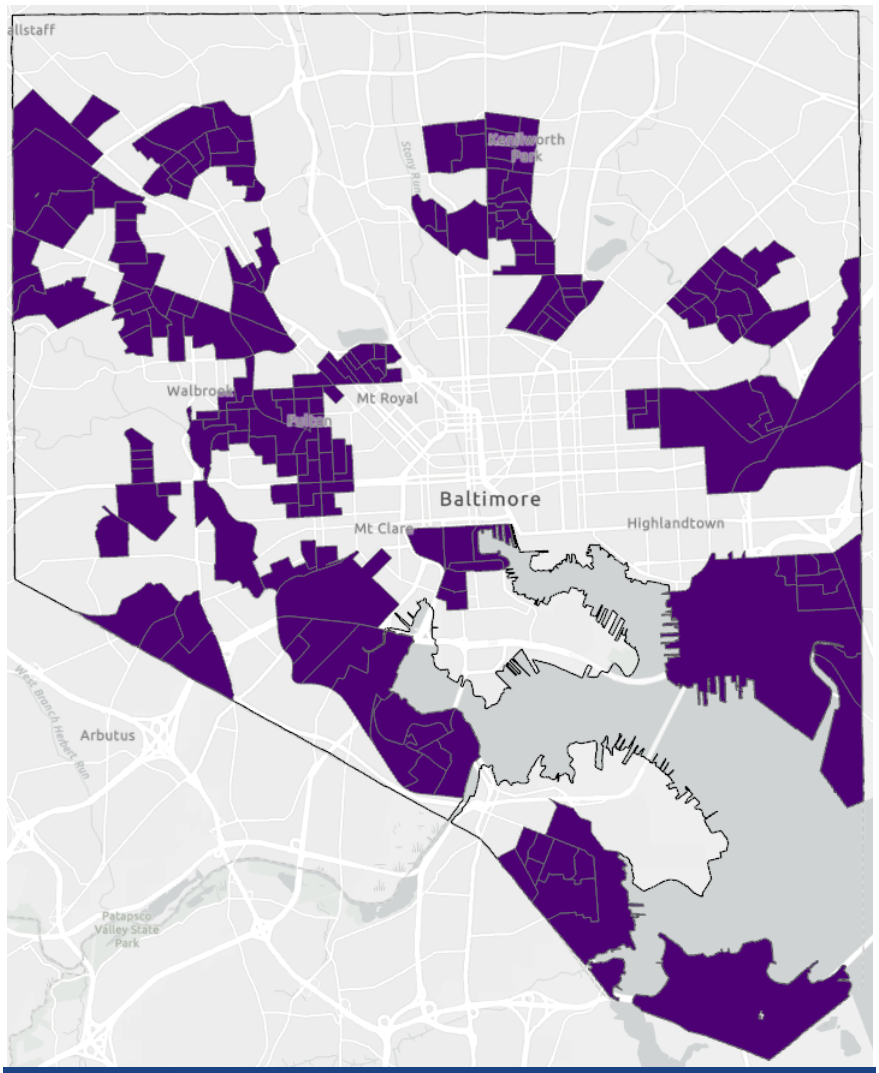


Figure 3. 2018 Reinvestment Fund Limited Supermarket Access Area

33% OF CITY DEEMED A FOOD DESERT
36% OF RESIDENTS LIVE IN A FOOD DESERT

Geographic Units
Block groups

Definition
Block Group Density/Car Ownership Classes
Block groups (BGs) are categorized into 7 classes based on population density and for high-density areas, vehicle availability

Reference Distance
The average distance to grocery store in BGs with median household incomes at or above 120% of area median income (AMI) ($58,608) (2016 ACS)

LSA Score
LSA calculated as percentage reduction by which that block group's distance to the nearest supermarket to equal reference distance

LSA Area
Contiguous BGs with LSA Score ≤ 0.45 with a collective population of at least 5,000 people

Drawbacks
Distance is calculated to nearest store

Strengths
Metric is dependent on population density
Nationwide definition

Another national definition is the Limited Supermarket Access (LSA) metric developed by the Reinvestment Fund (2018); see Figure 3. LSA was first developed to identify areas to attract supermarkets to distressed communities. This metric assigns every census block group in the contiguous 48 states and the District of Columbia to one of seven classes based on that block group's population density and, for densely populated block groups, car ownership. Within each class, the Reinvestment Fund calculates the typical distance traveled to the nearest supermarket by residents of well-served block groups, i.e., block groups with median household incomes at or above 120% of area median income (AMI). Each block group is then assigned a Low Access Score, which represents the percentage by which that block group's distance to the nearest supermarket would need to be reduced to equal the typical distance for well-served block groups in that class. Block groups with Low Access Scores greater than or equal to 0.45 are considered limited-access. In those limited-access block groups, residents must travel almost twice as far to a supermarket as residents in well-served block groups with similar population density and car ownership. Finally, contiguous limited-access block groups with a collective population of at least 5,000 people are combined to form LSA Areas – areas with both limited access to supermarkets and potentially enough market demand to support new or expanded supermarket operations. According to LSA, 33% of Baltimore is and 36% of residents live in a food insecure area.

Comparing Figures 1, 2, and 3, it is clear that there is a lack of agreement on how to geographically segment areas that have food insecurity. Though there is agreement on many of the common factors of food insecurity such as vehicle ownership, income, and physical location of stores, there is disagreement on how to combine these factors into a metric to denote areas of food insecurity. Most food desert metrics only consider car and walking as viable mode choices to the grocery store. For example, one metric considered bus access (Larsen and Gilliland, 2008) whereas the majority only consider reasonable walking distance thresholds ranging from 0.25 miles to 0.6 miles; see Table 1.

A better understanding of transportation and access is needed to determine where to focus food insecurity policies. By surveying approximately 500 residents of Baltimore City on their grocery shopping habits, this study investigates individual travel behavior to grocery stores to determine the measures and thresholds that best predict grocery store accessibility.

3. METHODOLOGY

The literature shows a wide array of food desert definitions; however, all determined transportation to be a critical determinant of food accessibility. By surveying approximately 500 Baltimore City residents, this study investigates the grocery travel patterns of city residents. The following chapter outlines the methodology. As shown in Figure 4, the activities of this study are divided into three parts: data collection, analysis, and development of a new food desert metric.

Figure 4. Methodology

Data Collection

Study Area and Stores

The study area, the City of Baltimore, Maryland, occupies a land area of 81 sq. mi. According to the 2018 U.S. Census, Baltimore City is a completely urban area with 602,495 inhabitants, including White (30.30%) and African American (62.80%) residents, with a median family income of $46,641 per year. The per capita income is $28,488 per year while 22.40% live under the poverty rate. Grocery stores inside and within 1.5 miles of Baltimore City were considered. Grocery store location data was obtained from the Baltimore Development Corporation and verified using the Maryland Food Environment Map and via internet searches. In this study, grocery stores are categorized into four groups: discounted grocery, superstores, supermarkets, and specialty stores. Discounted grocery stores (e.g., Save-A-Lot) provide affordable grocery items; superstores (e.g., Walmart Supercenter) provide a variety of home items as well as groceries; specialty stores (e.g., Mom's Organic Market) provide high-end and organic groceries; and supermarkets (e.g., Safeway) include all other stores.

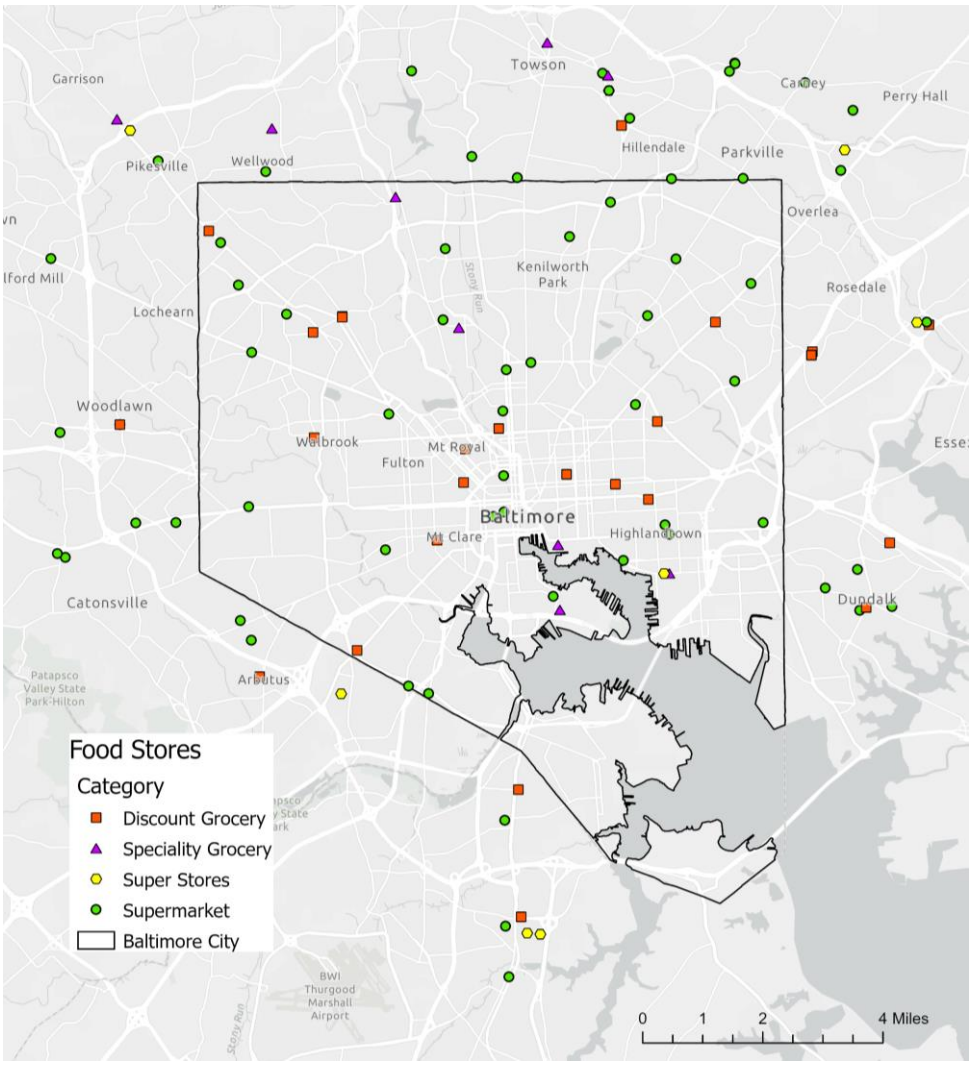


Figure 5. Study Area and Local Grocery Stores

Survey of Baltimore City Residents

The authors disseminated two surveys for this study: (1) a survey to residents on their grocery shopping behavior and (2) a supplementary survey of informal taxi drivers known as hacks.

In partnership with the Baltimore City Department of Planning the authors developed a survey that asked questions in the following five categories: Demographic Information, Household Information, Perception of Transit and Willingness to Pay, Grocery Shopping Habits, and Travel to Preferred Grocery Store. Surveys were disseminated online and in person. Online respondents were recruited via email list serves and social media. Each in-person participant received $20 in either cash or grocery gift card and online survey participants entered a raffle for one of two $100 gift cards.

Figure 6. Recruitment Flyer

Researchers collected in-person surveys at eight grocery stores on different days of the week, interviewing a total of 273 people. The participants were met in person at the different store locations and their consent was requested in order to participate in the survey. Researchers approached each participant randomly as they neared the store entrance or were shopping and collected their responses using the survey form, which was filled and checked for accuracy and completion. Due to the schedule constraints of the researchers, most data collection occurred during the afternoon. Online surveys were promoted by Morgan State University and the Baltimore Department of Planning. The survey link was promoted on social media groups, libraries and neighborhood organizations.

Table 2. Location of In-Person Surveys

Name	Address	Day of Week	Time
Food Depot	2401 Belair Rd	Saturday	Morning
Food Depot	2495 Frederick Rd	Tuesday	Midday
Shoppers	2000 Gwynns Falls Pkwy	Monday	Midday
Safeway	2401 N. Charles St	Monday	Midday
Save-a-lot	1101 Pennsylvania Ave	Monday	Afternoon
Save-a-lot	929 N. Caroline St	Thursday	Midday
Bi-Rite	5950 Belair Rd	Monday	Afternoon
Lexington Market	400 W. Lexington St	Tuesday	Midday

A total of 573 surveys were completed (301 online and 273 in-person). First, all respondents who did not live in Baltimore or who did not provide a home zip code were removed from the sample. Responses were reviewed for accuracy and completion. Home and store locations were manually geocoded. Home locations, given as the nearest major intersection, were verified using the provided zip codes. Some responses were unable to be determined due to inaccuracies in responses such as missing responses or providing only one street without a cross street. In total, we had 515 usable survey responses of which 494 had both a home and preferred grocery store geocoded. A summary of the socioeconomic characteristics of the respondents and city residents is provided below in Table 3. Figure 7 shows the responses by zip code. There were low response rates in the southern part of the city.

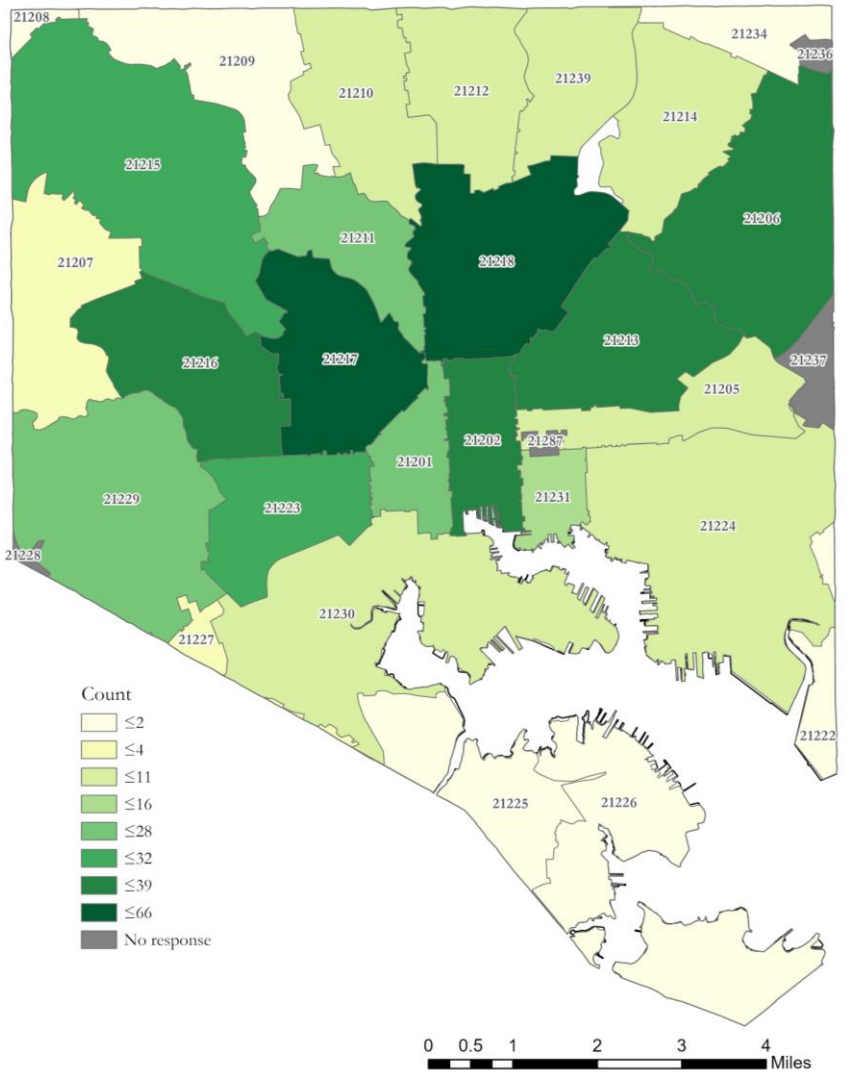


Figure 7. Responses by Zip Code

Table 3. Survey Respondents Social Demographic Profile				
Variable	**# of Valid Responses**	**Options**	**Percent of Sample**	**Percent in City[5]**
Gender	510	Female	69.8%	51.5%[6]
		Male	30.2%	48.5%
Age	515	18 to 24[7]	6.6%	8.8%
		25 to 34	28.7%	24.9%
		35 to 44	19.8%	16.4%
		45 to 54	16.7%	15.1%
		55 to 64	16.7%	16.6%
		65 or older	11.5%	18.2%
Race & Ethnicity	503	Asian	1.0%	2.6%
		Black	64.6%	61.7%
		White	28.4%	30.4%
		Two or more races	2.6%	2.8%
		Hispanic or Latino of any race	3.4%	5.5%
Marital Status	513	Married or in a domestic partnership	29.6%	28.2%
		Divorced or separated	13.6%	13.9%
		Single (never married)	53.6%	51.9%
		Widowed	3.1%	6.0%
Highest Level of Education	514	Less than high school diploma	5.1%	14.1%
		High school diploma or GED	42.4%	29.3%
		Associate degree	10.3%	23.4%
		Bachelor's degree	19.8%	16.6%
		Post-Secondary degree	22.4%	16.6%
Employment	514	Full time	50.0%	62.5%
		Part time	14.4%	
		Homemaker	2.5%	Not in labor force 30.7%
		Retired	11.5%	
		Student	3.7%	
		Unemployed	17.9%	6.8%
Household Size	496	1	20.0%	40.0%
		2	30.4%	30.1%
		3	17.9%	13.7%
		4	13.3%	4+ 16.1%
		5	9.3%	
		6+	9.9%	
Income	509	Less than $20,000	28.5%	27.1%
		$20,000 to $34,999	18.9%	8.8%
		$35,000 to $49,999	17.9%	13.1%
		$50,000 to $74,999	16.3%	16.4%
		$75,000 or $99,999	7.3%	11.1%
		$100,000 and higher	11.2%	23.5%

[5] Source: 2018 ACS 1-Year Estimates
[6] Over 18 population
[7] The Baltimore City estimate is for 20 to 24 year olds due to ACS categories

Survey of Hack Drivers

A hack is a commercial, unlicensed means of transportation in which the passengers stand by the roadside and flag down the hack drivers. Hacks are also widely patronized in malls and store locations where the driver parks in the parking lot while beckoning for potential riders with the popular phrase 'Need a ride.' This underground economy provides an essential service to grocery access in Baltimore. The first set of hack interviews occurred Wednesday, April 18, 2018, at Shoppers in Mondawmin Mall located at 2000 Gwynn Falls Pkwy and Sunday, April 22, 2018, at the Giant on 601 E. 33rd St. A total of 13 drivers were interviewed. The interviewee asked drivers demographic questions, when and where they service grocery stores, pricing structure, and questions about their customers.

The second round of hack interviews was carried out in November 2018 at the Shoppers at Mondawmin Mall, Giant on 33rd, and Food Depot in the Westside Shopping Center (2495 Frederick Ave.). These interviews focused more on the relationship between hacks and licensed ride-hailing services such as Uber and Lyft. The researchers interviewed a total of 17 drivers in this round, bringing the total number of drivers interviewed to 30. These drivers ranged in age from 27 to 86 years old. The majority were male.

Table 4. Hack Driver Demographic Profile

Variable	Category	Survey 1		Survey 2	
		Count	Percent	Count	Percent
Age	18-25	0	0%	0	0%
	26-35	2	15%	4	24%
	36-45	3	23%	7	41%
	46-55	5	38%	3	18%
	56-65	1	8%	1	6%
	Over 65	2	15%	1	6%
	No Data	0	0%	1	6%
Gender	Male	11	85%	16	94%
	Female	2	15%	1	6%

Other Data Sources

The sociodemographic and geographic data come from the American Community Survey (ACS) (U.S. Census Bureau, 2018) and Open Baltimore portal. The grocery store location data was acquired from the Baltimore City Health Department, Open Baltimore portal, and the Johns Hopkins Center for a Livable Future (City of Baltimore, 2020). The study considers 108 grocery stores and categorizes them into four categories. The transportation data include a detailed street network data from OpenStreetMaps that consists of all levels of the streets with essential information such as speed limits and directions. The transit schedule information is through General Transit Feed Standard (GTFS) data (Google, 2013), from the Maryland Transit Administration (MTA). The GTFS data are a standardized way for describing public transit routes, stops, and schedule information. Generally, it comprises of a series of text files on transit stop locations, scheduled arrivals and departures, and routes. The network buffers and travel times are computed using ESRI's ArcGIS Network Analyst

(Version 10.6) Extension. The Network Analyst is useful to calculate more accurate measurement as it considers impedance, barriers, and street routes for a more realistic travel time measurement.

Data Analysis

Grocery Shopping Behavior

First, a descriptive analysis was conducted on the survey data to analyze grocery shopping behavior. The study evaluates grocery store choice as a function of income and vehicle ownership. Grocery stores are categorized into broad categories such as discount grocery store, specialty grocery stores, supermarkets, superstores and convenience stores. The researchers asked respondents about grocery shopping frequency and choice of grocery store depending on the item type purchased.

Transportation and Access

Of particular interest in this study is how vehicle access affects access to healthy food. Using the results of the survey, the researchers determined the modes of transportation readily used for grocery shopping. Based on the geographic location of respondents, distance to the nearest grocery stores was determined. The team assessed the difference in grocery shopping behavior based on vehicle ownership and proximity to the grocery store. A detailed analysis of the informal taxis system known as hacks was undertaken based on the interviews of hack drivers to determine key characteristics and shopping behavior of hack customers and how ride-hailing impacts the hack industry. Lastly, the researchers summarized the use of alternatve food delivery services such as food takeout services (e.g., Grub Hub), meal prep services (e.g., Blue Apron), grocery delivery services (e.g., AmazonFresh), and grocery store pickup services.

Network Analysis in ArcGIS

ArcGIS Network Analyst extension (*ArcGIS Desktop*, 2018) was applied to create network buffers (service area) of 0.25 mile, 0.5 mile, 1 mile, and 3 miles from each grocery stores. The spatial impedance (network distance) is used to calculate the shortest vehicular travel time through the road network by following the speed limits. The transit travel times depended on route schedules and available transfers. Calculating the travel cost in time from one location to another is more complex than the drive time analysis. To calculate travel costs on the transit network, the GTFS dataset (Maryland Transit Administration, n.d.) is connected to the network dataset with BetterBusBuffer, a custom tool that can use transit networks with the standard suite of ArcGIS Network Analyst Tools. By linking information within these files and connecting them to a GIS, it is possible to compute shortest path routes across the transit network, subject to the unique transit system's schedule. The tools are used to estimate travel times between the survey respondent's home location (Origin) and the grocery store locations (Destinations). The custom script accounts for ingress and egress walking, waiting, and transfer times. It is assumed that the trip takes place Monday at 10 am and a person walks at a speed of three miles per hour to the nearest transit stop and does the same to reach the nearest healthy food option. It takes 30 seconds to get on and another 30 seconds to get off the bus. Origin–destination travel cost matrices are constructed for both automobile and transit service for supermarkets, specialty stores, and discounted grocery stores. The minimum time cost – including walk, transit vehicle, and transfer times – is captured for all the origins to the destinations.

Development of New Food Desert Metric

Validity of Food Desert Measures

As shown in the literature review and presented in Figure 1 through Figure 3, the area determined as food insecure varies widely. It was determined if each respondent who provided a home location lived in one of the five food desert definitions: Baltimore City Healthy Food Priority Areas, USDA Low Income and Low Access at 1 mile, USDA Low Income and Low Access at Half a Mile, USDA Vehicle Access, and Limited Supermarket Access (LSA). Since respondents reported the location of the nearest major intersection, a tolerance of 100 ft was used.

Researchers conducted normality tests for each of the five dependent accessibility variables and found none of them were distributed normally. Two statistical tests were conducted to determine if there are significant differences between respondents who live in a food desert area versus those who do not. The Mann-Whitney U Test tests the difference in mean across two non-normal independent groups. The null hypothesis is that the distribution is the same across the two groups – live in a food desert and does not live in food desert (Mehta and Patel, 2013). Researchers used this test to compare the number of grocery stores visited in a given month (Frequency), quality of food in the preferred grocery store (Quality), and number of different grocery locations visited in a month (No. of Stores) for those who live and do not live in a food desert. Also, researchers used a two-tailed Pearson's Chi-Squared Test to determine whether residents of a food desert are more or less likely to shop at the nearest grocery store. The Pearson's Chi-Square Test of Independence is a non-parametric test used to determine whether there is an association between categorical variables (Mehta and Patel, 2013).

Development of New Food Desert Metric

The study evaluates common accessibility measurements using GIS in a replicable methodology to measure food access in Baltimore. To begin, a CHAID decision tree is used to determine the factors that best predict the accessibility factors described above. The Chi-Square Automatic Interaction Detector (CHAID) decision tree builds a predictive model to determine which factors (independent variables) best predict the outcome of a given dependent variable. "At each step, CHAID chooses the independent (predictor) variable that has the strongest interaction with the dependent variable. Categories of each predictor are merged if they are not significantly different with respect to the dependent variable" (IBM, n.d.).

The most prevalent factors from the CHAID decision tree were used to determine the metrics for the new food desert measure. Though the survey had many data available such as mode choice and preferred grocery store location, only data readily available in the American Community Survey was evaluated. The scale of analysis for this study was at the block group level as it is most similar in size to natural neighborhood boundaries, ranging from 600 to 3,000 people or 240 to 1,200 housing units. Although most food desert studies reviewed for this study used units at the census tract level, using the smaller block group increases the precision with which food insecure areas are estimated. Using data aggregated to the block group level increases the precision of locating areas that have low access to healthy food sources. In order to implement changes, it is important to examine the spatial distribution of food access at as fine a geographic scale as possible (Raja et al., 2008).

4. GROCERY SHOPPING TRENDS

Grocery Store Choice

Respondents were asked to identify the grocery store that they normally go to. The majority (59%) identified a supermarket as the primary grocery store. Discount grocery stores served about 20% of those sampled and specialty grocery store 11%. A small number identified farmers market (0.4%), convenience stores (0.2%), and small grocers (0.4%). As shown in Figure 10, the preference for a discount grocery store decreases as income increases, as does the use of superstores such as Walmart. Supermarket use is relatively consistent across income categories; however, there is a slight reduction as income increases due to more choosing specialty grocers.

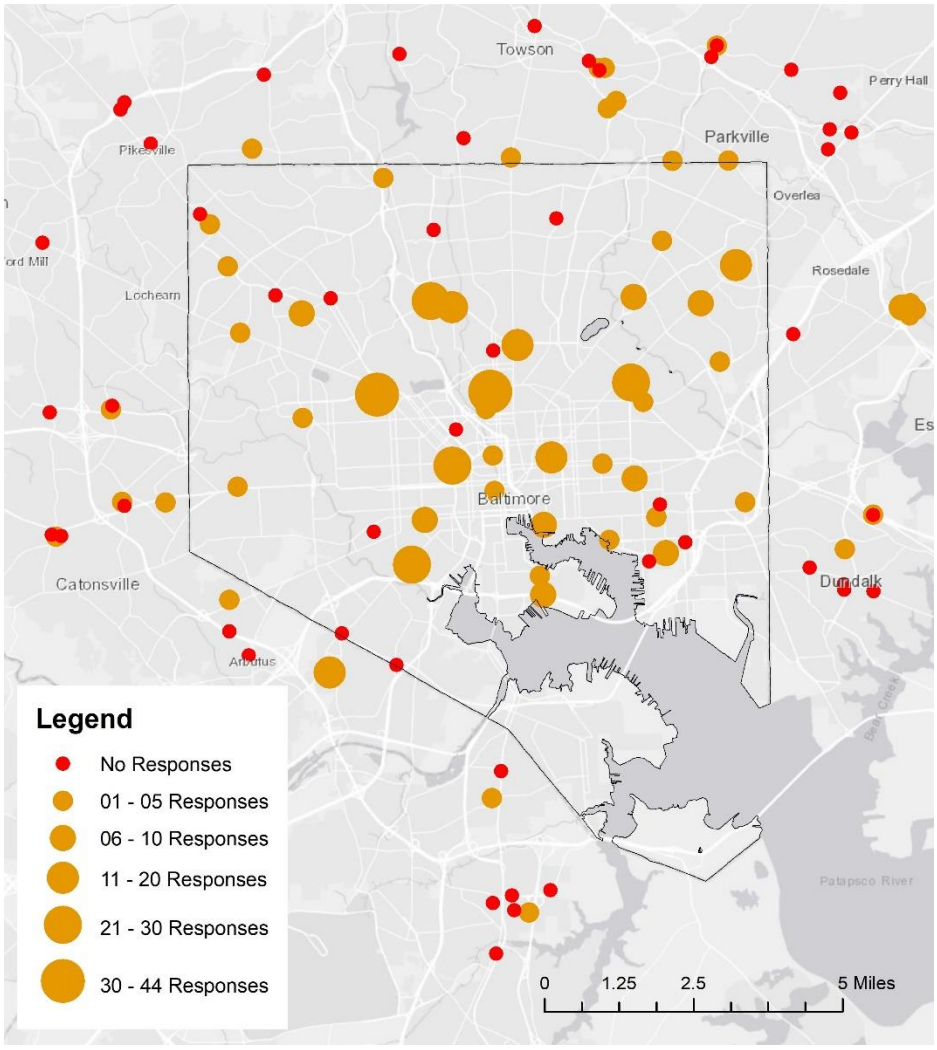


Figure 8. Preferred Grocery Store

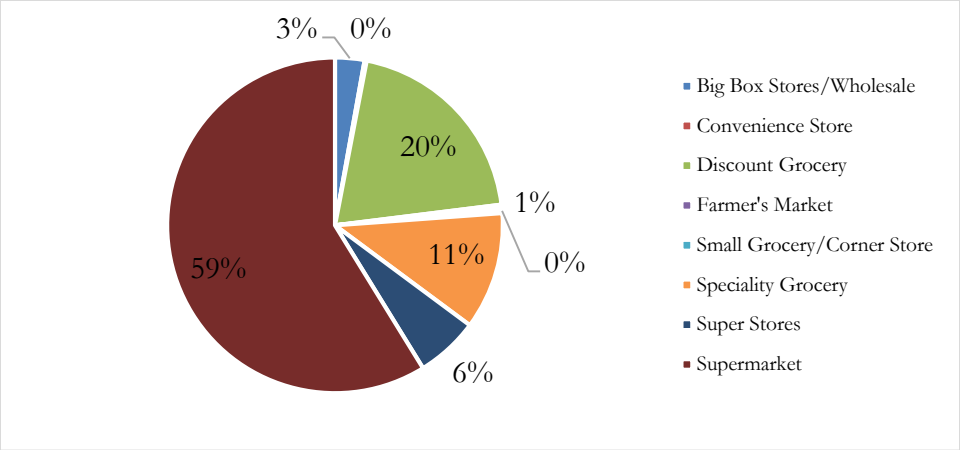


Figure 9. Type of Grocery Store Most Frequented

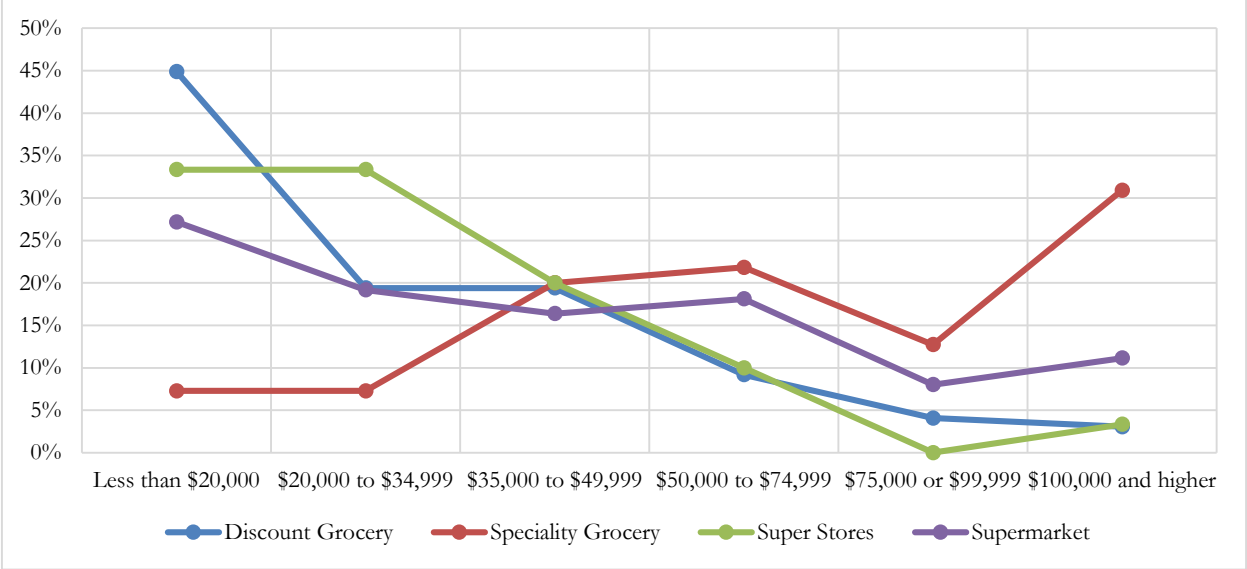


Figure 10. Grocery Store Type by Income

Table 5 shows the percent of respondents who shop at a grocery store by type based on the category of food purchased. Supermarkets are preferred to shop for groceries regardless of the type of item purchased. About 20%-30% are willing to shop at a discount grocery store depending on the type of food purchased; it is the least desirable to purchase fresh meat from a discount grocery store while non-perishable items are the most desirable. Some 15%-20% are willing to shop at specialty grocery stores such as Whole Foods Market, particularly for fresh produce. Another source of fresh produce is the farmers market; over one-third (36.7%) shop at farmers markets for fresh produce. Over one-quarter of all respondents stated that they shop at superstores such as Walmart Supercenter. Only 10% of the respondents shop at big box stores such as Costco. Non-profit co-ops were used by a small percentage to acquire fresh produce. Most did not shop at convenience stores; however, for those who do dairy and non-perishables were the most frequently bought item types.

Table 5. Grocery Store Type by Item Category

	Fresh produce	Frozen food	Fresh meat	Non-perishables	Dairy	Grains
Non-profit co-op	10.0%	4.2%	5.6%	5.2%	5.3%	4.8%
Farmers market	36.7%	4.8%	10.1%	3.9%	8.7%	9.9%
Discount grocery	27.9%	29.7%	21.7%	31.6%	25.6%	28.7%
Specialty grocery	22.1%	15.3%	18.8%	16.1%	17.5%	20.3%
Supermarket	60.6%	63.4%	61.0%	61.0%	63.3%	62.9%
Superstore	24.9%	30.5%	22.2%	32.2%	28.4%	27.5%
Big box store	9.8%	13.6%	12.6%	10.5%	9.2%	10.7%
Convenience stores	1.8%	2.7%	0.7%	4.1%	4.3%	1.9%

Accessibility Indicators

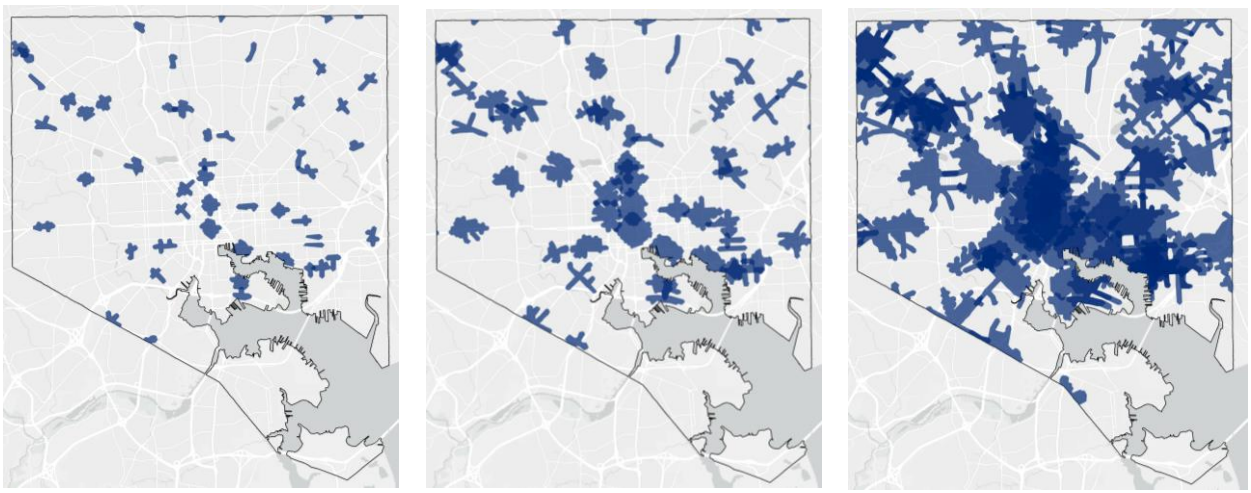
Nearest Grocery Store

Most food desert metrics look at the proximity of a person's residence to the nearest grocery store. The results of this study show that many do not shop at the store closest to their home. Table 6 shows the percent of respondents who are within a quarter, half, and one mile of a grocery store. Additionally, the last columns display what percent of the geographic area of Baltimore City is near a grocery store at the same thresholds when measured by network and Euclidean (straight-line) distance. As shown in Figure 11, there are several grocery stores along the central spine of the city but the city lacks grocery stores in the southwest and southern most parts. Only 9.3% of those sampled were within 0.25 miles of a grocery store, 26.1% were within 0.5 miles of a grocery store, and nearly two-thirds were within one mile of a grocery store.

Table 6. Percent of Respondents and City with a Grocery Store by Network Distance from Store

Distance from home to grocery store	% of Respondents (network distance)	% of City (network distance)	% of City (Euclidean distance)
0.25 miles	9.3%	6.1%	11.0%
0.50 miles	26.1%	17.2%	36.8%
1 mile	67.6%	47.5%	83.5%

Many food desert metrics use a Euclidean distance from the store as a proxy for walking distance. Figure 11 shows that using a Euclidean distance overestimates access to a grocery store. At the quarter-mile distance only 6.1% of the city can reach a grocery store when following the roadway network versus 11.0% when assuming a Euclidean distance. At the half mile mark, the percentages for network and Euclidean distance are 17.2% and 36.8%, respectively. Using a one-mile estimate, nearly the whole city has coverage (83.5%) when the Euclidean distance is used but when the road network is considered only 47.5% of the city is within one-mile of a grocery store.



(a) Network distance – 0.25 mi (b) Network distance – 0.5 mi (c) Network distance - 1 mi

(d) Euclidean distance – 0.25 mi (e) Euclidean distance – 0.5 mi (f) Euclidean distance – 1 mi

Figure 11. Quarter, Half, and One Mile Grocery Coverage Areas by Network & Euclidean Distance

As shown in Table 7, in our study nearly half of respondents reported that they shopped at the grocery store nearest to their residence. However, GIS analysis found that only 23% actually shop at the store closest to them. However, when considering the type of grocery store, 36% of people go to the nearest grocery store of that type. The average distance traveled to the grocery store was 2.74 miles while the average distance to the closest grocery store was 0.8 miles.

Table 7. Percent Who Shop at Nearest Store

Category	Self-Reported	GIS Report	GIS Report by Type
Shops at nearest store	54.4%	23.0%	36.2%
Does not shop at nearest store	43.4%	77.0%	63.8%
Unsure	2.2%		

Frequency of Grocery Trips

Table 8 summarizes the grocery shopping patterns of the survey respondents. Additionally, three vulnerable groups are parsed out for detailed analysis: the elderly, the carless, and those with household incomes under $35,000. The study found that most people made between 2-4 grocery trips per month. Those with an income of less than $35,000 were more likely to only make one trip per month. As shown in Figure 12, the households with incomes over $100,000 shopped more frequently, with most shopping four or more times per month. Nearly half of the respondents stated that they coordinate their grocery trips with their paychecks. For the elderly, they coordinate their shopping with retirement and government assistance. For those with incomes under $35,000 or without a vehicle, approximately 40% coordinated their shopping with government assistance and 19% with disability benefits.

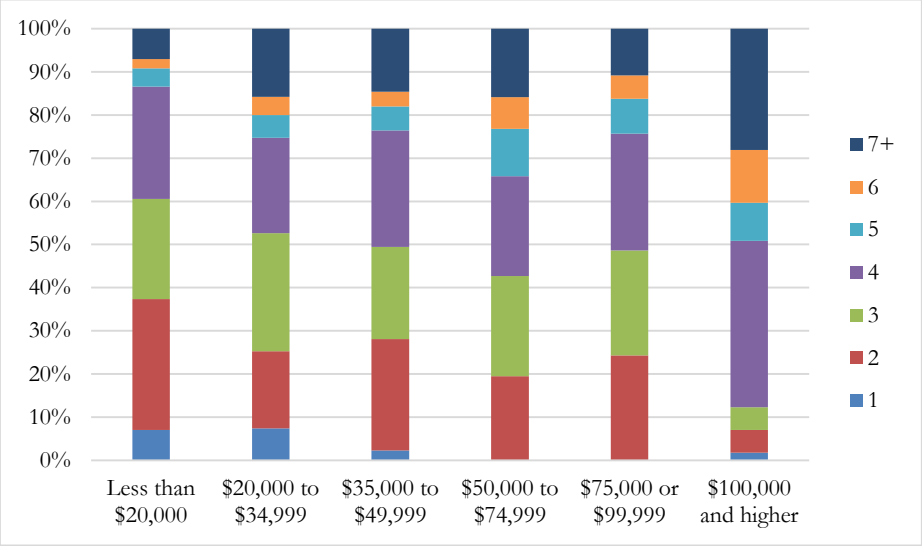


Figure 12. Number of Grocery Shopping Trips per Month by Income

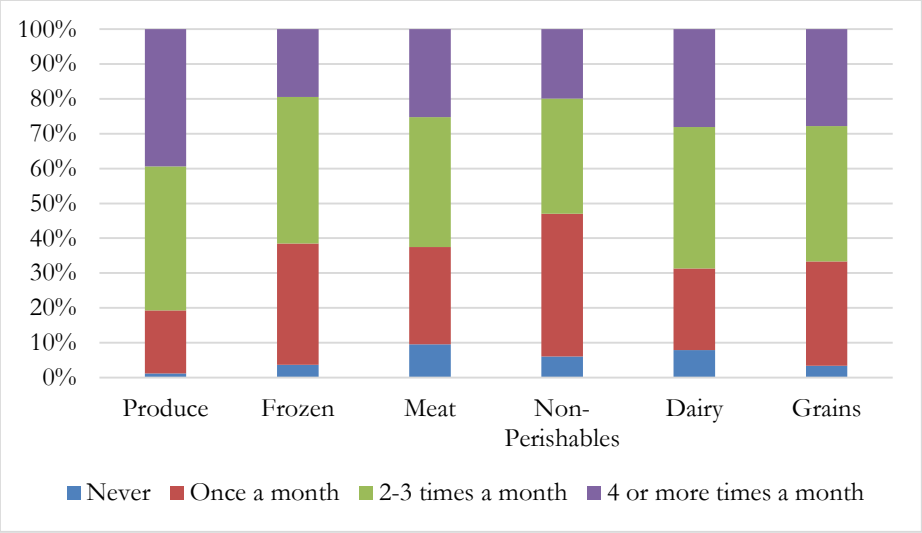


Figure 13. Number of Trips per Month by Item Category

Table 8. Grocery Shopping Habit Summary

Variable	# of Valid Responses	Options	All Persons	Elderly	Zero car households	Income < 35,000
Day of week	511	Weekdays	61.8%	80.0%	65.4%	64.3%
		Weekend	38.2%	20.0%	34.6%	35.7%
Time of day	507	Early morning: 12 – 5 am	7.7%	3.6%	10.8%	11.1%
		Morning: 5 – 9 am	10.1%	12.7%	7.5%	12.0%
		Late morning: 9 am – 12 pm	26.4%	36.4%	25.8%	26.5%
		Afternoon: 12 – 4 pm	22.9%	25.5%	26.9%	22.6%
		Evening: 4 – 7 pm	28.4%	18.2%	24.7%	23.5%
		Night: 7 pm - 12 am	4.5%	3.6%	4.3%	4.3%
Number of grocery trips per month	508	1	3.9%	1.8%	5.3%	7.2%
		2	22.0%	23.6%	27.0%	25.3%
		3	21.7%	21.8%	23.8%	24.9%
		4	26.6%	20.0%	22.2%	24.5%
		5	6.5%	7.3%	7.9%	4.6%
		6	5.3%	5.5%	3.2%	3.0%
		7+	14%	20.0%	10.6%	10.5%
Number of stores	508	1	10.0%	5.6%	17.6%	15.7%
		2	42.3%	37.0%	45.7%	46.8%
		3	33.5%	42.6%	27.1%	27.2%
		4	8.7%	9.3%	5.3%	5.1%
		5+	5.5%	5.6%	4.3%	5.1%
Coordinate trips?[8] ***Select all***	515	Pay period/paycheck	49.9%	27.3%	47.1%	48.1%
		Retirement benefits	11.6%	34.5%	6.9%	8.9%
		Disability benefits	11.5%	10.9%	19.6%	19.0%
		Government assistance	29.0%	52.7%	39.7%	42.6%
Common dietary restricts ***Select all***	485	None	75.7%	80.8%	78.5%	81.6%
		Vegetarian or vegan	8.9%	7.7%	4.4%	3.5%
		Lactose	4.5%	3.8%	5.7%	2.2%
		Diabetic/Low sugar	3.9%	9.6%	5.0%	5.3%
		Meat restrictions	3.1%	1.9%	4.4%	3.9%
		Low sodium	2.9%	3.8%	2.2%	2.6%
		Gluten sensitivity	1.6%	0.0%	2.4%	0.4%
		Nuts	1.2%	0.0%	1.7%	2.2%
		Seafood	1.2%	0.0%	1.7%	1.3%
		Organic	0.8%	1.9%	0.6%	0.4%
Reasons for preferred store ***Select all***	513	Location	67.4%	63.0%	71.4%	67.1%
		Affordable prices	63.2%	51.9%	61.1%	70.0%
		Produce selection	36.3%	44.4%	32.8%	29.5%
		Fresh meat options	25.5%	29.6%	23.8%	23.2%
		Seafood options	17.5%	18.5%	14.8%	15.2%
		Bakery	16.2%	22.2%	15.9%	16.5%
		Ready to eat foods	11.5%	18.5%	14.3%	11.0%
		Pre-packaged foods	10.7%	11.1%	12.7%	13.1%
		Vegan options	9.6%	5.6%	9.0%	5.9%
		Ethnic food options	9.4%	13.0%	23.8%	8.0%
		Gluten free options	5.8%	9.3%	5.8%	5.1%

[8] Missing entries were assumed to not coordinate grocery shopping trip with the given category

Given that produce is perishable, people shop for produce with the most frequency; 80% shop for produce more than three times a month. Dairy and grains were purchased with the next highest frequency followed by frozen food items and meat. Non-perishable items are purchased the least often, with 40% purchasing these items about once per month. Figure 13 summarizes the purchasing frequency of these common grocery item types.

Number of Stores Visited Per Month

Most people (75%) traveled to 2-3 different grocery stores in a given month. Those with no vehicle and lower income were more likely to only shop at one grocery store per month. Grocery store choice is complicated as people choose a grocery store for a variety of reasons. Location and affordability were the primary reasons for choosing a grocery store. Produce selection and ready to eat foods were more important to the elderly. For persons without a car, 70% said that location was important in choosing a grocery store. Ethnic food options were also a consideration for nearly a quarter of respondents. For those with incomes under $35,000, produce selection was less critical, and affordability and location were of the highest importance. Most people do not have any dietary restrictions. Vegetarian or veganism was the most common dietary restriction. About 10% of elderly respondents were diabetic or on a low-sugar diet.

Quality of Store

Three-fourths of all respondents were satisfied or strongly satisfied with the food selection at their primary grocery store; see Table 9. For those without a car, 70% were satisfied with the food quality at their grocery store while 77% of those with a car were satisfied with the quality of food at their primary grocery store. The average healthy food availability index (HFAI) for those who own a car is 28.0 while those without a car shopped at stores with an average HFAI of 27.4. The average HFAI score increases with income; see Figure 14.

Table 9. Level of Satisfaction with Quality of Food at Primary Grocery Store

Level of Satisfaction	All Respondents	Those Who Do Not Own Car	Those Who Own Car
Strongly Satisfied	31.3%	35.2%	28.8%
Satisfied	43.2%	35.2%	48.1%
Neutral	18.0%	19.2%	17.1%
Dissatisfied	4.9%	6.2%	4.1%
Strongly Dissatisfied	2.7%	4.1%	1.9%

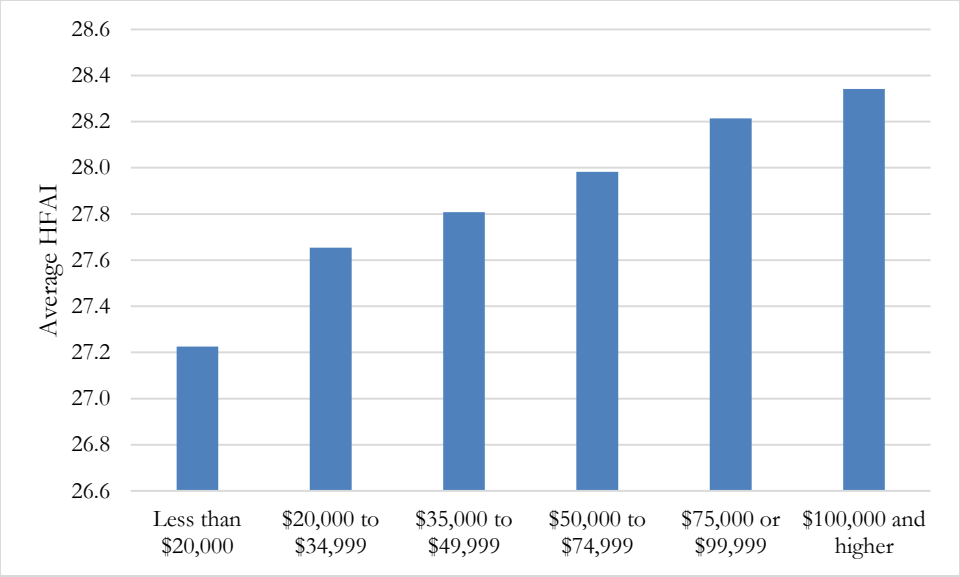


Figure 14. Average Healthy Food Availability Index by Income

5. TRANSPORTATION AND ACCESS

Vehicle Access and Mode Choice

Of the 512 people who reported vehicle access, 318 (62.2%) own a vehicle and 194 (37.8%) do not. However, of those who do not own a vehicle 11.9% say that they may borrow a vehicle when needed and 5.7% are members of a car share. For those who do not own a car, 83.4% do not have access to a car by any of the reported means. Table 10 provides a summary of vehicle access.

Table 10. Vehicle Access Summary

Category *(select all)*	Those Who Do Not Own Car	Those Who Own Car	All Respondents
Household has 1+ vehicles	0%	100%	62.2%
May borrow vehicle when needed	11.9%	0.3%	4.7%
Member of a car share	5.7%	1.9%	3.3%
Has no access to vehicles	83.4%	0.0%	31.6%

Table 11 provides a summary of the self-reported modes available. Though self-reported modes available may, in fact, differ from what modes are actually available, the self-reported mode reflects the modes considered by the respondents. Nearly all have access to a bus line in their neighborhood; however, only 40% have access to a train. At the time of data collection, Baltimore had an operating bike share station, but only 17.2% had access to the bike share. Car share is only available for 24% of survey respondents but those who own a car have better access to car share than those without (27.4% vs. 18.4%). Additionally, those without a car reported less access to ride-hailing services such as Uber and Lyft compared to those who own a car (45.8% vs. 60.5%).

Table 11. Self-Reported Modes Available

Mode	All Respondents	Those Who Do Not Own Car	Those Who Own Car
Bus	97.2%	96.8%	97.5%
Train	40.0%	46.8%	36.0%
Taxis	61.8%	53.7%	66.6%
Hacks	46.3%	50.0%	43.9%
Bike share	17.2%	14.2%	19.1%
Car share	24.0%	18.4%	27.4%
Ride-hailing (e.g., Uber)	54.9%	45.8%	60.5%

Respondents were asked to identify all modes that they have taken to the grocery store in the last month. As shown Table 12, 56.3% of people have driven to the grocery store and 46.7% have walked to the grocery store in the reported month. For those who don't own a vehicle, 63.4% reported that they walked to the grocery store in the last month, 44.5% took transit, and 50.8% took a car to the grocery store. Aside from getting a ride, taking the informal mode hack was the most common, followed by ride-hailing services such as Uber. For those who own a car, the majority (80.1%) usually

drive to the grocery store; however, 10.8% reported that walking is their primary means of getting to the grocery store. For those without a vehicle, the primary mode split was a bit more uniform with 41.1% reporting that they walk, 25.0% taking transit, and 30.7% going by car.

Table 12. Modes to Grocery Store in Last Month

	All Modes Taken in Last Month			Primary Mode Taken in Last Month		
Mode	**All**	**Those Who Do Not Own Car**	**Those Who Own Car**	**All**	**Those Who Do Not Own Car**	**Those Who Own Car**
Drive personal car	**56.3%**	**5.2%**	**87.1%**	**50.9%**	**3.1%**	**80.1%**
NonMotorized	**46.7%**	**63.4%**	**37.1%**	**22.1%**	**41.1%**	**10.8%**
- Walk	46.3%	63.4%	36.5%	20.4%	39.1%	9.2%
- Bike	5.3%	3.7%	6.3%	1.8%	2.1%	1.6%
Transit	**22.7%**	**44.5%**	**9.4%**	**11.0%**	**25.0%**	**2.5%**
Other car modes	**29.1%**	**50.8%**	**15.7%**	**16.0%**	**30.7%**	**6.6%**
- Get a ride	18.4%	29.3%	11.3%	7.0%	12.5%	3.2%
- Hack	10.5%	23.0%	3.1%	2.7%	5.2%	1.3%
- Ride-hailing	7.2%	15.2%	2.5%	2.7%	7.3%	0.0%
- Taxi	4.3%	9.4%	1.3%	1.8%	4.2%	0.3%
- Carshare	2.0%	1.6%	2.2%	1.8%	1.6%	1.9%

Table 13 compares the mode to and the mode from the grocery store. Due to errors in the logic of the survey form, only 290 records are used in this analysis. The percentages shown in red are mode combinations that are illogical. For example, we assume that if you drive a personal vehicle to the store then you must take that same vehicle home. These records were a small portion (5.5%) of the sample. The majority took the same mode to and from the store, but 2.4% switched from a non-motorized mode to a car and 2.4% from public transit to car.

Table 13. Comparison of Mode to and Mode from the Grocery Store

		Mode from				
		Non-motorized	**Other car modes**	**Public transit**	**Drive personal vehicle**	**Grand Total**
Mode to	**Non-motorized**	19.7%	2.4%	0.7%	0.3%	**23.1%**
	Drive Other	1.4%	15.2%	1.4%	0.0%	**17.9%**
	Public transit	0.7%	2.4%	7.6%	1.0%	**11.7%**
	Drive personal vehicle	0.7%	2.1%	0.0%	44.5%	**47.2%**
	Grand Total	**22.4%**	**22.1%**	**9.7%**	**45.9%**	**100.0%**

As shown in Table 14, 65.1% of people stated that their mode choice was affected by weather, and 51.2% by the amount of groceries. This was fairly consistent for those with and without a vehicle. Those who stated that a physical or mental disability affects their mode choice also were less likely to have a vehicle (17.7% without a vehicle vs. 8.6% with a vehicle). Only one-tenth of respondents stated that traveling with dependents affects their mode choice to the grocery store. Approximately 43% of respondents stated that they usually grocery shop alone, 22% grocery shop with children, and 40% shop with other adults living in their household; see Table 15. Approximately 5% shop with someone with mobility limitations.

Table 14. Factors Affecting Mode Choice

	All	No Vehicle	Vehicle
Weather	65.1%	69.3%	62.5%
Amount of groceries	51.2%	53.1%	50.2%
Physical or mental disability	12.0%	17.7%	8.6%
Children or other dependents	10.6%	12.5%	9.5%

Table 15. Who Accompanies on Grocery Store Trips

	All	No Vehicle	Vehicle
Other adults in household	40.1%	36.1%	42.9%
Adults living in other households	16.4%	17.3%	15.4%
Children	22.1%	26.2%	19.9%
Persons with mobility limitations	4.9%	7.9%	3.2%
None	42.9%	40.3%	44.6%

On average, people traveled 2.74 miles to the grocery store. The average distance traveled by motorized modes ranged from 2.91-3.54 miles; see Table 16. However, for those taking nonmotorized modes, the average distance was considerably less at 1.58 miles.

Table 16. Average Distance to Preferred Grocery Store

Mode	Average Distance to Store
Non-motorized	1.58 mi
Drive Other	3.44 mi
Public transit	2.91 mi
Drive personal vehicle	3.54 mi
All Modes	***2.74 mi***

As displayed in Figure 15, individuals who do not own a vehicle are willing to pay more to get to the grocery store. Some 42.8% of respondents who do not own a car are willing to pay $8 or more to get to the grocery store whereas only 28.6% of individuals with a car are willing to pay $8 or more dollars. This reflects that those who do not own a car often pay a private provider such as a taxi, hack, or ride-hailing company to get to or from the grocery store.

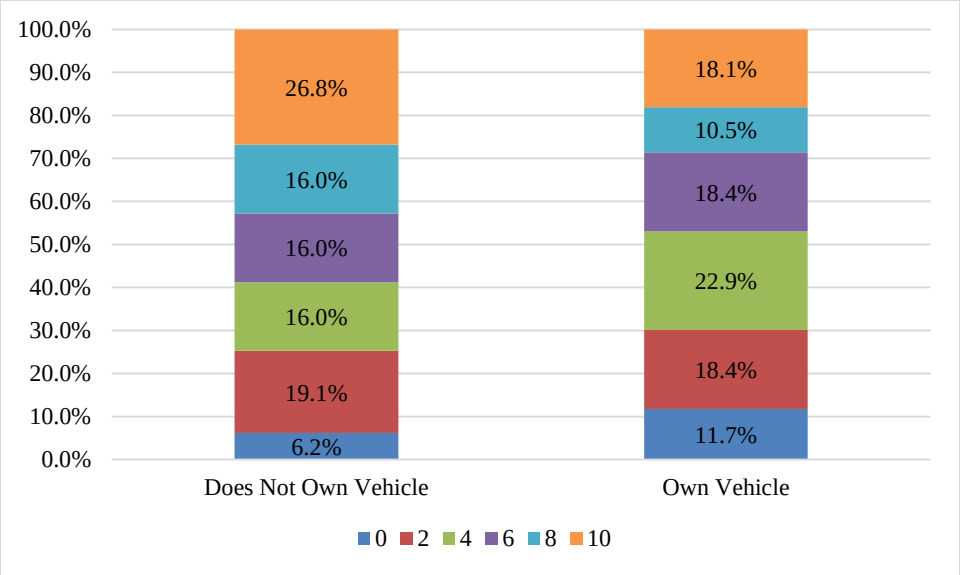


Figure 15. Maximum Willing to Spend on One-Way Trip to Grocery Store

Informal Taxi Service - Hacks

In Baltimore, a thriving informal taxi economy known as hacks plays a pivotal role in grocery access. Although not an officially instituted body, hacks are widely accepted in the area as a major alternative to the existing transit system, taxis and ride-hailing platforms, and a means of connection to grocery stores. Ten percent of those surveyed have used a hack in the last month, and of those who do not own a vehicle, 23% have used a hack. Hacks provide an affordable and convenient service to riders. At the time of the interviews, there were between 5-10 hack drivers onhand at the grocery store. Though informal, there is a relatively consistent fare structure. Competition for customers keeps the pricing low. Most grocery trips are a minimum of $5 one-way (for a distance around 2-3 miles), and the price increases from there with distance.

Despite not being legally instituted, hacks have an informal code of conduct. Drivers know one another and have an organized way of taking turns to provide rides. There is often a personal relationship between the customer and driver that provides a better sense of safety, which is strengthened by the fact that most hacks also live in the area they serve. Hack drivers rely on regular and on-the-spot customers. Regular customers are usually cultivated by 'word of mouth,' and references for hack drivers come from friends and community members.

Customer Characteristics

Generally, drivers stated that 70%-90% of their grocery store customers are female. Customers of all ages take hacks. Some drivers tended to focus on a particular demographic. For example, one driver stated that he served mostly senior citizens. Another driver prefers to serve customers 40 years and older. Some customers are traveling by themselves; others are with other adult family members or kids. Regular customers take hacks to and from the grocery store whereas others take them for the return trip only. Customers who take hacks on average have several bags with them. Most drivers

stated their customers have at least 10 grocery bags, but that number can often be upwards of 25-30 bags. Drivers noted that they are most busy the first half of the month due to retirement and government assistance disbursements, and Fridays and Saturdays are the busiest days of the week. Customers typically live 5-15 mins away by car from the grocery store. Drivers estimated that 0%-20% of customers had mobility impairments.

Driver Characteristics

As shown in Table 4, the majority of hack drivers are male and between the age of 35-55. Forty percent of drivers (12 out of 30) stated that hacking is their main occupation. Drivers interviewed have been hacking from less than a year to 42 years; the median was 8 years hacking. Over half (17 out of 30) drive 5 or more days a week, generally driving between 4-8 hours a day. Depending on the length of time they work, they serve 5-30 customers a day, not all of which are grocery trips.

Drivers work grocery stores that are near their residence or in areas that they are familiar with, but they will travel to different stores based on customer demand. Only 4 out of 13 drivers from the first interview stated that the majority of their grocery trips were roundtrips; most rely on on-demand customers returning home from the grocery store. Roundtrip customers are cultivated by developing a rapport with customers they meet at the grocery store. Payments are generally made via cash; however, 33% stated that they have alternative provisions such as Cash App or Square Card.

Influence of Ride-hailing Companies

Notwithstanding the growth in ride-hailing companies such as Uber and Lyft, the hacking economy thrives in Baltimore. The majority of hack drivers (12 out of 16) do not drive with ride-hailing companies due to the signup process and the per-mile rate. Hack drivers were mixed in their response about the impact ride-hailing companies have had on their business. Seventeen drivers said that these services had no impact on hacks, four a slight impact, and six that there was a negative impact on their business. The impact may be limited because unlike taxis and ride-hailing services, hack drivers offer incentive and services to riders that influence part of the rider's decision to go grocery shopping and willingness to pay. These services include picking up the customer from home, taking them to the store, going around the store with them pushing the shopping cart, helping them carry the bags back into the car, making the trip back home, and carrying bags to the customer's doorstep. The drivers are connected with the areas they serve because they mostly grew up and live in those areas, so they are conversant with the area, which makes riders feel safer. Hacks also have an advantage over the other platforms because they are readily available at the store locations and they can be contacted directly to schedule future trips or immediate trips. Taxis have a similar mode of operations in which they are sometimes located at some store locations. Still, the hack prices and services offered by the hacks result in people in their areas of operation using them more.

Role of Alternative Food Delivery

In the age of technology and on-demand services, many are using alternative forms of food delivery. Figure 16 shows the percent of respondent households with the internet and smartphones. At lower incomes, the rate of owning smartphones is considerably higher than the rate of having internet at home. However, as income increases nearly all households have both internet and a smartphone. Nearly three out of every four people stated that they have used food delivery services such as Grubhub, and about one out of every four people stated that they have used grocery delivery services. However, very few people use grocery pickup services and meal prep services such as Blue Apron. Table 17 shows the breakdown by vehicle ownership, Figure 17 by income, and Figure 18 by age.

Using takeout food services is not influenced by income or vehicle ownership; however older individuals are slower to adopt takeout services. Conversely, grocery delivery services are used more by older and more affluent individuals. Surprisingly, those who own a vehicle are more likely to use grocery delivery services. This may be due to the fees associated with grocery delivery. Most respondents did not use meal prep services such as Blue Apron; however, there was a strong positive correlation with income. Those who made over $75,000 were much more likely to use a meal preparation service. Grocery pickup services were the least utilized alternative food service. There were no discernable trends with income and age.

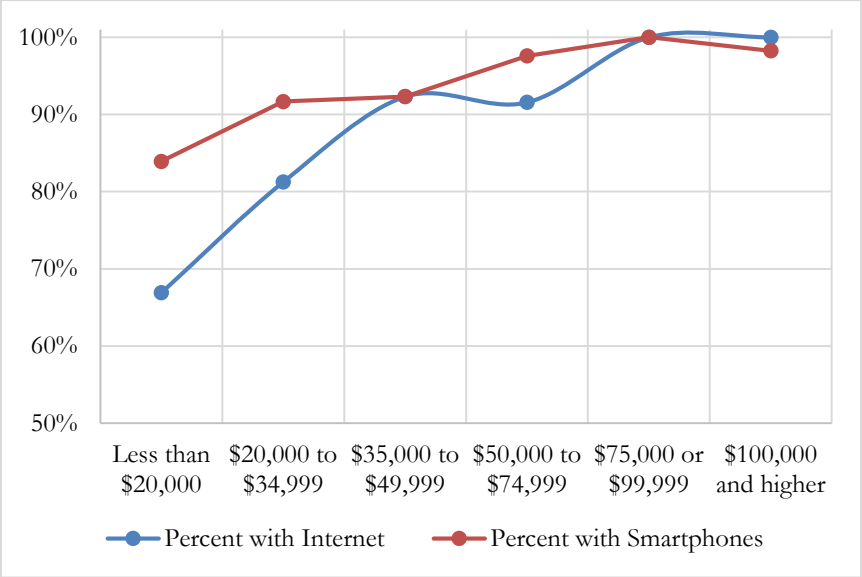


Figure 16. Percent of Households with Internet and Smartphones by Income

Table 17. Percent who Use Alternative Food Delivery Services by Vehicle Ownership

Alternative Food Delivery Type	Does not own Vehicle	Owns Vehicle	All
Food takeout delivery services (e.g., Grubhub)	73.9%	76.1%	75.3%
Meal prep services (e.g., Blue Apron)	9.2%	18.6%	14.7%
Grocery delivery services	20.3%	31.0%	26.6%
Grocery pickup services	15.0%	11.9%	13.2%

Figure 17. Percent who Use Alternative Food Delivery Services by Income

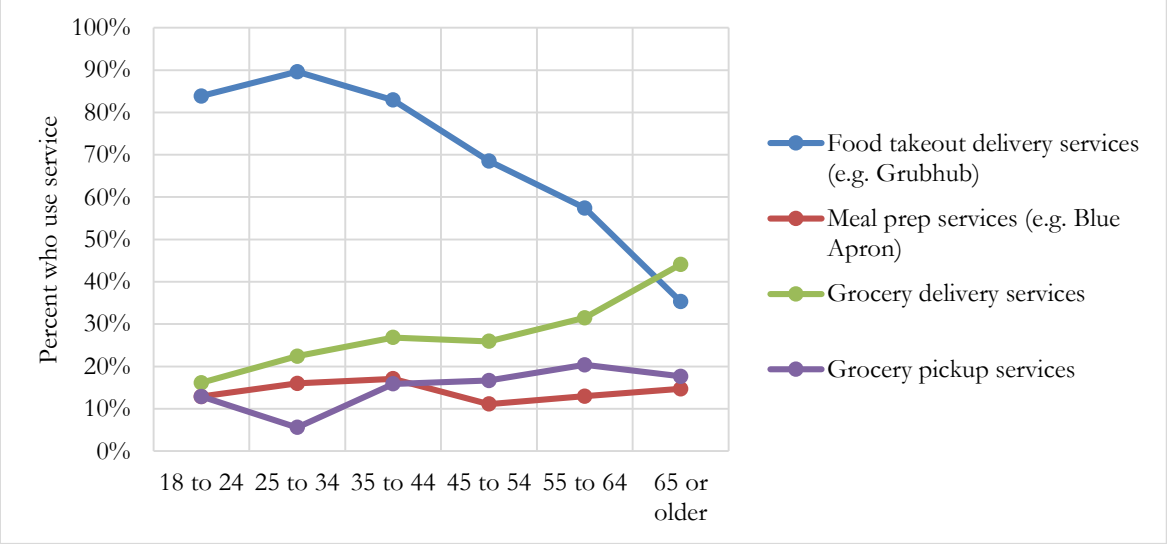


Figure 18. Percent who Use Alternative Food Delivery Services by Age

6. TOWARD A FOOD DESERT METRIC

Factors Affecting Access

Overview

Food desert metrics are used to identify geographic areas with a large proportion of residents who have difficulty accessing healthy food. Five measures of access are considered in this study:

1. Frequency of grocery store visits (Frequency)
2. Number of stores visited in a month (No. Stores)
3. Quality of food at preferred stores as measured by the healthy food availability index (HFAI) of the grocery store (Quality)
4. Shop at the nearest grocery store as reported by GIS. (Nearest)
5. Shop at the nearest grocery store of that category type as calculated in GIS. (Nearest by Type)

Because the geographic areas of the select food deserts varied widely, the percent of respondents who lived in a food desert varied from 1.2% to 48.2% depending on the food metric; see Table 18. Due to the limited percentage of residents residing in the USDA LILA @ 1 mi food desert area, this metric is excluded from the subsequent analysis.

Table 18. Percent of Respondents Living in Food Desert by Metric

Food Desert Metric	In Study Area
Baltimore City	30.6%
USDA LILA @ 1 mi	1.2%
USDA LILA @ 0.5 mi	48.2%
USDA Vehicle	40.1%
LSA	34.8%

Table 19. Summary of Accessibility Measures by Food Desert Metric

Metric	In a Food Desert?	Frequency (average visits per month)	No. of Stores (average stores per month)	Quality (average HFAI)	Nearest (% who shop at nearest)	Nearest by Type (% who shop at nearest)
Baltimore City	No	4.53	2.57	27.806	24.5%	61.3%
	Yes	4.61	2.60	27.448	18.0%	70.1%
USDA LILA @ 0.5 miles	No	4.90	2.52	27.759	23.7%	68.7%
	Yes	4.18	2.64	27.648	21.8%	58.6%
USDA Vehicle	No	4.80	2.55	27.809	25.7%	64.9%
	Yes	4.18	2.62	27.545	18.5%	62.1%
LSA	No	4.58	2.55	27.737	25.7%	62.9%
	Yes	4.51	2.62	27.648	17.0%	65.5%

Table 19 summarizes the five accessibility measures asked in the survey. Three of the four food desert metrics found that those who live in a food desert shop more often than those who do not, whereas the Baltimore City index found that those in a food desert shop slightly less. All measures showed that on average those who live in a food desert shop at stores with lower quality. Additionally, all measures showed that those who live in a food desert shop at more stores. As previously stated, the majority of people do not shop at the store nearest to their home; however, those who live in a food desert are more likely to shop at the nearest store. When considering the type of store (discount grocery, specialty grocery, supermarket, or superstore), nearly two-thirds shop at the nearest store by type; however, there were no perceivable trends based on the food desert measures. Statistical tests are conducted to see if the differences shown above are statistically significant using the Mann-Whitney U-Test and Pearson's Chi-Squared Test. Researchers conducted normality tests for each of the five dependent accessibility variables and found none of them were distributed normally.

To determine the factors which best predict the accessibility outcomes, a CHAID decision tree analysis was conducted. The study limited the factors to those accessible via the American Community Survey. All distances are measured along the road network. The researchers developed three models; the factors are given below.

- Model 1 - Traditional Variables: Household income is less than income thresholds of 20k, 35k, 50k, 75k, and 100k, Household vehicle ownership, At least one grocery store within distance thresholds of 0.25 miles, 0.50 miles, and 1 mile.
- Model 2 - Additional Socioeconomic Variables: This model includes all variables from Model 1 plus Education, Household size, and Employment status.
- Model 3 - Total Number of Stores: Includes all variables from Model 1 plus the total number of stores within a quarter, half, one, and three miles of residence

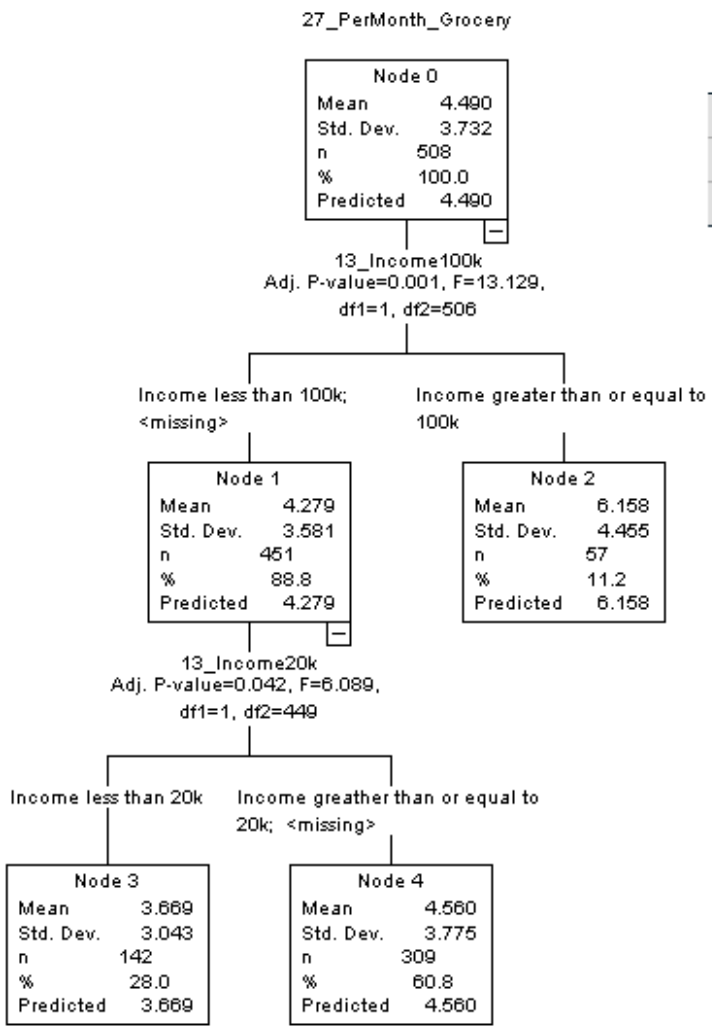
Model 1 only considers the factors commonly found in food desert metrics. Model 2 considers additional socioeconomic variables that could impact grocery access. Lastly, Model 3 recognizes that people value choice and a variety of grocery stores and looks at the total number of stores within various distance thresholds of the respondent's home. Additionally, the authors ran decision tree tests using drive time and transit travel time; however, distance remained a more important predictor and travel time was insignificant in all analyses.

Frequency of Grocery Store Visits

Table 20 presents the results for Frequency of Grocery Store Visits. There is no significant correlation between the frequency of grocery store visits and any of the food desert metrics. Figure 19 shows the decision tree for the frequency of grocery store visits. The influencing variables remained constant across models. Income was the only determinant in predicting grocery store frequency. The first most important predictor was if income is less than $100,000. Those with an income greater than or equal to $100,000 go to the store on average of 6.158 times in a month. Those with very low income (less than $20,000) go to the store on average 3.669 times in a month and all others (incomes between $20,000-$100,000) go to the store an average of 4.560.

Table 20. Frequency of Grocery Store Visits (Mann Whitney U Test)

Metric	Sig.	Food Desert	N	Mean Rank	Mean
Baltimore City	.818	No	337	244.96	4.53
		Yes	150	241.84	4.61
USDA LILA @ 0.5 mi	.215	No	254	251.42	4.90
		Yes	233	235.91	4.18
USDA Vehicle Access	.147	No	292	251.40	4.80
		Yes	195	232.92	4.18
LSA	.476	No	317	247.26	4.58
		Yes	170	237.92	4.51



Gain Summary for Nodes

Node	N	Percent	Mean
2	57	11.2%	6.16
4	309	60.8%	4.56
3	142	28.0%	3.67

Risk

Estimate	Std. Error
13.396	2.289

Figure 19. Decision Tree for Frequency of Grocery Store Trips (Model 1,2,3)

Number of Stores Visited

The number of stores visited per month ranged from one to five or more. Five or more was coded as 5 stores. There was no significant correlation between living in a food desert and the number of stores visited per month; see Table 21. For all models, an income threshold of $35,000 was the sole predictor of the number of stores visited. Current food desert metrics use a higher income threshold. Baltimore City uses an income threshold of $44,862 (185% of the federal poverty level of four), USDA $55,146 (80% of statewide income), and LSA $58,608 (120% of area median income).

Table 21. Number of Stores Visited Per Month (Mann Whitney U Test)

Metric	Sig.	Food Desert	N	Mean Rank	Mean
Baltimore City	.742	No	338	242.68	2.57
		Yes	149	246.98	2.60
USDA LILA @ 0.5 mi	.130	No	254	235.30	2.52
		Yes	233	253.49	2.64
USDA Vehicle Access	.370	No	293	239.62	2.55
		Yes	194	250.62	2.62
LSA	.357	No	319	239.99	2.55
		Yes	168	251.62	2.63

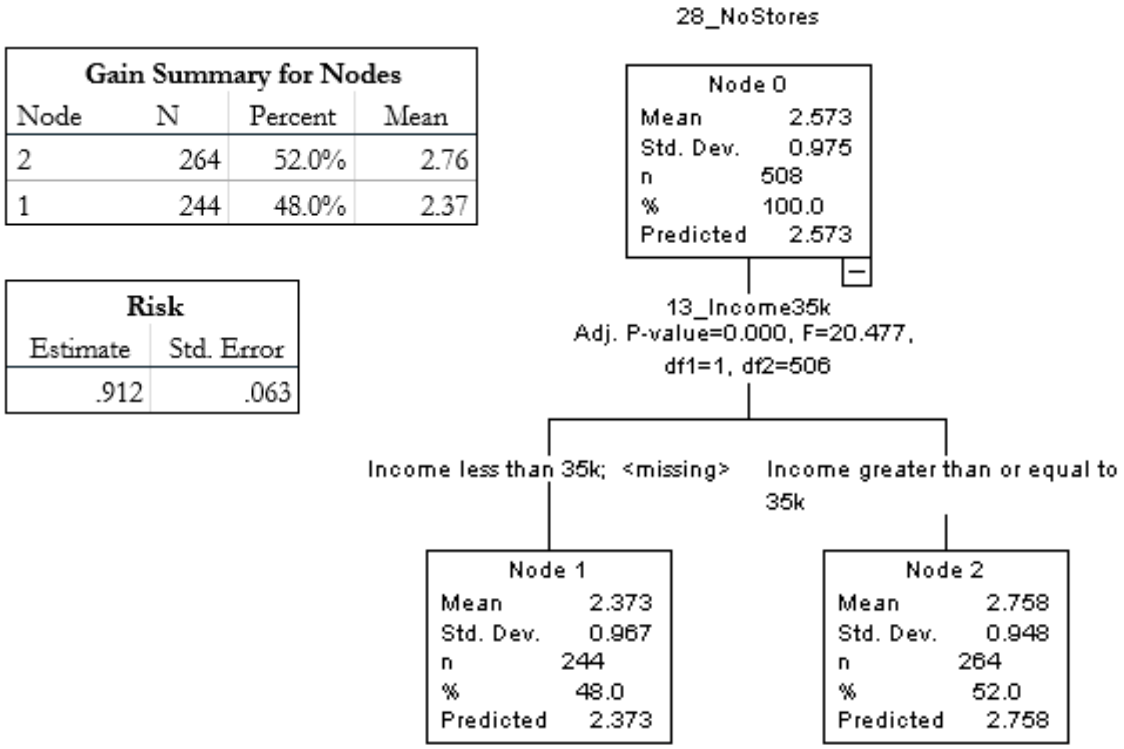


Figure 20. Decision Tree for Number of Stores Visited (Model 1,2,3)

Quality of Preferred Store

All food desert metrics predicted a significant difference in the quality of food at the preferred store; see Table 22. Respondents who live in a food desert shop at stores with a significantly lower HFAI score. The USDA Vehicle Access and LSA measures had the most significant difference in the quality of food. With the exception of USDA LILA @ 0.5 miles which is significant at the 95% confidence interval, all food desert metrics were significant at the 99% confidence interval.

Table 22. Quality of Food at Store (Mann Whitney U Test)

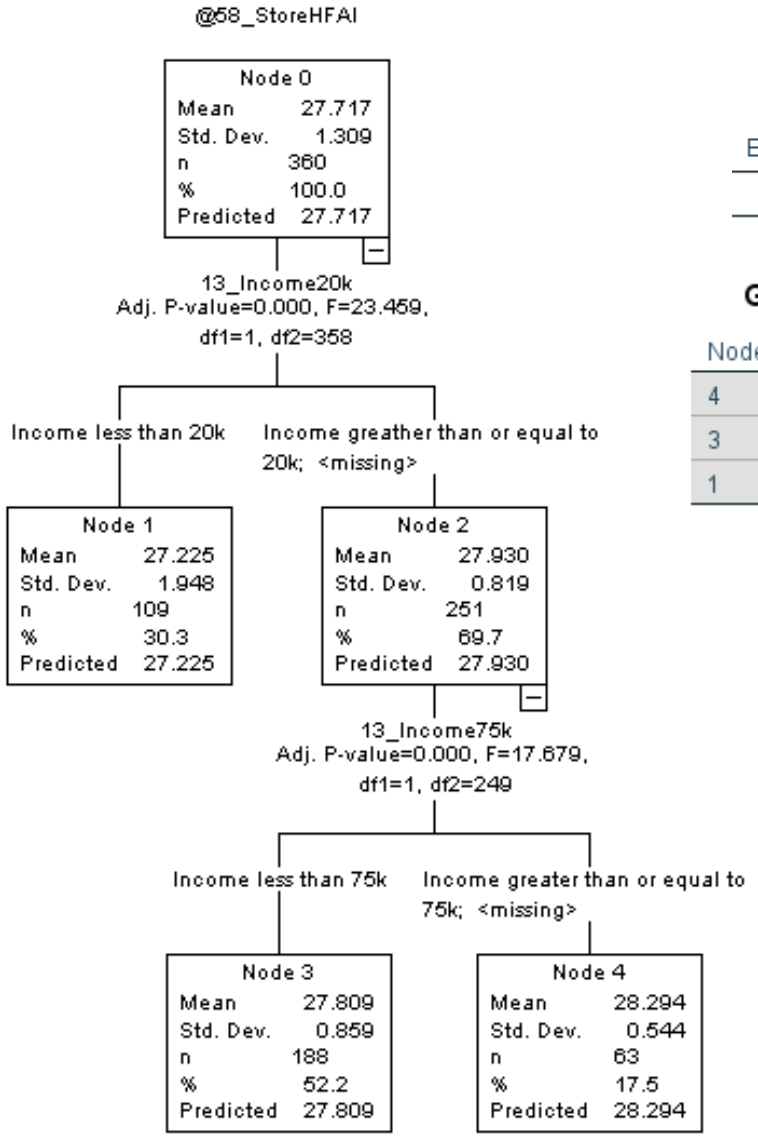
Metric	Sig.	Food Desert	N	Mean Rank	Mean
Baltimore City	.002**	No	255	185.38	27.806
		Yes	96	151.08	27.448
USDA LILA @ 0.5 mi	.021*	No	189	186.45	27.759
		Yes	162	163.81	27.648
USDA Vehicle Access	.000**	No	217	191.59	27.809
		Yes	134	150.76	27.545
LSA	.002**	No	236	186.57	27.737
		Yes	115	154.31	27.648

*Significant at the 95% confidence interval, **Significant at the 99% confidence interval

The factors predicting the quality of food varied with each of the models. For Model 1, the model which considers traditionally used food desert factors only, income was the only important determinant of store quality; Figure 21. Those who make less than $20,000 shopped at stores with the lowest quality (HFAI=27.225), followed by those who make between $20,000-$75,000 (HFAI=27.809). Those who made more than $75,000 were able to shop at the highest quality stores on average (HFAI=28.294).

Recall that Model 2 considers all factors in Model 1 plus education, household size, and employment status. When the additional socioeconomic factors are added to the model, educational attainment is the sole predictor of quality of food; see Figure 22. Those with a college degree shop at higher quality stores than those without a college degree (HFAI 28.153 vs. 27.415).

Model 3 considers all factors in Model 1 plus the total number of stores within a quarter, half, one, and three miles of residence. As in Model 1, those at very low incomes (under $20,000), shopped at stores with the lowest quality as indicated by an HFAI of 27.225. For those over $20,000, choice in stores became important as measured by the number of stores available within three miles from home. For people who live in areas with the most store options, an income threshold of $50,000 predicted the quality of food in the preferred grocery store.



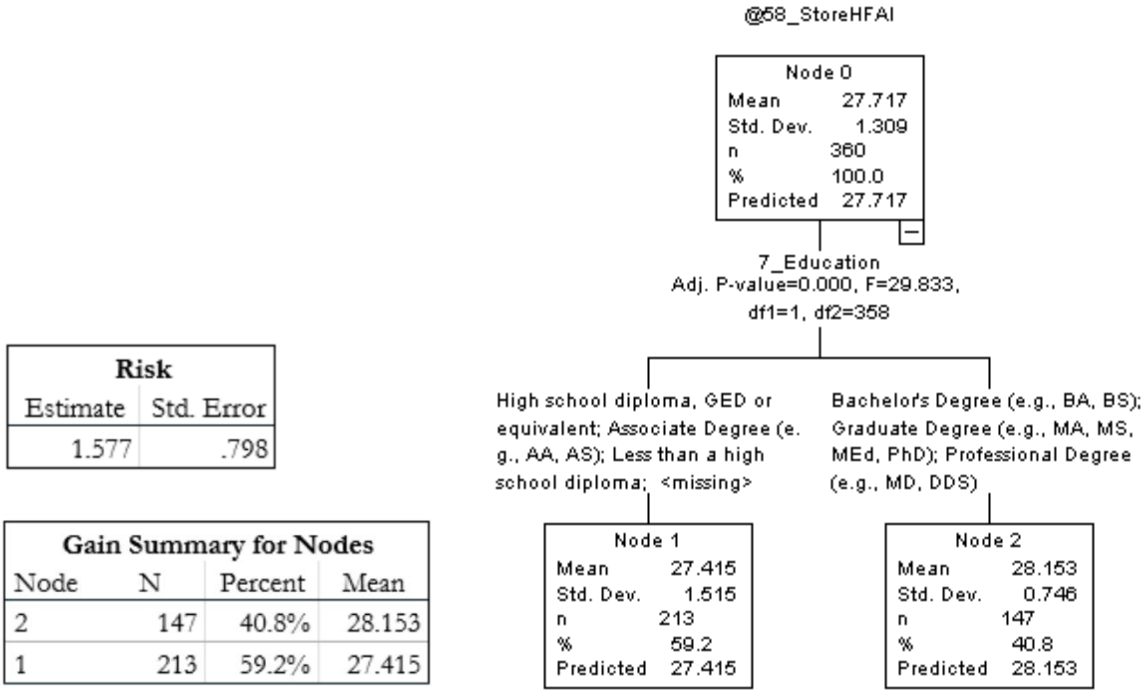
Risk

Estimate	Std. Error
1.573	.780

Gain Summary for Nodes

Node	N	Percent	Mean
4	63	17.5%	28.294
3	188	52.2%	27.809
1	109	30.3%	27.225

Figure 21. Decision Tree for Food Quality (Model 1)



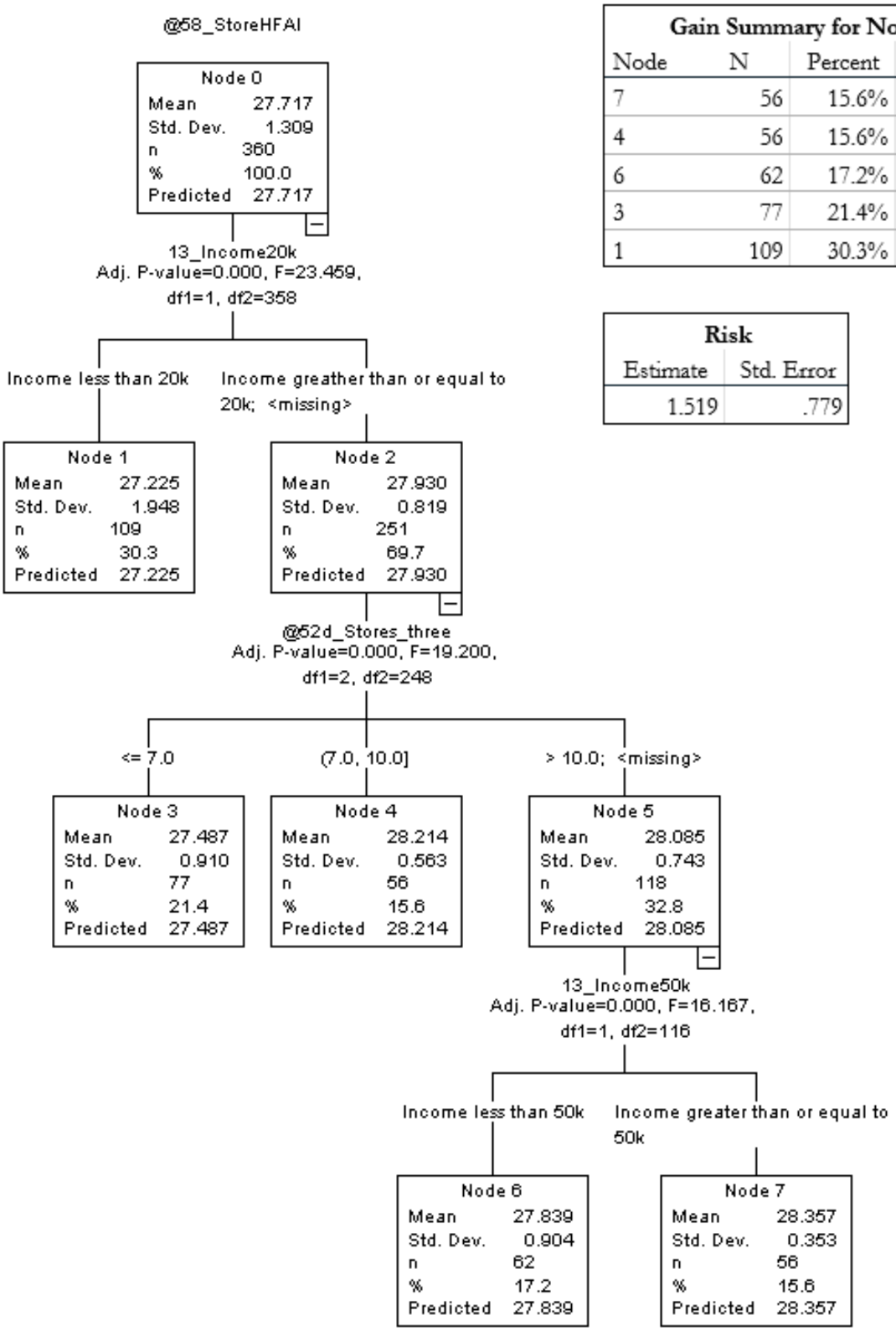
Risk

Estimate	Std. Error
1.577	.798

Gain Summary for Nodes

Node	N	Percent	Mean
2	147	40.8%	28.153
1	213	59.2%	27.415

Figure 22. Decision Tree for Food Quality (Model 2)



Gain Summary for Nodes

Node	N	Percent	Mean
7	56	15.6%	28.357
4	56	15.6%	28.214
6	62	17.2%	27.839
3	77	21.4%	27.487
1	109	30.3%	27.225

Risk

Estimate	Std. Error
1.519	.779

Figure 23. Decision Tree for Food Quality (Model 3)

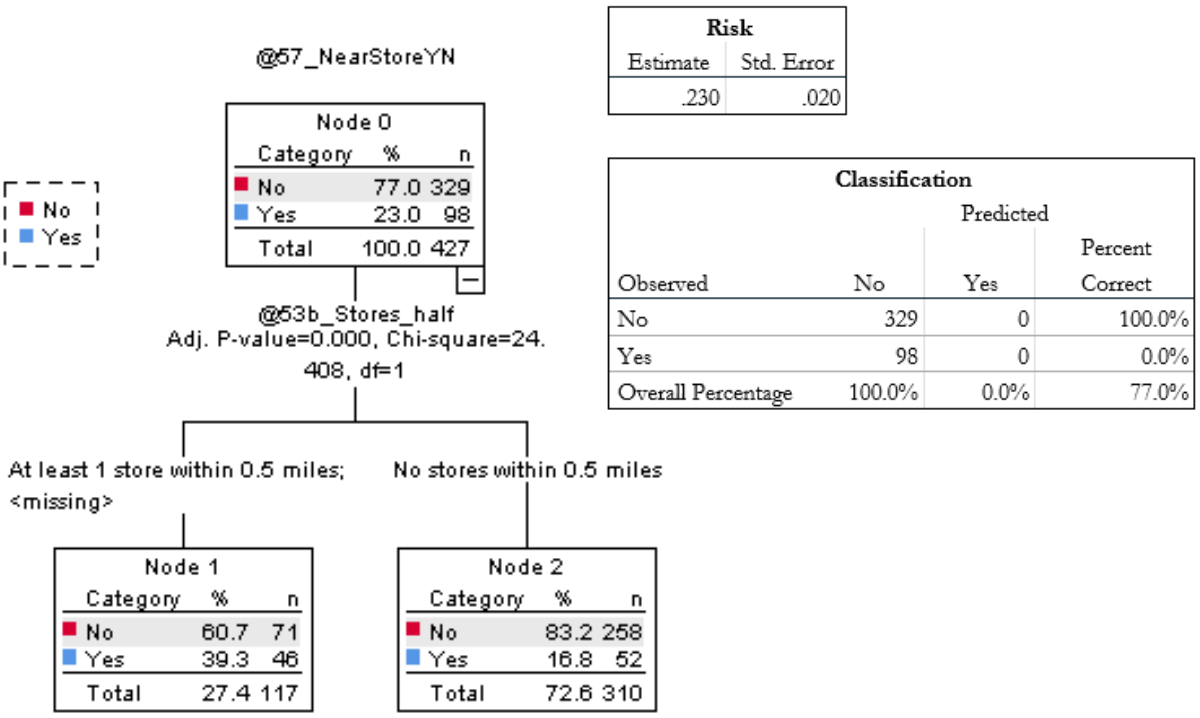
Shop at Nearest Store

For shopping at the nearest store, only the LSA food desert metric showed that the difference between those in a food desert and those outside of a food desert could not be attributed to randomness; see Table 23. Those who live in a food desert were less likely to shop at the nearest grocery store. For all models, the only significant predictor of whether a person shops at the store nearest to their home was having a store within 0.5 miles of residence; see Figure 24.

Table 23. GIS Calculated Shop at Nearest Store (Pearson Chi Square)

			# of observations, N (% of row total)		
Metric	**Sig.**	**Nearest Store Food Desert**	**No**	**Yes**	**Total**
Baltimore City	.135	No	228 75.2%	75 24.5%	*303*
		Yes	100 82.0%	22 18.0%	*122*
USDA LILA @ 0.5 mi	.641	No	167 76.3%	52 23.7%	*219*
		Yes	161 78.2%	45 21.8%	*206*
USDA Vehicle Access	.083	No	191 74.3%	66 25.7%	*257*
		Yes	137 81.5%	31 18.5%	*168*
LSA	.045*	No	211 74.3%	73 25.7%	*284*
		Yes	117 83.0%	24 17.0%	*141*
Total			*328*	*97*	

*Significant at the 95% confidence interval, **Significant at the 99% confidence interval



Risk

Estimate	Std. Error
.230	.020

Classification

Observed	Predicted No	Predicted Yes	Percent Correct
No	329	0	100.0%
Yes	98	0	0.0%
Overall Percentage	100.0%	0.0%	77.0%

Figure 24. Decision Tree for Shopping at Nearest Store (Model 1,2,3)

Shop at Nearest Store Based on Type of Store

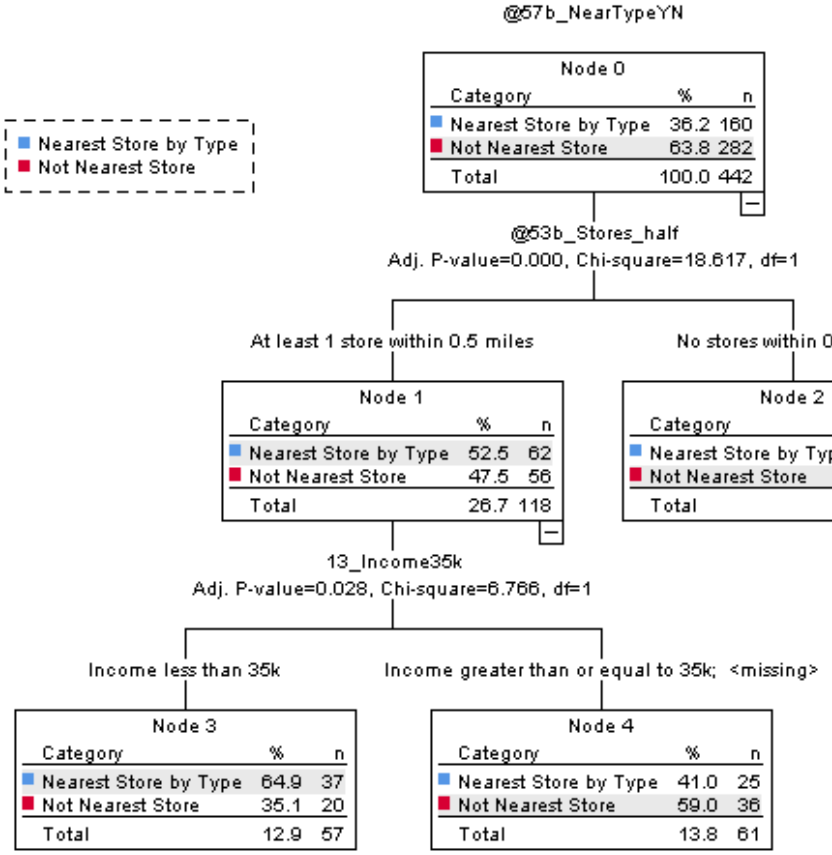
The USDA Low Income and Low Access at 0.5 miles was significant at the 95% confidence interval; see Table 24. For Model 1 and 2, Figure 25, the most significant predictor of shopping at the nearest grocery store that is of the same category of your preferred store is if there is a store within half a mile from home. This aligns with the model for shopping at the nearest store absent of type (Figure 24). However, when considering the type of store, an additional factor, income less than $35,000, is also important in predicting the likelihood of shopping at the nearest store by type. This is likely due to the importance of affordable discount grocery stores for those at lower income levels.

Model 3 is similar to Model 1/Model 2. However, for people who do not have a store within half a mile from their home, the number of stores within 3 miles from home is a significant factor for shopping at the nearest store. For those with 12 or fewer stores within 3 miles from home, having a store within 1 mile from home impacts the likelihood of shopping at the nearest store by type. See Figure 26 for the decision tree for Model 3.

Table 24. GIS Calculated Shop at Nearest Store of Preferred Store Type (Pearson Chi-Square)

			# of observations, N (% of row total)		
Metric	**Sig.**	**Nearest Store Food Desert**	**No**	**Yes**	**Total**
Baltimore City	.081	No	122 38.7%	193 61.3%	*315*
		Yes	38 29.9%	89 70.1%	*127*
USDA LILA @ 0.5 mi	.027*	No	71 31.3%	156 68.7%	*227*
		Yes	89 41.4%	126 58.6%	*215*
USDA Vehicle Access	.554	No	93 35.1%	171 64.9%	*265*
		Yes	67 37.9%	110 62.1%	*177*
LSA	.589	No	109 37.1%	185 62.9%	*294*
		Yes	51 34.5%	97 65.5%	*148*
Total			*160*	*282*	

*Significant at the 95% confidence interval, **Significant at the 99% confidence interval



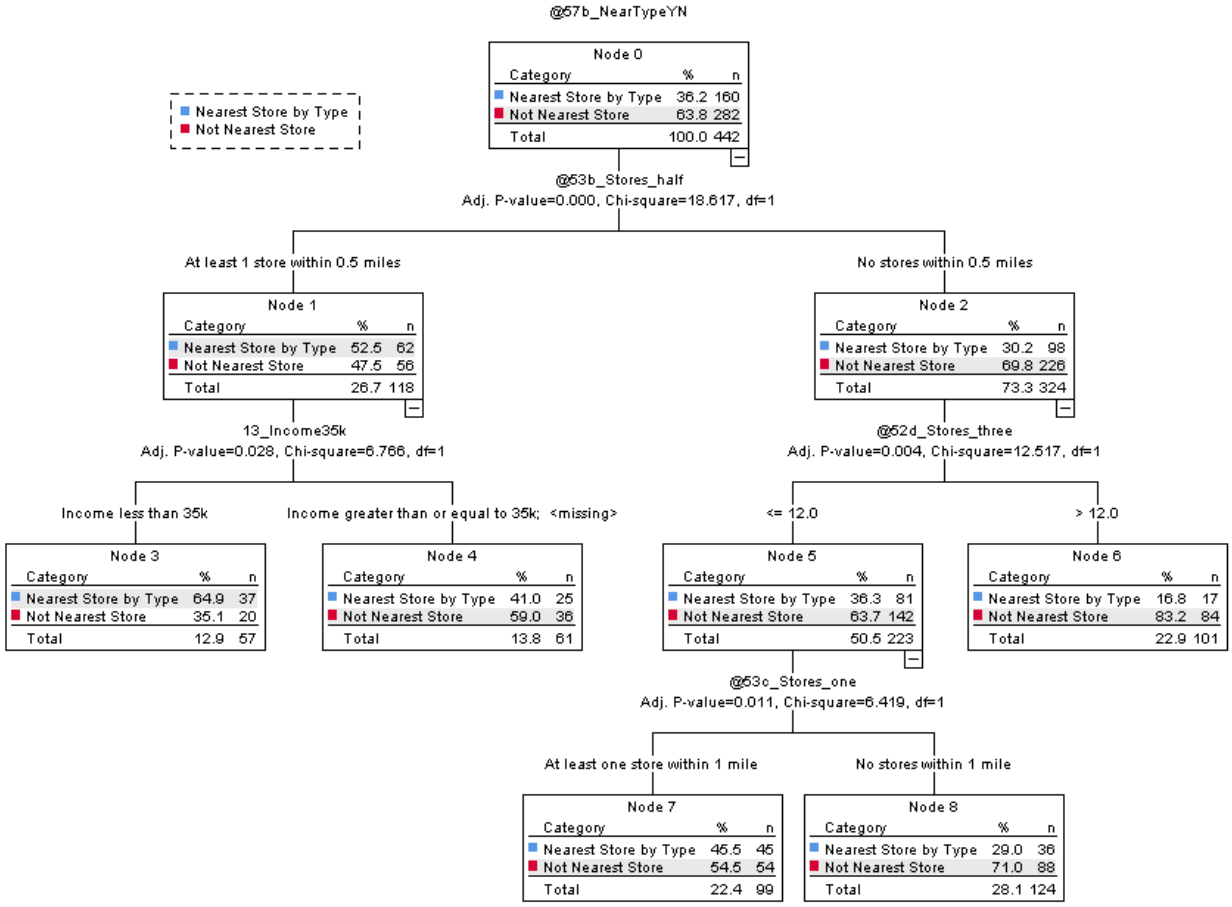
Classification

Observed	Predicted: Nearest Store by Type	Predicted: Not Nearest Store	Percent Correct
Nearest Store by Type	37	123	23.1%
Not Nearest Store	20	262	92.9%
Overall Percentage	12.9%	87.1%	67.6%

Risk

Estimate	Std. Error
.324	.022

Figure 25. Decision Tree for Shopping at Nearest Store by Type (Model 1,2)



Risk

Estimate	Std. Error
.324	.022

Classification

Observed	Predicted: Nearest Store by Type	Predicted: Not Nearest Store	Percent Correct
Nearest Store by Type	37	123	23.1%
Not Nearest Store	20	262	92.9%
Overall Percentage	12.9%	87.1%	67.6%

Figure 26. Decision Tree for Shopping at Nearest Store by Type (Model 3)

New Food Desert Metric

The previous section showed that current food desert metrics did not adequately predict access to grocery stores. The difficulty with food desert measures is that individual-level data is aggregated to a geographic area to determine the area to prioritize for food security. Table 25 summarizes the results of the CHAID Decision Tree Analysis; the p-value and level in tree are provided. Income was the most important determinant in the accessibility factors. However, the threshold varied depending on the dependent variable under consideration. Income thresholds of $20,000 and $35,000 were the most prevalent. Since income of less than $35,000 was the sole predictor of the number of stores visited, it

will be considered in developing the new food desert metric.

Vehicle ownership was not a significant predictor of any of the measures. Vehicle ownership and income are highly correlated. The study found that income was a more significant indicator of accessibility. Additional socioeconomic variables were considered in Model 2. Education was the new socioeconomic factor that was significant for any of the accessibility variables; those with a college degree shopped at stores with higher quality. However, since this factor only appears in one accessibility measure, it is not considered for the new food desert metric.

The decision to shop at the nearest store is based on proximity to the nearest grocery stores. Those who have a store within half a mile from home are most likely to shop at the nearest store. This was the first level in all nearest store models. For shopping at the nearest store of your preferred type, income less than $35,000 was significant. For Model 3, the number of stores within 3 miles also was important.

Based on the results presented in Table 25, the following is recommended for predicting food insecurity in Baltimore:

- Median household income of census block group less than $35,000 (source: ACS 2018 1-year estimate), and
- Residential land use (source: Open Data Baltimore).

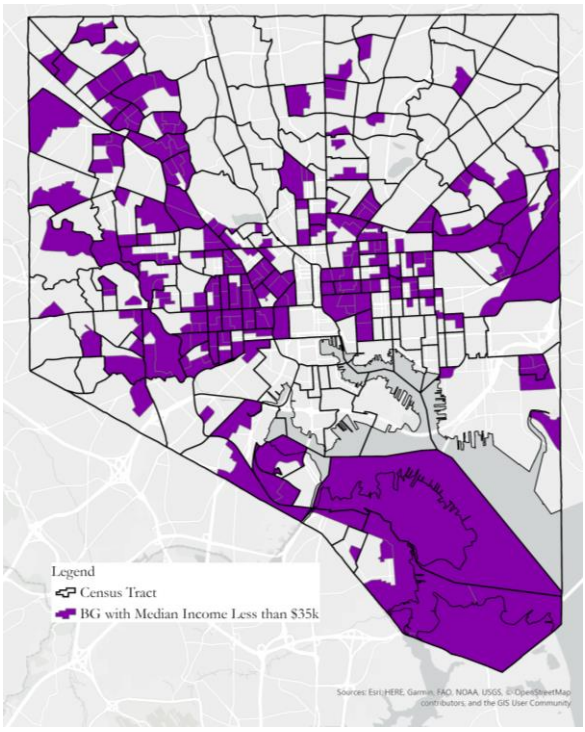
Figure 27a shows the median income in each block group. The more affluent areas of Baltimore are concentrated in the north-central and southeast portions of the city. In alignment with the Baltimore City Healthy Food Priority Area measure, only areas zoned for residential use are included in the food insecurity measure. As shown in Figure 27b, some census block groups have concentrated residential areas or are absent of residential use all together.

Since this study found that people value choice in grocery stores, locations near a grocery store were not excluded as food insecure as proximity to a grocery store did not preclude individuals from reduced grocery accessibility. To address choice and proximity, a prioritization index was created where 1 = high priority and 4 = low priority. The prioritization index is based on network distance to the grocery store where:

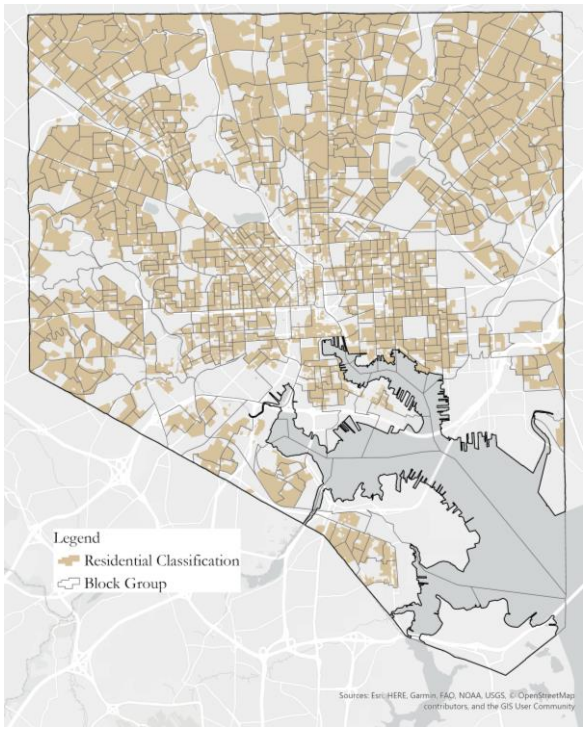
- Priority #1 = 7 or fewer grocery stores within 3 miles and the nearest store is more than 0.5 miles away
- Priority #2 = 8-10 grocery stores within 3 miles and the nearest store is more than 0.5 miles away or 7 OR fewer stores within 3 miles and the nearest store is within 0.5 miles
- Priority #3 = More than 10 grocery stores within 3 miles and the nearest store is more than 0.5 miles away OR 8-10 grocery stores within 3 miles and the nearest store is within 0.5 miles
- Priority #4 = More than 10 grocery stores within 3 miles and the nearest grocery store is within 0.5 miles.

Table 25. Summary of CHAID Decision Tree Analysis

Factor	Frequency Model 1,2,3	No. of Stores Model 1,2,3	Quality Model 1	Quality Model 2	Quality Model 3	Nearest Model 1,2,3	Nearest by Type Model 1,2	Nearest by Type Model 3
Income < 20k	(L2) p=.042		(L1) p=.000		(L1) p=.000			
Income < 35k		(L1) p=.000					(L2) p=.028	(L2) p=.028
Income < 50k					(L3) p=.000			
Income < 75k			(L2) p=.000					
Income < 100k	(L1) p=.001							
Store within 0.5 mi?						(L1) p=.001	(L1) p=.000	(L1) p=.000
Store within 1mi?								(L3) p=.011
Education (college degree or not)				(L1) p=.000				
# of Stores within 3 mi (0-7, 8-10, 11+ stores)					(L2) p=.000			
# of Stores within 3 mi (0-12, 13+)								(L2) p=.004



(a)



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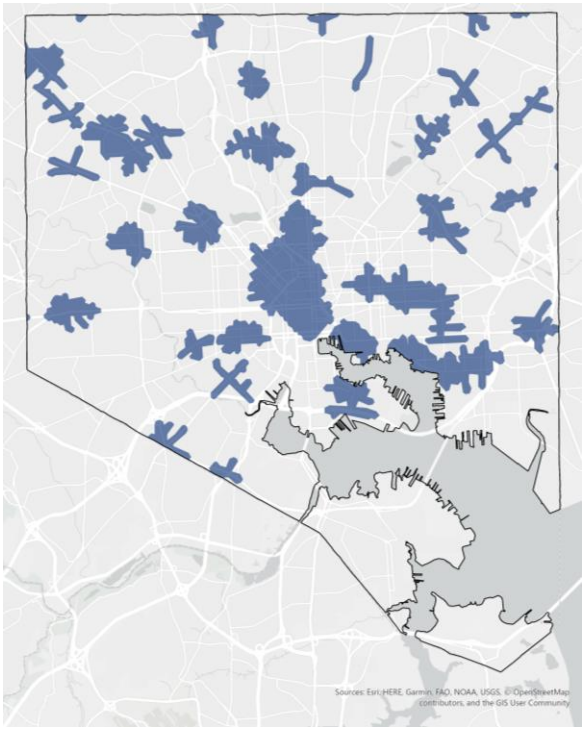

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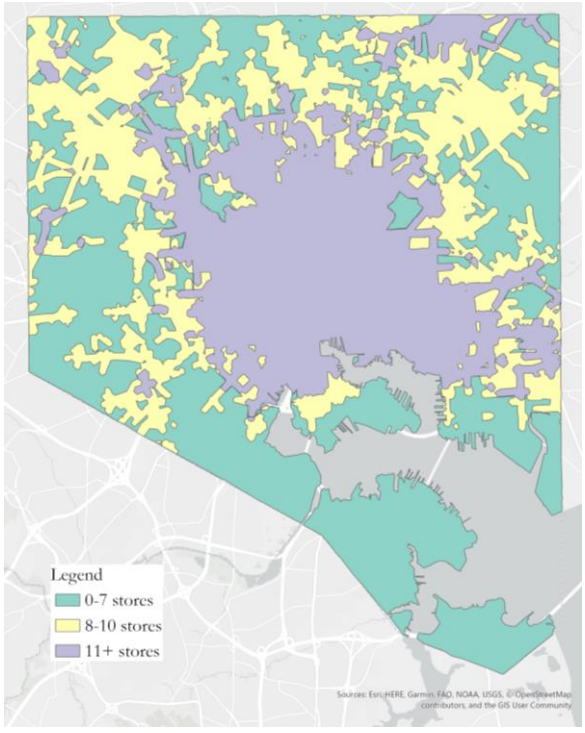

(d)

Figure 27. Factors for New Food Desert Metric (a) Census Tracts with Median Income Less than $35,000, (b) Areas Zones Residential, (c) Half Mile Network Distance From Store, (d) Number of Stores in 3 Miles

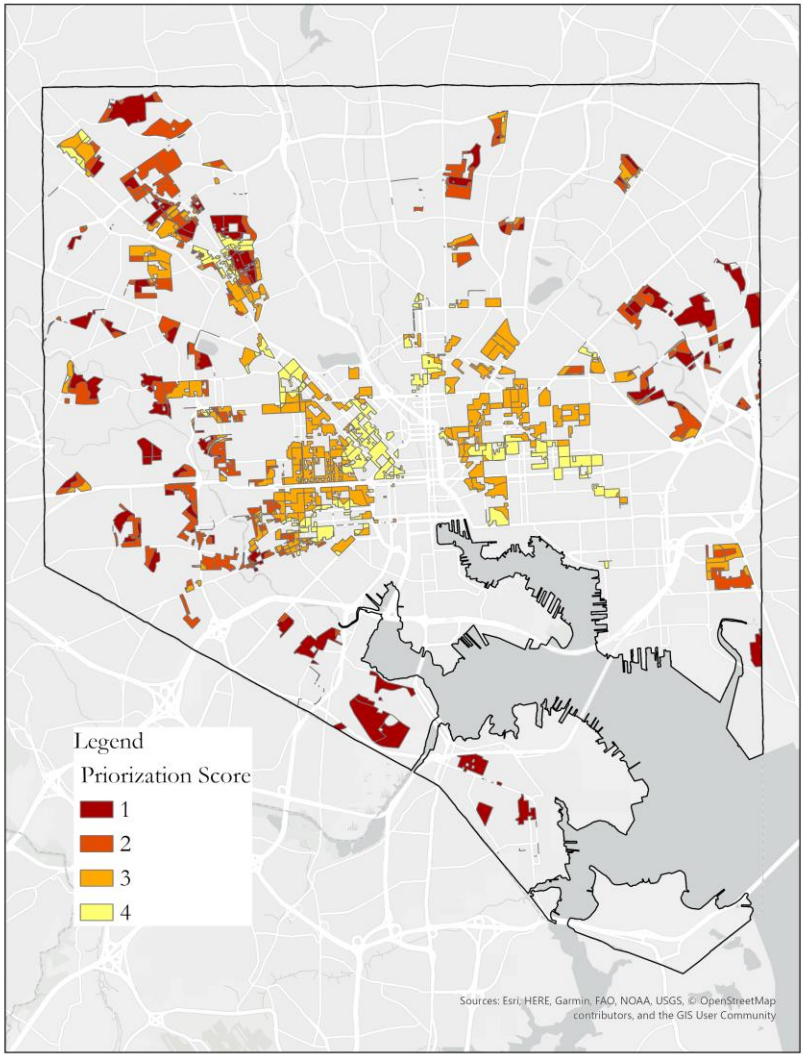

Figure 29. New Baltimore City Healthy Food Prioritization Area

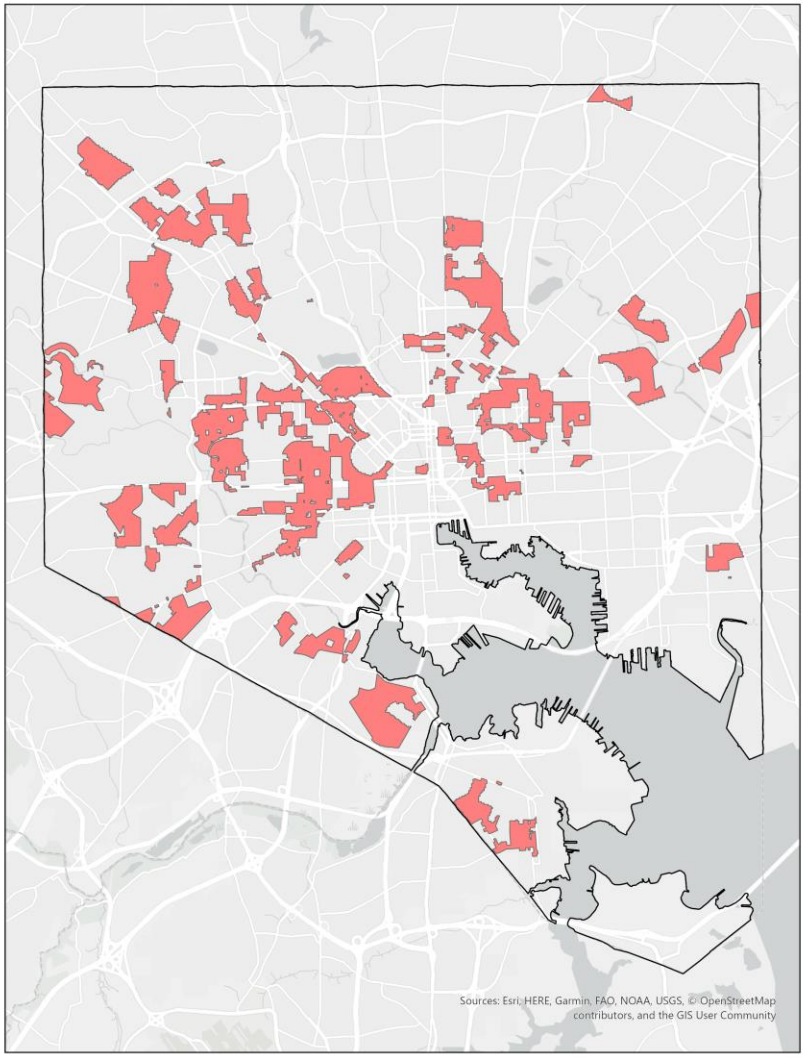

Figure 28. Current Baltimore City Healthy Food Prioritization Metric

Comparison of New Metric to Existing Metrics

Figure 29 shows the New Baltimore City Healthy Food Prioritization Metric next to the existing Baltimore City Healthy Food Priority Areas in Figure 28. Generally, the areas denoted as a food desert in the new metric align with the current metric used by Baltimore City. However, this new metric identifies additional areas in the far north, far northeast, and far northwest portions of the city. Moreover, the new metric shows that areas on the outside and in the far east should be prioritized for investment.

Table 26 shows that the new food desert metric found that at the 95% confidence interval those who live in food deserts grocery shop less often than those who do not. Additionally at the 99% confidence interval, the quality of food at the preferred grocery store is less for those living in a food desert.

Table 26. Accessibility Indicators and the New Food Desert Metric

Metric	Sig.	Food Desert	N	Mean Rank	Mean
Frequency of Visits	.012*	No	286	257.22	4.68
		Yes	201	225.19	4.38
Number of Stores Visited Per Month	.377	No	287	248.43	2.62
		Yes	200	237.65	2.51
Quality of Food at Preferred Store	.000**	No	199	197.27	27.952
		Yes	152	148.15	27.388

*Significant at the 95% confidence interval, **Significant at the 99% confidence interval

Table 27 shows the results of nearest store analysis for the New Food Desert Metric. The study concluded that shopping at the nearest grocery store is not important to customers. Thus, when developing the food desert metric proximity to the nearest grocery store was used in the prioritization index but not in establishing whether an area is a food desert. As expected, the new food desert metric does not show a significant difference in the likelihood of shopping at the nearest store. However, when those in priority level #4 (block groups with access to 11 or more stores and who have a grocery store within half a mile from home), shopping at the nearest grocery store regardless of type was significant.

Table 27. Likelihood of Shopping at Nearest Store based on the New Food Desert Metric

			# of observations, N (% of row total)		
Metric	**Sig.**	**Nearest Store Food Desert**	**No**	**Yes**	**Total**
Nearest Store (Not a Food Desert vs. Food Desert – All levels)	.062	No	194 77.6%	56 22.4%	*250*
		Yes	134 77.2%	41 22.8%	*175*
Nearest Store by Type (Not a Food Desert vs. Food Desert – All levels)	.192	No	88 33.7%	173 66.3%	*261*
		Yes	72 39.8%	109 60.2%	*181*
Nearest Store (Not a Food Desert & Food Desert-Level 4 vs. Food Desert – Levels 1-3)	.042*	No	233 71.0%	95 29.0%	*328*
		Yes	79 81.4%	18 18.6%	*97*
Nearest Store by Type (Not a Food Desert & Food Desert-Level 4 vs. Food Desert – Levels 1-3)	.083	No	116 72.5%	44 27.5%	*160*
		Yes	208 73.8%	74 26.2%	*282*

*Significant at the 95% confidence interval

7. CONCLUSIONS

This study evaluated the grocery shopping behavior of over 500 residents of Baltimore City with the goal of better understanding how transportation availability and grocery store location impact individual access to food. In our study, 38% of those surveyed did not own a car. The carless relied on a variety of means to get the store including getting rides to the store, walking, taking public transit, and hiring private cars such as taxis or hacks. Transit was not a substitute for transportation by car in Baltimore. Of those who do not own a car 44.5% have taken transit to the store in the last month but only 25% stated that it was their primary mode of transportation to the store.

The supplemental interview of hack drivers determined that despite the changing transportation landscape, hacks play an integral role in grocery access in Baltimore. Longstanding customers patronize hack drivers for roundtrip service to the grocery store; other customers flag awaiting hack drivers for the return trip home. Though ride-hailing systems have had a slight impact on the hack industry, hacks' customer service, availability, and affordability make them a preferred option for many carless households in Baltimore.

In evaluating food desert metrics, two common assumptions are made: (1) trips originate from home and (2) people shop at the nearest store. This study found that the second assumption does not hold as an overwhelming percentage of those surveyed (77%) do not shop at their nearest grocery store and those living in a food desert were less likely to shop at the nearest grocery store. Moreover, the majority shop at 2-3 different stores in a month. Location and affordability were the two primary reasons for selecting preferred stores.

Current food desert measures were ineffective at predicting grocery store accessibility. Five measures of accessibility were evaluated: frequency of grocery store visits, number of different grocery stores visited, quality of food at preferred grocery store, shopping at the nearest grocery store, and shopping at the nearest grocery store of a particular category. Of the five, only quality of food was significantly different for those who reside in a food desert versus those who do not using all of the evaluated food desert metrics.

The study provides a systematic, evidence-based methodology for determining the geographic areas which are food insecure through the analysis of individual choice survey data. Though transportation plays an important role in accessibility, the CHAID decision tree analysis of the accessibility indicators found that vehicle ownership was not a predictor of grocery store accessibility and that income was the primary factor. Highlighting the importance of choice, the number of stores available within 3 miles was a secondary predictor of some of the accessibility metrics. Proximity to the grocery store was important in determining the likelihood of shopping at the nearest grocery store only. The study found that using a network distance of half a mile was the most significant. Additionally, using Euclidean or straight-line distance overestimates access to stores by nearly a factor of 2.

A new healthy food priority area measure was developed for Baltimore that deemed all residential

areas where the median income of the census block group is less than $35,000 as food insecure. A prioritization matrix was developed based on the secondary factors of proximity to the nearest grocery store (at the half-mile threshold) and the number of stores within 3 miles. This measure found a significant difference in the frequency of grocery store visits as well as the quality of food for those who live in a food desert as opposed to those who do not.

This research provided a replicable method for determining food insecure areas in a locality by aggregating individual data to identify geographic areas of need. Such a metric can aid policymakers in investment decisions and direct resources to areas of need. The results of the survey highlight the importance of choice in grocery access, which is not properly accounted for in the more common grocery accessibility measures. Though the method is replicable, more work is needed to determine if the conclusions found in this study on mode choice, income and distance thresholds, and vehicle ownership translate to other jurisdictions. Future work should also further explore how individuals choose grocery stores based on sociodemographics, temporal trends, and items purchased.

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APPENDIX A: SURVEY

URBAN MOBILITY & EQUITY CENTER

Food Acquisition in Baltimore City Survey

Informed Consent

The purpose of this survey is to collect data to better understand grocery travel habits of residents in Baltimore City. This study, conducted by Dr. Celeste Chavis at Morgan State University, will identify travel and access needs for households that do not have access to grocery stores and supermarkets. By doing so, we hope to promote improved accessibility to healthy food stores in Baltimore City neighborhoods. Any information that is obtained in connection with this study and that can be identified with you will remain confidential. Your decision whether or not to participate will not prejudice your future relations with Morgan State University. If you decide to participate, you are free to discontinue participation at any time without prejudice. If you have any questions, please do not hesitate to contact us. Additional questions about the study may be directed to Dr. Celeste Chavis at 443-885-5061 or celeste.chavis@morgan.edu. If you have further administrative questions you may contact the MSU IRB Administration, Dr. Edet Isuk, at 443-885-3447.

If you would like to have a copy of the informed consent please go to: http://bit.ly/MSUfoodsurvey

1. I acknowledge that I read the consent form above and I agree to participate in this study? *Mark only one.*
- ○ Yes
- ○ No

2. I am a resident of Baltimore City? *Mark only one.*
- ○ Yes
- ○ No

If you answered "Yes" to both Q1 and Q2, you are eligible to complete the survey.

Section A: Demographic Information

3. Which gender do you identify? *Mark only one.*
- ○ Male
- ○ Female
- ○ Decline to answer
- ○ Other:_____

4. What is your age? *Mark only one.*
- ○ 18 to 24
- ○ 25 to 34
- ○ 35 to 44
- ○ 45 to 54
- ○ 55 to 64
- ○ 65 or older

5. What is your ethnicity or race? *Select all that apply.*
- ☐ White
- ☐ Black or African American
- ☐ Hispanic, Latino or Spanish origin
- ☐ Asian
- ☐ American Indian or Alaska Native
- ☐ Other:_____

6. What is your marital status? *Mark only one.*
- ○ Single (never married)
- ○ Married or in a domestic partnership
- ○ Widowed
- ○ Divorced or separated

7. What is the highest level of education you have completed? If you are currently enrolled in school, please indicate the highest degree you have received. *Mark only one.*
- ○ Less than a high school diploma
- ○ High school diploma, GED or equivalent
- ○ Associate Degree (e.g., AA, AS)
- ○ Bachelor's Degree (e.g., BA, BS)
- ○ Graduate Degree (e.g., MA, MS, MEd, PhD)
- ○ Professional Degree (e.g., MD, DDS)

8. What is your current employment status? *Mark only one.*
- ○ Employed full time (40 or more hours per week)
- ○ Employed part time
- ○ Unemployed and currently looking for work
- ○ Unemployed but not currently looking for work
- ○ Homemaker
- ○ Student, unemployed
- ○ Retired
- ○ Unable to work

Section B: Household Information

9. Please enter your residence (home) five-digit zip code.

_____

10. What is the nearest major intersection to your household or neighborhood?

_____

11. How many adults (people 18 years or older) are in your household including yourself?

_____

12. How many children (people under the age of 18) are in your household?

_____

13. What is your annual household income? *Mark only one.*

- ○ Less than $20,000
- ○ $20,000 to $34,999
- ○ $35,000 to $49,999
- ○ $50,000 to $74,999
- ○ $75,000 or $99,999
- ○ $100,000 and higher

14. Do you have internet access in your house? *Mark only one.*

- ○ Yes
- ○ No

15. Does anyone in your household have a smartphone (e.g. iPhone, Galaxy S4 or higher)? *Mark only one.*

- ○ Yes
- ○ No

16. Does your household have access to a vehicle? *Select all that apply.*

- ☐ Yes, we own 1 or more vehicles
- ☐ Yes, we can borrow a vehicle when needed
- ☐ Yes, we are members of a car sharing company (e.g. Zipcar)
- ☐ No, we don't have access to a vehicle

17. What services are available in your neighborhood? *Select all that apply.*

- ☐ Buses
- ☐ Trains (light rail or metro)
- ☐ Taxis
- ☐ Hacks
- ☐ Bike-shares
- ☐ Car-shares (e.g. Zipcar)
- ☐ Ride-hailing apps (e.g. Uber, Lyft)

Section C: Perception & Willingness to Pay Questions

18. Do you consider public transit reliable (is it consistently on time)? *Mark only one.*

- ○ Yes
- ○ No
- ○ I don't know

19. What is the most you would be willing to spend on a one-way trip from the grocery store to home? *Mark only one.*

- ○ $0
- ○ $2
- ○ $4
- ○ $6
- ○ $8
- ○ $10

20. What is the MOST time, in minutes, you would be willing to spend to get to the grocery store (one-way) by each mode? *Mark only one circle per row.*

	5 min or less	6-10 min	11-20 min	21-30 min	30+ min	Unsure or Unwilling
Walk	○	○	○	○	○	○
Bike	○	○	○	○	○	○
Drive	○	○	○	○	○	○
Transit	○	○	○	○	○	○

Section D: Grocery Shopping Habits

21. Which food delivery services and apps has your household used? *Select all that apply.*

- ☐ Grocery delivery services (groceries delivered to home)
- ☐ Grocery pickup services (groceries delivered to car/pickup window at store)
- ☐ Meal prep delivery services (e.g. Blue Apron or other services which provide ingredients for meal(s) or recipe(s))
- ☐ Food takeout delivery services (e.g. Uber Eats, GrubHub)

22. In the last month, how have you traveled to and/or from the grocery store? *Select all that apply.*

- ☐ Walk
- ☐ Bike or bike-share
- ☐ Public transit (e.g. bus or train)
- ☐ Drive personal vehicle
- ☐ Get a ride or borrow a vehicle
- ☐ Car-share (e.g. Zipcar)
- ☐ Ride-hailing apps (e.g. Uber, Lyft)
- ☐ Taxi
- ☐ Hack

23. Do any of the following affect your mode choice (e.g. drive, walk, take transit) when going to the grocery store? *Select all that apply.*

- ☐ Weather
- ☐ Amount of groceries
- ☐ Physical or mental disability
- ☐ Children or other dependents
- ☐ None above

24. When going to the grocery store, select all individuals or groups who are usually accompanying you on a grocery store trip. *Select all that apply.*

- ☐ Other adults in my household
- ☐ Adults living in other households
- ☐ Children (persons under 18)
- ☐ Persons (adults or children) with mobility limitations
- ☐ None - No one accompanies me

25. When do you normally do your grocery shopping? *Mark only one.*

- ○ Weekdays (Mon, Tues, Wed, Thu, Fri)
- ○ Weekends (Sat, Sun)

26. What time of day do you typically do your grocery shopping? *Mark only one.*

- ○ Early Morning: 12 AM to 5 AM
- ○ Morning: 5 AM to 9 AM
- ○ Late morning: 9 AM to 12 PM
- ○ Afternoon: 12 PM to 4 PM
- ○ Evening: 4 PM to 7 PM
- ○ Night: 7 PM to 12 AM

27. How many times a month do you purchase groceries?

_____

28. How many different grocery store locations do you visit in a month? *Mark only one.*

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5 or more

29. Do you coordinate your grocery shopping with any of the following? *Select all that apply.*

- ☐ Pay period / Paycheck
- ☐ Retirement benefits
- ☐ Disability benefits
- ☐ Government assistance

30. List any dietary preferences or restrictions in your household? (If none, write "N/A")

Section D (continued): Grocery Shopping Habits

31. How many times a month do you purchase the following. *Mark only one circle per row.*

	Never	Once a month	2-3 times per month	4+ times per month
Fresh produce (fruits & vegetables)	○	○	○	○
Frozen food items	○	○	○	○
Fresh meat	○	○	○	○
Non-perishable items (canned foods)	○	○	○	○
Dairy	○	○	○	○
Grains (rice & bread)	○	○	○	○

32. What type(s) of store(s) do you shop at for the following items? *Select all that apply.*

	Non-profit co-op	Farmer's market	Discount grocery Aldi's	Specialty grocery Whole Foods	Super-market SafewayGiant	Super-store Walmart Target	Big box store Costco Sam's	Convenience Stores 7-Eleven Royal Farms
Fresh produce	☐	☐	☐	☐	☐	☐	☐	☐
Frozen food items	☐	☐	☐	☐	☐	☐	☐	☐
Fresh meat	☐	☐	☐	☐	☐	☐	☐	☐
Non-perishable items	☐	☐	☐	☐	☐	☐	☐	☐
Dairy	☐	☐	☐	☐	☐	☐	☐	☐
Grains	☐	☐	☐	☐	☐	☐	☐	☐

Section E: Grocery Shopping Trips to Your PREFERRED Grocery Store

For the following questions, please consider trips to the grocery store you shop at <u>most often</u>.

33. Which grocery store do you normally go to?

Name: _____ *City:*_____

*Intersection:*_____

34. Is your preferred grocery store the grocery store nearest to your home? *Mark only one.*

- ○ Yes
- ○ No
- ○ Don't know

35. I am pleased with the quality of food selection at my primary grocery store. *Mark only one.*

- ○ Strongly agree
- ○ Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly disagree

36. For what reason(s) do you shop at your primary grocery store? *Select all that apply.*

- ☐ Affordable prices
- ☐ Location
- ☐ Produce selection
- ☐ Seafood options
- ☐ Vegan options
- ☐ Gluten free option
- ☐ Fresh meat options
- ☐ Ethnic food options
- ☐ Bakery
- ☐ Pre-packaged foods
- ☐ Ready to eat foods
- ☐ Other:_____

Section E (continued): Grocery Shopping Trips to Your PREFERRED Grocery Store

37. How long would it take to get from your preferred grocery to your home by each of the following travel modes? *Mark only one circle per row.*

	5 min or less	6-10 min	11-20 min	21-30 min	30+ min	Unsure
Walk	○	○	○	○	○	○
Bike	○	○	○	○	○	○
Drive	○	○	○	○	○	○
Transit	○	○	○	○	○	○

38. <u>If you have ever taken TRANSIT to go to your preferred grocery store</u>, select the amount of time spent on each of the following? *Mark only one circle per row.*

	0 min	1-5 min	6-10 min	11-20 min	21-30 min	More than 30 min
Walking to the stop or station	○	○	○	○	○	○
Waiting for 1st vehicle (bus/train)	○	○	○	○	○	○
On the 1st vehicle	○	○	○	○	○	○
Waiting to transfer to 2nd vehicle	○	○	○	○	○	○
On the 2nd vehicle (bus/train)	○	○	○	○	○	○
Walking to grocery store	○	○	○	○	○	○

39. When going to the grocery store, from where does your trip usually start? *Mark only one.*

- ○ Home
- ○ Work
- ○ School
- ○ Other: _____

40. What is the average travel cost for one trip <u>TO</u> the grocery store? Include any parking costs. *Mark only one.*

- ○ $0 to $5
- ○ $6 to $10
- ○ $11 to $15
- ○ More than $15

41. What travel mode do you use most often when traveling <u>TO</u> the grocery store? *Mark only one.*

- ○ Walk
- ○ Bike or bike-share
- ○ Public transit (e.g. bus or train)
- ○ Drive personal vehicle
- ○ Get a ride or borrow a vehicle
- ○ Car-share (e.g. ZipCar)
- ○ Ride-hailing apps (e.g. Uber, Lyft)
- ○ Taxi
- ○ Hack

42. I use the same travel mode (e.g. bus, train, car) when leaving the grocery store (i.e. going from the grocery store to home)? *Mark only one.*

- ○ Yes ----------→ continue to #43
- ○ No----------→ survey complete

If you answered yes on question #42

43. What is the average travel cost for one trip <u>FROM</u> the grocery store? Include any parking costs. *Mark only one.*

- ○ $0 to $5
- ○ $6 to $10
- ○ $11 to $15
- ○ More than $15

44. What travel mode do you use most often when traveling <u>FROM</u> the grocery store? *Mark only one.*

- ○ Walk
- ○ Bike or bike-share
- ○ Public transit (e.g. bus or train)
- ○ Drive personal vehicle
- ○ Get a ride or borrow a vehicle
- ○ Car-share (e.g. ZipCar)
- ○ Ride-hailing apps (e.g. Uber, Lyft)
- ○ Taxi
- ○ Hack

Optional Information for Raffle

If you would like to be entered into a raffle for a $100 gift card, please provide your contact information below. This information will be kept confidential.

Email address:_____

Phone number: _____

APPENDIX B: HACK SURVEY #1

Grocery store location _____

Driver's gender _____

Driver's age _____

Number of years as a hack driver _____

Main occupation _____

Date & time of interview_____

# of hacks on site _____

Questions about the Driver

1. How many times a week do you hack at the grocery store?
2. Which grocery stores do you serve?
3. How do you decide which grocery stores to serve and when?
4. On a given day, how many hours do you work?
5. On that day, how many customers do you serve?
6. Do you have regular customers? How did you first get in touch with them? How frequently do they hack to/from the grocery?
7. When is your peak (busy) period? (day of the week, time of day, etc.)
8. Are there particular times in the month you find yourself the busiest? Why?
9. Do you drive in inclement weather?
10. How much do you charge customers? What is the fare structure?
11. How has Uber and Lyft affected your business?

Questions about the Customers

12. Where do your customers live? Where are they being dropped off at?
13. On average, how far do your customer live from the grocery store (in minutes)?
14. What percent of your customers have mobility impairments?
15. Do a majority of your customers use the service for a one-way trip or round trip?
16. Do you take more customers to the grocery store or from the grocery store?
17. What percent of your customers are female?
18. What is the average age of your customers?
19. Do your customers usually travel alone or with others?
20. Why do you think your customers choose to take hacks?
21. How many grocery bags do your customers usually have?
22. Do your customers shop at multiple grocery stores?

Conclusion

23. Any suggestions on way access to grocery stores can be improved?

APPENDIX C: HACK SURVEY #2

1. How old are you?
2. How long have you been hacking?
3. How many days a week do you hack?
4. What locations do you mostly hack?
5. Do you reside in Baltimore?
6. Is hacking a fulltime career?
7. What is the minimum and maximum price you charge your customers?
8. Are these fares fixed or based on distance?
9. Do you use a smartphone?
10. Do you accept cash only or do you accept other payment methods such as Cash App, credit cards, etc.?
11. Have you heard about Lyft or Uber?
12. Do you currently drive for either of them (if Y = SKIP *, **)
13. Are you familiar with their requirements? (Discuss the car spec requirement) *
14. Under what conditions would you drive for Lyft or Uber? **
15. Does Uber or Lyft have any impact on your work as a hack driver?
16. Do you think hacks have contributed to grocery store access in this area?