BEYOND FOOD DESERTS: ASSESSING THE IMPACT OF PUBLIC TRANSIT AVAILABILITY CHANGE ON SPATIAL ACCESS TO FOOD

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DEDICATION

I dedicate this thesis to my Bubbe, whose love, support, and commitment has always been the foundation to my success. I am eternally grateful.

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Food access is a dimension of food security that many struggle with even in high-income countries, which is a contributing factor to chronic diet-related disease. Inequalities in economic access to food has been addressed in public policy for several decades, but spatial access to food has only been seriously studied and addressed by policy for the past twenty-five years. After the food desert metaphor emerged, it was promptly accepted as a standard measure of food access for governments and a basis for policies created to address inequalities. Conceptual criticisms and methodological limitations of the metaphor have led the study of spatial access to food towards newer methods that measure food access more realistically and assist in the development and assessment of intervention strategies to inform policy decisions. This thesis describes the history of the food desert metaphor from its emergence until its adoption in US public policy, the conceptual criticisms and methodological limitations that surround it, and offers an analysis that measures the impact of change in the availability of public transportation on spatial access to food for various population subgroups that are more at risk of food insecurity in Marion County, Indiana. Results demonstrate that policies and plans designed without consideration for food access have an impact on it nevertheless, and that policymakers and planners can leverage such strategies to better coordinate efforts across government to reduce inequalities in spatial access to food and food insecurity overall.

Jeffrey S. Wilson, Ph.D., Chair

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Food insecurity is a global issue currently affecting approximately two billion (26.4% of) people worldwide who do not have consistent access to safe, nutritious, or sufficient food (FAO, IFAD, UNICEF, WFP and WHO, 2019). Generally associated with income and wealth inequalities and disparities in access to basic services, food insecurity can be conceptualized according to a scale of severity, such as with the FAO's Food Insecurity Experience Scale which ranks food insecurity as mild, moderate, or severe (Ballard et al., 2013; Cafiero et al., 2018). Measuring food security is an alternative approach that serves a similar purpose, such as the method employed by the United States Department of Agriculture (USDA) which ranks food security as high, marginal, low, and very low (*Definitions of Food Security*, n.d.). According to the classification scheme used by the FAO and other specialized agencies of the United Nations (UN), moderate food insecurity is associated with malnutrition and chronic diet-related diseases such as obesity and diabetes, resulting from uncertainty in the ability to obtain food necessary for a healthy diet, whereas severe food insecurity is attributed with undernutrition and hunger stemming from overall inadequate energy consumption (FAO, IFAD, UNICEF, WFP and WHO, 2019). Although low-income countries have higher rates of food insecurity, especially severe food insecurity, it remains an issue in middle- and high-income countries where today it is experienced by 102 million people (9%) (FAO, IFAD, UNICEF, WFP and WHO, 2019; Pollard & Booth, 2019).

While food insecurity is a broad and complicated issue, access to food, economic and physical, has been recognized as one of its four main dimensions, the others being the physical availability of food, food utilization, and overall stability (FAO, 2008). Food

consumption patterns are affected when access to food is inhibited, either through reduced overall consumption, or often, particularly in middle- and high-income countries, through unhealthy consumption. These nutritionally inadequate consumption patterns in turn increase the likelihood for poorer health outcomes. For several decades, governments of high-income nations have recognized growing inequalities in health and access to food and have developed and implemented programs and policies to address them. Social welfare programs, such as the Supplemental Nutrition Assistance Program (SNAP) in the United States, and others within and outside of the US, have specifically sought to address the economic component to food access inequalities. More recently, however, specifically throughout the past twenty-five years, governments of high-income countries have begun to develop policies to address inequalities around the physical component to food access inequalities.

The background section of this thesis describes the emergence and evolution of the study of spatial access to food, including the popularization of the food desert metaphor in public policy and academic research. In addition, this section highlights selected criticisms around and limitations involved with food desert identification and how the study of spatial access to food has advanced into a more complex science. The subsequent sections then demonstrate a method for modelling spatial access to food that goes beyond the simple methodology of food desert identification. The analysis assesses the impact of change in public transit availability on spatial access to food for groups vulnerable to food insecurity in Marion County, Indiana following two years of changes to the IndyGo bus system, including increased extended hours of operation, increased frequency of buses, route revisions, and stop relocations. The results reveal the

importance of consideration for spatial access to food by planners and policymakers and the opportunity and need for more coordinated efforts to mitigate inequalities in access to food in the larger effort to reduce food insecurity.

BACKGROUND

Emergence of Thought

Throughout the twentieth century, certain societal changes inspired the inquiry into inequalities in spatial access to food. Among these changes were ongoing restructuring of the food retail landscape, developments in the fields of public health and geography, and widening inequalities in health. The culmination of these large-scale changes ultimately prompted attention from policymakers and researchers to the issues people face physically accessing healthy food.

Transformations in the food retail landscape of the twentieth century began with rapid industrialization of food production processes, which significantly impacted what food people buy and where they buy it. Due to economics of scale, a growing range of products, advancements in food transportation and storage, and a demand for convenience, grocery stores began to replace the smaller specialty shops of the past, such as butchers, produce markets, and bakeries (Bentley & Hobart, 2014). By the end of the Second World War, large grocery store chains had grown more abundant and became the common source for food procurement. The 1980s brought further restructuring of the food retail landscape, an era that became known as the "store wars" (Wrigley, 1994). Major grocery chains, who had become dominant economic actors, began to pull out of city centers, opting instead for development of larger, but fewer stores located around the periphery of urban centers and into the suburbs (Deener, 2017). This phenomenon has been called supermarket redlining (Eisenhauer, 2001; Zhang & Ghosh, 2016) and, in part, was due to lower land values which were favorable for rising start-up costs (C M Guy, 1996; Wrigley, 1998b). This left many inner-city neighborhoods without convenient

access to healthy food, especially neighborhoods with higher concentrations of low-income and minority populations (Eisenhauer, 2001; Thibodeaux, 2016). As a result, the only readily accessible food retail outlets left in these neighborhoods were convenience stores and fast food restaurants, leaving a high concentration of processed and otherwise unhealthy foods (Bentley & Hobart, 2014).

Simultaneous with these market-driven transformations of the food retail environment, the study and practice of public health and geography was also evolving throughout the twentieth century. Public health, like many other fields of study and practice, has undergone paradigm shifts over time (Ridgway et al., 2019). The line of thought ultimately responsible for the study of spatial access to food, specifically as it relates to health outcomes, emerged as a consequence of what can be understood as a particular paradigm shift in public health, that is, the integration of social ecology and adaptation of the social-ecological model (SEM) (Kartman, 1967; McLeroy et al., 1988; Stokols, 1996). Since the late 1960s, the intersection of social ecology and public health began as a criticism of previously accepted understanding that an individual's health is solely determined by their own agency regarding health-impacting behaviors (Shannon, 2014). The SEM increased focus on geographical context in public health research, with the community as a unit of observation for disease prevention (J. Gordon, 1963), and with attention to both compositional and contextual characteristics of environments that influence the health-impacting behaviors of individuals within them (Curtis & Jones, 1998; Macintyre et al., 1993; Stokols, 1996). Concurrently with the adoption of the SEM in public health, developments within the field of geography were underway. First, geographic information systems (GIS) technology was introduced, making spatial

analysis and identification of area-specific issues related to health much easier for geographers and public health professionals alike, and influencing public policy as a result (McKinnon et al., 2009; Shannon, 2014). In addition to the technological capabilities that came with GIS, a new subdiscipline, the geography of health, also emerged, which brought focus to the spatial distribution of health outcomes and health-impacting factors of the environment (Kearns & Moon, 2002; Moon, 2009). Prior to the geography of health, spatial analyses of health-related topics were confined to the medical geography subdiscipline, closely related to epidemiology and founded on the biomedical model (Dummer, 2008). Unlike medical geography, health geography is situated within the social, cultural, and political contexts that impact health.

As these advancements within the fields of public health and geography took place, researchers and policymakers began to question the relationship between continuously widening inequalities in health outcomes across socioeconomic groups, specifically, the increasing rates of diet-related chronic disease such as obesity and diabetes, with the inequalities that resulted from changes to the food retail landscape, including a lack of healthy food or an overabundance of unhealthy food in certain neighborhoods (Shannon, 2014). This led to the beginning of what has now been thirty years of public policy and academic study dedicated to the topic of spatial access to food.

Origins of the Food Desert Metaphor in Public Policy and Academic Research

The term ‘food desert’ is a metaphor that has had significant influence over the study of spatial access to food and public policy directed at mitigating inequalities involving it. Building off the developments of the twentieth century outlined above, political activity in the United Kingdom (UK) was ultimately responsible for introducing

the term, which, despite criticisms since its origin, grew popular among researchers and policymakers within and beyond the borders of the UK in a matter of just a few years. This section provides a chronological description of the introduction and proliferation of the food desert metaphor in government and academia, as it began to appear in government publication and academic journals, and how it eventually led to the development of initiatives for improving food access in the US.

In 1980, the UK Department of Health and Social Security released the report *Inequalities in Health* (D. Black, 1980). This report described a connection between increasing inequalities in health outcomes and factors of socioeconomic deprivation related to income and employment, housing, education, and diet, and it recommended significant public expenditure on social programs to address the issue. Although the report had a profound impact on political and academic thought throughout the UK and elsewhere, including within the WHO (Crombie et al., 2005), it was neglected and downplayed by the Thatcher Administration, in office at its time of release (Gray, 1982). By the 1990s, however, the continued increase in health inequalities between socioeconomic groups prompted more serious attention and a stronger push for political intervention in the UK. With a growing prevalence of food poverty, it was suspected that nutrition played a role in the poorer health outcomes of less advantaged socioeconomic groups. In response, the UK government, through its report entitled *The Health of the Nation* (Department of Health [DoH], 1992), created the Nutrition Task Force (NTF), a committee of senior government officials to investigate the matter. Although it is said that the food desert metaphor was first used in the early 1990s by a public housing resident in the West of Scotland (Cummins & Macintyre, 2002a), and while it was not the

first publication to draw attention to inequalities in spatial access to food (Macintyre et al., 1993), a report authored by a policy working group of the NTF's Project on Low Income (Beaumont et al., 1995) often receives credit for coining the term 'food desert', which it generally defined as an area where residents experience physical and economic barriers to obtaining healthy food. In addition to assigning a name to the phenomenon, the report also acknowledged how the changes that had occurred to the food retail landscape over prior decades had assisted in the production of these newly named places. Another notable contribution of this report was that it called for the development of systematic methods and indices to measure the availability and cost of healthy food in specific areas to avoid dependency on subjective classification. This report was said to have laid the foundation for future study of food deserts (Whitehead, 1998).

Perhaps motivated by the report, though beyond the scope of food access, political activity began on the retail planning front to address inequalities in access to services. An era of tightened land use planning regulations began (Wrigley, 1998a; Wrigley, Guy, et al., 2002) and as a result, the development decisions of major food retailers was impacted, forcing the adoption of urban regeneration agendas by several of the largest food retailers. This was notably driven by a 1996 revision to the Department of Environment (DoE)'s Planning Policy Guidance Note 6 (PPG6) *Town Centres and Retail Development* (DoE, 1996), formerly named *Major Retail Development* (DoE, 1993). The name change of PPG6 alone indicated a shift in focus toward supporting the town centers which had been harmed by previous development trends (Reisig & Hobbiss, 2000). Through the revision to PPG6, to make obtaining permission more difficult for new retail development outside of town centers, a 'sequential test' was introduced to the planning

approval process which prioritized retail development within town centers. Although difficult under the new regulation, retail development could still occur on the edges of town, but only under certain conditions: if transit-assessable, if proof of a need could be established, and if locating within a town center would result in disruption to the existing retail landscape. It can be argued that this contributed to the introduction of several centrally-located, smaller, and more compact format stores by major food retailers, however, competition with emerging discount retailers likely also played a role (Wrigley, 1998b).

Following the election and establishment of Tony Blair's government in May 1997, the food desert metaphor proliferated further in UK policies. While the NTF that had been created by the previous government was dissolved, attention to inequalities in food access was welcomed under the new administration's agenda focused on addressing issues of social exclusion. Two significant actions were taken within the first year of the new leadership that brought the concept of food deserts into the spotlight. First, in July 1997, the Secretary of State for Health commissioned the *Independent Inquiry into Inequalities in Health*, chaired by Donald Acheson and overseen by a scientific advisory group, to review issues around inequalities in health and to identify priority areas for policy development to address them. Second, the Social Exclusion Unit (SEU) was formed in December 1997 as a new body under the Cabinet Office. The SEU would go on to play an influential role in the years to follow regarding promotion of the food desert metaphor.

September 1998 was a significant month for the proliferation of the food desert metaphor, with three major developments. First, a little more than a year after its

commencement, the *Independent Inquiry* came to a close and a final report was presented to the DoH (Acheson, 1998). While the content of the report covered a wide range of topics related to inequalities in health, a section specific to nutrition highlighted increasing inequalities in access to healthy food. This topic spanned two sub-sections: 'Increasing the availability and accessibility of food' and 'Reducing food poverty and improving retail provision'. Both were concerned with economic access to healthy food, but the later was especially concerned with physical access, particularly the ways in which it can worsen existing economic access. To support this, the report explained how supermarkets, which tend to be located further out from town-centers, sell a larger variety of food at lower cost than smaller local stores, and that food deserts are created as a result, or areas where "cheap and varied food" is inaccessible to those without access to public or private transportation. Beyond merely drawing attention to the issue though, the report also delivered recommendations for the development of policies "which will increase the availability and accessibility of foodstuffs to supply an adequate and affordable diet", and "which will ensure adequate retail provision of food to those who are disadvantaged" (p. 65-66).

The second development that month was the SEU's release and presentation to Parliament of *Bringing Britain Together: A National Strategy for Neighbourhood Renewal* (SEU, 1998), which emphasized the food desert theme within a broader focus on neighborhood deprivation. With another explicit use of the term in its review of the various issues faced among residents of deprived neighborhoods, including poor access to services, the report outlined how limited access to food retail exacerbates the affordability of a healthy diet and thus contributes to inequalities in health, similar to

what had been reported in the Independent Inquiry's report. It set forth an objective for the development of a comprehensive strategy to address social exclusion at the neighborhood level through area-based interventions (Wrigley, Guy, et al., 2002), a strategy criticized by some (Chatterton & Bradley, 2000; Oatley, 2000; Watt & Jacobs, 2000), but for which efforts prevailed nevertheless. To devise the various components of the comprehensive strategy, the SEU employed 18 cross-disciplinary Policy Action Teams to integrate with government departments down to the local level. Policy Action Team 13 (PAT13) was specifically involved with access to shops, including food retail, and was charged with developing policy recommendations for the comprehensive strategy that could improve access for residents of low-income urban neighborhoods.

A third development that occurred in September 1998 was the debut of the food desert metaphor in an academic publication when the *Health Education Journal* released an issue with a leading editorial piece titled "Food Deserts – What's in a name?" (Whitehead, 1998). Acknowledging that no formal definition for the term existed, the article provided a summary of the phenomenon and also argued that its granting of a name may have ultimately been what captured the interest of policymakers. A two-part article series on access to healthy food followed and delved further into the topic. In the first of these two articles, Caraher et al. (1998) found that income and transportation had significant influence on food shopping behaviors such as where people shop and what they shop for. While this article made no use of the term 'food desert', the second article discussed the specific impact that food deserts have in relation to the food shopping behaviors outlined by the first paper (Lang & Caraher, 1998). Both articles called for a new direction for health promotion strategy regarding food consumption, one less

focused on the choices made by individuals, as had previously been the norm, but rather one that recognizes access impacts an individual's choice to begin with.

In 1999, greater political momentum built around addressing food deserts when PAT13 released a report titled *Improving Shopping Access for People Living in Deprived Neighborhoods* (PAT13, 1999). This report expressed that the food choices people make are impacted by the availability and affordability of food acquired locally, and that residents of low-income neighborhoods in particular experience poorer access to a healthy diet. Interviews conducted with residents of low-income neighborhoods indicated that distance to stores was the most significant barrier to shopping, and as a result, the report questioned what effect a non-healthcare intervention could have on the situation and supported the idea of local, community-based retail regeneration in deprived areas as well as health impact assessments on retail planning proposals. This report, along with others (DoH, 1999a, 1999b), gave attention to the issue and contributed to development of a comprehensive strategy.

While the food desert metaphor was continuing to gain influence within policy circles, criticisms began to surface around the way it had been embraced by government before it was supported with empirical evidence, in addition to criticism over the existence of inequalities in spatial access to food to begin with. Two articles published in an issue of the *British Food Journal* expressed these criticisms and presented the earliest spatial analyses on the topic utilizing GIS. In addition to pointing out the lack of systematic evidence on the prevalence of the problem, Cummins and Macintyre (1999), in a study of Glasgow, Scotland, found that food retail existed in greater abundance in deprived areas, the opposite of the assumptions by those promoting the metaphor. Despite

this, the authors also emphasized that policies that seek to increase access to healthy food must also take into account income levels, mobility, and social support benefits for the most vulnerable. In a second study, Donkin et al. (1999), also failed to find evidence for the existence of food deserts in their larger-scale analysis of two wards in London, which, unlike the first study, considered walking time and distance to retailers.

Despite these mounting criticisms, investigations into the existence of food deserts continued. In the East London and The City Health Authority Study of Food Access (1999), spatial analysis using GIS showed support for the existence of food deserts, contrasting with the two studies that appeared in the *British Food Journal*. In it, access to food retail for every household of each ward within three boroughs of East London was calculated and revealed a significantly sized population of deprived areas that resided beyond a reasonable walking distance of five-hundred meters to food retail outlets. The study then took a closer look at specific wards where access was poorest and identified smaller geographic areas within them where access was especially problematic. The impact of the study included a new commitment by the City Health Authority to address these access issues via partnerships with the communities and, by calling for the attention of urban regeneration decision-makers, highlighted the need for an integrated approach in conjunction with the comprehensive strategy on addressing social exclusion.

By the turn of the century, the commitment of policymakers to addressing food deserts in the context of social exclusion was well established, including support for a new criterion in retail planning policy by the DoE with concern for impact on food access. Again, this was despite continued criticisms around the use and legitimacy of the metaphor. In its inquiry into the supply of groceries from major food retailers in the UK,

the Competition Commission, an independent public body responsible for inquiries into mergers, markets, and regulated industries for the benefit of companies and consumers, looked into the issue of food deserts and produced a report (Competition Commission, 2000) for the Department of Trade and Industry on its findings. While the report expressed an overall skepticism regarding the scale of the issue, based off a lack of evidence found through its own research, it did challenge the analysis conducted in the Donkin et al. (1999) study, claiming that the area selected for observation had a relatively wide range of food retail outlets and therefore could not preclude evidence for the existence of food deserts. Studies on food deserts continued as the government began to sponsor several interdisciplinary research projects on diet-related health via the Eating, Food and Health LINK Programme in 2000 (Shepherd, 2001a, 2001b). Of the six themes of the program, one placed particular focus on how consumer food purchasing is affected by access to retail outlets. Under this theme, three major projects were coordinated that contributed meaningfully to the initial research on food deserts.

First, a study in Newcastle, funded by the Food Standards Agency, involved a multiscale observation of the existence of food deserts (White et al., 2004). Investigating the relationship between diet and socioeconomic factors at the individual, household, and neighborhood levels, in addition to geographic proximity to healthy food retail, it was unable to find a relationship between indicators of healthy eating and factors related to the spatial access to food retail. Instead, the study found that the key predictors of healthy eating centered around dietary knowledge, relative affluence, and an otherwise healthy lifestyle overall. While the study failed to show a relationship between diet and access to healthy food retail for most people, it did not dismiss the existence of food deserts

completely. Rather, the study concluded that food deserts do exist, but only for some, including a minority of people who cannot access food outside their immediate localities for various reasons, including lack of transportation.

The second study, the largest and likely the most influential, was the Food Deserts in British Cities project (Wrigley et al., 2003). Funded by the Economic and Social Research Council and one of the major food retailers in the UK, the study was conducted by researchers from the Universities of Southampton, Leeds, and Cardiff spanning the fields of geography, public health and nutrition, and urban planning. This multiscale project incorporated both quantitative and qualitative methods. The first part of the project involved the city-wide modelling of food retail access in Leeds and Cardiff and simulated the introduction of new supermarkets, including a store that was actually slated for development in the Seacroft ward of Leeds, a heavily deprived urban area. The second and third parts of the project then focused in on the impacts of the store development in Seacroft, making it the first ever before-and-after study of the impacts on food access and diet outcomes from introduction of a new food retail outlet. The project also included a survey (Warm et al., 2001) of food shopping and consumption behavior of neighborhood residents both before and after the introduction of the new supermarket, and utilized focus groups to gain an understanding of the lived experiences of the residents through the change. While the project was ongoing until 2003, interim results which showed an increase in fruit and vegetable consumption following the introduction of the new supermarket were presented at a workshop at the University of Leeds in 2001 and later published in a five-part article series in a special issue of the journal *Urban*

Studies (Clarke et al., 2002; Whelan et al., 2002; Wrigley, 2002; Wrigley, Guy, et al., 2002; Wrigley, Warm, et al., 2002).

Similar to the study in Leeds, the third study (Cummins et al., 2008) also looked at the introduction of a new supermarket, but in an area of Glasgow that had not been specifically identified as having low access to food (Cummins & Macintyre, 2002b). Unlike the Leeds study, the Glasgow study was more controlled and compared results to another area that did not receive a new supermarket. While the Leeds study looked at a connection to diet, the study in Glasgow went further to look also at the impacts on general wellbeing beyond diet alone. Unlike the two studies just described, the Glasgow study did not seek to identify food deserts nor prove their existence, but rather intended to observe the impacts of new food retail provision as an intervention strategy. The findings ultimately suggested the introduction of a new supermarket did not have a major impact on fruit and vegetable consumption, however, an overall increase in fruit and vegetable consumption was observed for both the area that received a new supermarket and the area that did not. Because of this, the authors questioned the positive results that came out of the Leeds study, given its uncontrolled design and the possibility of other factors which were responsible for the increase in fruit and vegetable consumption.

By the time policy efforts in the UK around social exclusion eventually culminated into the National Strategy for Neighbourhood Renewal (SEU, 2001), the food deserts metaphor had spread internationally. Studies on the existence of food deserts continued in the UK with mixed results, consistent with similar studies in other high-income countries including Canada, Australia, and New Zealand (Beaulac et al., 2009). In the United States (US), however, the existence of food deserts and studies on them

gained the widest support due to greater evidence for inequalities (C. Black et al., 2014; Cummins & Macintyre, 2006; Walker et al., 2010). With this, the study of food deserts quickly became integrated with research on food insecurity, which had already emerged as a popular area of research in the US (Shaw, 2006).

The food desert theme, and disparities in spatial access to food overall, was eventually picked up by municipal, state, and federal policymakers in the US. In 2004, the Commonwealth of Pennsylvania launched its Fresh Food Financing Initiative (FFFI), the first program of its kind (B. Lang et al., 2013). Under a public-private partnership structure, the program helped finance the development of grocery stores and nontraditional retailers, such as farmers' markets, food co-ops, community-supported agriculture, and public markets, in underserved areas. Since its creation and celebrated success, it has informed various programs in other states and municipalities, including the Healthy Food & Healthy Communities Fund in New York and the Fresh Food Retailer Initiative in New Orleans, Louisiana. The federal government began its involvement with the food desert metaphor through a one-year study initiated by the 2008 Farm Bill (Food, Energy and Conservation Act of 2008, 2008) to assess the extent, characteristics, and causes of areas with limited access to affordable and nutritious food. The report produced from the study was presented to Congress and featured the FFFI as an example for successful mitigation policy to the food desert problem (Ploeg et al., 2009). The FFFI also inspired the creation of the federal government's Healthy Food Financing Initiative (HFFI) in 2010, a partnership between the USDA, the Departments of Treasury, and the Department of Health and Human Services under the Obama administration. Similar to the FFFI, the HFFI provided financing to reduce barriers that exist for the opening,

expansion, or renovation of food retail spaces in areas lacking adequate access to healthy food. The HFFI was launched in conjunction with the Former First Lady Michelle Obama's Let's Move! initiative on childhood obesity, for which the FFFI and the food desert metaphor were focus points. The Partnership for a Healthier America, an independent foundation created to continue the work of the Let's Move! initiative has since been involved in various private sector partnerships that address the spatial component of healthy food access (Simon et al., 2017). These efforts have included the building and renovation of hundreds of grocery stores and over a thousand convenience stores in areas classified as food deserts.

In 2011, The USDA's Economic Research Service (ERS) launched the Food Desert Locator, later renamed the Food Access Research Atlas in 2015, an interactive map that uses web-based GIS technology to identify areas across the US with low access to food ("Food Access Research Atlas," n.d.). The method employed for identifying and mapping food deserts coincides with the definition developed by a working group for the HFFI, that is, low-income census tracts with a substantial number of residents with low levels of access to retail outlets that sell healthy and affordable foods. To qualify as low-income, a census tract must have a poverty rate of twenty percent or greater, or must have a median household income at or below eighty percent of that for its respective state or metropolitan area. To qualify as low-access, at least five hundred people or thirty-three percent of the population residing within the census tract must live more than a one-mile distance from a supermarket or large grocery store. This definition has become the most widely used in studies on food deserts and is regularly used in the design of mitigation strategies by governments across the country.

Conceptual Criticism and Methodological Limitations of the Food Desert Metaphor

Although the concept of food deserts has been met with acceptance by policymakers across various levels of government to tackle disparities in access to food, criticisms of it have been consistent. While some of the earliest criticism involved overall skepticism regarding inequalities in spatial access to food in the first place (Competition Commission, 2000; Cummins & Macintyre, 1999; Donkin et al., 1999), criticism since has been concerned more so with the metaphor itself as a conceptualization and measure of spatial access to food (Adams et al., 2010; Sadler et al., 2015). One issue recognized early on (Cummins & Macintyre, 2002a), which has never been resolved, is that a standardized definition of a food desert and systematic method of identifying them does not exist (McEntee, 2009; Shaw, 2006; Widener, 2018). This has resulted in various interpretations, which can result in inconsistencies when comparing results across studies (Adams et al., 2010; McKenzie, 2014) and can lead to poorly informed policy decisions (Glanz et al., 2016). While not truly universal, the most widely used criteria for identifying food deserts is the USDA's definition, described in the previously, which is the basis for many, if not most, US government policies and programs that seek to address inequalities in spatial access to food. Because of this "semantic infancy", as McEntee (2009) appropriately asks, "how can we expect food desert literature and identification strategies to progress and evolve?" (p. 358).

Besides the fact that a universal definition or method has not come about for over two decades, the concept of food deserts remains challenged for other reasons as well. For example, Widener (2018) explained how the food desert metaphor overemphasizes space and neglects other factors that influence access to food, and that it creates a false

binary for the measurement of spatial access where areas are classified either as having access or not. This poorly captures reality and can be problematic in the determination and implementation of solutions intended to target inequality in spatial access to food. Widener (2018) also makes the case for retiring the metaphor altogether so that a more holistic understanding of food access can be embraced, one where the availability of food is just one component of access among others, such as accessibility, accommodation, affordability, and acceptability, which adhere to Penchansky and Thomas's (1981) dimensions of access. In a review of food access studies classified according to these dimensions of access, Caspi, Sorensen, et al. (2012) demonstrated how GIS-based spatial methods have primarily focused only on the availability and accessibility dimensions. This is likely due to the dominant role that the food desert metaphor has had over studies involving spatial access to food, which ignores the complexity of food procurement behaviors at the individual and household level. To make spatial analysis more inclusive of the other dimensions of access, a more comprehensive and integrated measurement approach is needed, one which blends the quantitative measures of physical and economic access with qualitative measures of other factors that also influence what food people buy and where they buy it (Alkon et al., 2013; McEntee, 2009), such as, but not limited to, nutritional knowledge (Reisig & Hobbiss, 2000), cultural preference (Behjat et al., 2013), and perception (Caspi, Kawachi, et al., 2012; Flint et al., 2013; Haynes et al., 2007). Shannon (2014) also stresses that critical GIS methods (Pettygrove & Ghose, 2016; Sheppard, 2005) can play a necessary role in the study of spatial access to food going forward, including the use of participatory science and volunteered geographic information.

Going Beyond the Food Desert Metaphor for Measuring Spatial Access to Food

In addition to the conceptual criticisms of the food desert metaphor as a measure of spatial access to food, several methodological limitations exist with it as well. Over time, however, newer and more complex analytical methods have been employed to address these limitations, which can be categorized into structural limitations, mobility limitations, and temporal limitations. Structural limitations are inherent to spatial analyses in general, beyond just the topic of spatial access to food. They include the boundary problem, the Modifiable Areal Unit Problem (MAUP), and the Uncertain Geographic Context Problem (UGCoP). All of these problems arise from the use of enumeration units to partition geographic space, within which data is tabulated. For spatial access to food in particular, this applies to the units by which performance indicators are calculated, including basic performance indicators, such as summary statistics like total store counts, accessibility indicators, such as proximity measures, and model-based indicators, such as outputs from spatial interaction models (Clarke et al., 2002). Administrative boundaries are often used as enumeration units, the boundaries of which are often administrative boundaries, which are often arbitrary when it comes to how and where people access food, although they can sometimes adhere to natural geographic barriers such as rivers and forests, as well as to transportation networks such as highways and railroads, which can influence access. Without sensitivity to these types of problems, spatial analyses may produce results that are unrealistic and inaccurate (Bao & Tong, 2017).

The boundary problem (Griffith, 1980, 1983; Griffith & Amrhein, 1983) involves both the edge effect and the shape effect. The edge effect relates to the idea that a

phenomenon occurring within a spatial unit is interdependent upon that which occurs within adjacent units. Because of this, what is measured for one unit can starkly contrast from what is measured for a neighboring unit, inaccurately portraying the real world where boundaries may not have as large of an impact. When measuring spatial access to food, failure to address the edge effect dismisses the reality that people may cross a boundary, sometimes multiple boundaries, to procure food, and that sources for food procurement may exist along a boundary (Bao & Tong, 2017). There are a variety of statistical methods for dealing with this effect (Griffith & Amrhein, 1983), such as the use of gravity-based accessibility models (Chen, 2017). Another element of the boundary problem, the shape effect, deals with the structure of boundaries themselves. Spatial enumeration units aren't always the same shape or size, nor do they always have consistent numbers of neighboring units. This problem is evident when unit centroids are used as a point of origin from which proximity to food procurement sources is measured, as is the case with the USDA's method for measuring spatial access to food that relies on census tracts, which can vary drastically in both shape and size. Not only is it possible that the centroid of a unit can be skewed toward a certain geometric direction, but depending on the method used to determine its location, it can also exist outside the unit altogether. Further, the centroid of a unit also may not align with where people are concentrated within it, which is especially problematic when it comes to Census tracts.

The MAUP (Fotheringham & Wong, 1991; Openshaw & Taylor, 1981) is the idea that the same set of data can yield different analytical results depending on the spatial units chosen for aggregation. This includes both the scale effect and the zoning effect. The scale effect relates to the spatial resolution of the data and how many units are used.

Generally speaking, the larger the scale of analysis area, the greater the number of units. When looking at spatial access to food, a nation- or state-wide focus is uncommon, and studies typically approach the topic at the local level where it is more relevant. Still though, there are various units that can and have been used for analysis. While the USDA and many others use Census tracts (Abel & Faust, 2020; Bodor, Rice, et al., 2010; Larsen & Gilliland, 2008), some have made efforts to study the topic at an even larger scale to increase precision, including through use of Census block groups (Berg & Murdoch, 2008; Jiao et al., 2012; Kowaleski-Jones et al., 2009), land parcels (Andres et al., 2019), or a geometric grid (Shaw, 2006). The zoning effect of the MAUP relates to the demarcation of enumeration units, regardless of their scale. Again, units may not be the same shape or size, nor do they necessarily represent equal populations. Further, their boundaries are often arbitrary. For a given unit, the result calculated through an analysis may portray a certain level of access, however, the experience of some individuals at one end of the unit may relate more with the result calculated for individuals within their nearest adjacent unit, despite being grouped together with individuals for whom that does not also apply. This is an example of the ecological fallacy and the fallacy of division (Schwartz, 1994).

The UGCoP (Kwan, 2012a), which also deals with the problem of geographic delineation, is different than the MAUP and has different solutions (Kwan, 2012b). It involves the idea that there is uncertainty around the contextual influences on the individuals which "can vary over space and time in a highly complex manner" (Kwan, 2012a p. 961), potentially leading to confounded analytical results. An example of this as it relates to spatial access to food is how and when people get to and from sources of

food. This problem ties the structural limitations with the study of spatial access to food directly to the mobility and temporal limitations which are discussed below.

Mobility limitations can be broken down to origin-and destination-constraints, proximity measures, and mode of travel. Because people do not live out their lives confined to a single spatial enumeration unit, summarizing access to food as if they do distorts reality. Most studies on spatial access to food follow an origin-constrained design, typically representing the individuals' place of residence as where they travel from to procure food. This ignores the fact that most people interact with other geographic areas throughout their day-to-day lives, including their places of employment, education, and residences of family members and friends, which may lead to an overemphasis on the direct role of the food environment (LeDoux & Vojnovic, 2014). While it's difficult to derive an inclusive measure that is not origin-constrained, Chen and Yang (2014) attempt to do so using social media data, specifically what food sources they are exposed to and the choices they make based off the geolocation of their Tweets, in other words, based around the dynamic location of the individual rather than the static location of their residence. Methods have also been used attempting to capture access to food procurement sources based on the commutes of individuals (Horner & Wood, 2014; Widener et al., 2013, 2015), or potential path areas (Kim & Kwan, 2003), which go beyond traditional origin-constrained methods. Approaches such as these are valuable because they consider access and exposure (Clary et al., 2017). Similar to the limitations of origin-constraints, are destination-constraints. While where people are coming from isn't always static, neither is where they are travelling to. People can procure food from various sources, and where they choose is often determined by personal and cultural

preferences, as well as economic means. Commonly in analyses of spatial access to food, destinations are restricted to only supermarkets, often due to the relative ease of obtaining data. Some studies have gone further, however, including the use of shops where SNAP benefits are accepted (Chen, 2019), ethnic specialty shops (Behjat et al., 2013), small grocery stores and convenience stores (Bodor, Rice, et al., 2010; Bodor, Ulmer, et al., 2010; Raja et al., 2008), farmers' markets (Lowery et al., 2016; McCracken et al., 2012; Sadler, 2016), and even urban gardens (Corrigan, 2011). Another limitation when it comes to mobility is measures of proximity, which can impact the outcome of an analysis depending on the method that is used. Many studies on spatial access to food utilize Euclidian distances when considering how far people can and will travel to procure food. Another Cartesian distance measure is Manhattan distance; however, this has shown to be a less preferable measure and often produces similar results as Euclidean distance measures (Apparicio et al., 2008; Sparks et al., 2011; Zenk et al., 2005). Other studies on spatial access to food have given greater consideration to how people actually traverse geographic space, along networks, often roads, which can be used to represent travel using either distance or time according to Shortest Network Paths (Apparicio et al., 2008; Bilková et al., 2017; Smoyer-Tomic et al., 2006). Another mobility variable that is important to consider in proximity measures, specifically network-based measures, is mode of transportation. While road networks can easily be used to model access to food assuming access to a private vehicle, an entire city may have adequate spatial access to food using this mode, as seen in the work of Andres et al. (2019). The road network can also be a means for modelling walking (Donkin et al., 1999; Clifford M. Guy & David, 2004; McEntee & Agyeman, 2010) and public transportation (Farber et al., 2014; Su et

al., 2017; Widener, 2017; Widener et al., 2015), both which can also be used to measure access by distance or time.

Finally, temporal limitations are another challenge to studies of spatial access to food, as time can have major influence in a variety of ways. When measuring spatial access, an individual should only be expected to travel for a reasonable amount of time, just as is the case with distance. As explained, proximity measures and mode of travel open the door to a temporal component when measuring spatial access to food. In addition to the amount of time spent procuring food, another consideration is temporal variations is the availability of food procurement sources. While it is true that some stores may be open twenty-four hours a day, seven days a week, the reality is that most are not. Some studies have been done which demonstrate the way that spatial access to food changes through the day according to the hours of operation of food procurement sources (Chen & Clark, 2013, 2016; Widener et al., 2017), as well as the seasonality of sources such as farmers' markets (Widener et al., 2011). The availability of public transportation also changes through the day, as shown by Farber et al. (2014) and Widener et al. (2017).

Public Transit Availability Change in Marion County, Indiana

Bus service has been available in Indianapolis since 1953 when it replaced the streetcar system that came before it. The Indianapolis Public Transit Corporation was eventually established in 1975 when the City of Indianapolis took over the previous private-owned bus system, and in 1996 was renamed IndyGo. The system underwent a significant reduction in service from the 1990s through the early 2000s due to funding cuts; however, various plans to significantly improve it have taken shape since. Beginning with the 2010 launch of IndyConnect, a multi-agency transit planning

initiative of IndyGo, the Metropolitan Planning Organization (MPO), and the Central Indiana Regional Transportation Authority (CIRTA) an agenda to improve transportation for the region was established (CIRTA, 2016). In 2014, the Marion County Transit Plan (MCTP) advanced this agenda, with a vision for development of a grid-based bus system to replace the existing hub-and-spoke system, extended hours of bus service, increased frequency of bus routes, and the introduction of three electric Bus Rapid Transit (BRT) lines. The envisioned system, originally anticipated to be completed in 2021, by design would reach 65.5% of the county's population, including 75.8% of the minority population, 86.8% of households without a car, 84.6% of households with income below the poverty level, 72.2% of households that have at least one person with a disability, 65.0% of seniors age 65 or over. Momentum for implementing the plan increased in 2016, including the completion of a centrally located transit center in downtown Indianapolis which acts as a transfer point for various bus routes, as well as the release of the Central Indiana Transit Plan (CITP) which replaced the MCTP to incorporate plans for neighboring counties. Further, in the 2016 General Election, residents of Marion County voted 57.8% in favor of a tax increase to fund a large amount of the plans for the IndyGo system, the first ever public transportation referendum for the region, which opened the doors for several developments that have occurred over the past four years. These changes have included extended hours of operation, increased frequency of bus routes, as well as construction of the Red Line, which began operation in the fall of 2019 and led to the modification of some bus stops and routes.

METHODS

Two multimodal networks were created using the Network Analyst geoprocessing tools in Esri ArcGIS Pro, one for the summer of 2018 and the other for the summer of 2020, a timeframe during which a majority of recent changes to the bus system have taken place. Both networks utilized the most recently available US Census Tiger/Line road data from 2018, assuming any changes over the two-year period were minor. The spatially-referenced line data allowed for the modelling of pedestrian travel by using a constant walking speed of 3.12 miles per hour (83.33 meters per minute), a value recommended by the software developer, which enables the conversion of distance to travel time. Pedestrian restrictions were placed on highways, highway ramps, unpaved dirt roads, and service drives (MTFCC codes S1100, S1500, S1630, and S1640), since they are neither walkable, nor do they include bus stops. Streets extended beyond the borders of the county by one mile to allow for any potential instances of routes that may leave and reenter the county. The only difference between the two networks was the timeframe of the General Transit Feed Specification (GTFS) data of the IndyGo bus system that was used to model public transportation. GTFS data includes both the locations of bus stops and route schedules which determine the amount of time to travel between them. Having undergone various modifications to bus stops and routes from 2018 to 2020, the spatial and temporal availability differences of the IndyGo system were ultimately the cause for any variations in public transportation travel times for the two years that were measured. Bus stops were linked topologically to their nearest road lines, allowing for the integration of the two modes of transportation. Therefore, travel times

across the network could be calculated for both walking trips and trips consisting of a mixture of walking, waiting for, and riding a bus.

Service area analyses were performed on both networks for 12PM on weekdays (July 2, 2018 and July 2, 2020), and Sundays (July 8, 2018 and July 5, 2020), representing days with the highest and lowest frequency of buses and longest and shortest hours of operation, respectively. Sundays also represent federal holidays, during which all routes run according to their Sunday schedules, no matter the day of the week. Eighty-nine supermarket locations were extracted from 2019 Marion County Department of Public Health grocery store data, accessed through the Social Assets and Vulnerability Indicators (SAVI) service, and were used as origin points for the service areas. Stores selected for inclusion in the analyses were those that presumably offer the widest range of products, are inclusive of various diets, and offer the lowest available prices. For the most part, these stores are part of national chains (Table 1). Being that service areas represent one-way travel, the outputs of the four analyses delineate the extent of access along the networks according to a specified maximum travel time allowance. To maintain a reasonable expectation for individuals in an urban area, this was set to 30 minutes, which would be an hour of round-trip travel to obtain groceries.

Changes in the service areas for weekdays and Sundays for each year were then summarized by the total miles of road that gained or lost access, as the extent of access is determined by distance that can be travelled given the allowed travel time. This was performed for the entire county and for each of the 632 block groups that fall within. While not essential to the analysis, the gains and losses of miles of road with access among USDA-designated low-access tracts are also calculated. To observe how changes

Table 1: Count of Supermarkets in Marion County, Indiana, 2019

Aldi	10
Big Lots	6
Fresh Market	1
Fresh Thyme	5
Kroger	24
Meijer	5
Needler's Fresh Market	1
Safeway	5
Saraga International Grocery	2
Save-A-Lot	8
Target	5
Trader Joe's	2
Walmart Supercenter	9
Walmart Neighborhood Market	4
Whole Foods	2
Total	**89**

to the bus system have impacted spatial access to food for those among population subgroups most vulnerable to food insecurity, due to mobility-, economic-, and time-constraints, as well as racial inequality, which have also been explored in various food access studies (Bodor, Rice, et al., 2010; C. Gordon et al., 2011; Raja et al., 2008; Shannon et al., 2015; White et al., 2004; Zenk et al., 2005), the net change of road miles with access by block groups based on the prevalence of select sociodemographic variables (Figures 1-5), as reported in the 2018 American Community Survey 5-Year Estimates, is also calculated. These variables include households without a vehicle, households in poverty, single-parent families in poverty, households of people age 65 and older living alone, and population of racial and ethnic minorities. As Cromley (2019) stated, most studies to date observe spatial inequalities in access as it relates to geographic locations rather than subgroups of the population. This study attempts to challenge that trend.

Owner- and renter-occupied housing units without a vehicle in each block group were summed to estimate total units, and because total occupied housing unit counts were identical to total household counts, it is referred to as such going forward. Households in poverty was calculated based off households with income in the last 12 months below the poverty limit, with households as the unit of consideration, rather than individuals or families, since they are inclusive of both individuals who live alone as well as individuals who live with families and likely share finances. Single-parent families in poverty was calculated by combining families with a single male or female householder living with related children younger than 18 with an income over the last 12 months below the poverty limit. Households of people age 65 and older living alone was calculated based off the age of householder and household size. And finally, the racial and ethnic minority population was calculated by subtracting the non-Hispanic White population from the total population.

In addition to calculating the net change of miles of road with access according to the prevalence of these variables among block groups, the distribution of the county-wide total miles of road with access that was gained and lost according to the prevalence of the five variables at the block group level was then compared to the distribution of households, families, and population, depending on the variable, within them. This was done to observe more detail about how changes in the bus system have either helped or hurt food access for these vulnerable population subgroups.

Figure 1: Prevalence of Households without a Vehicle, 2018

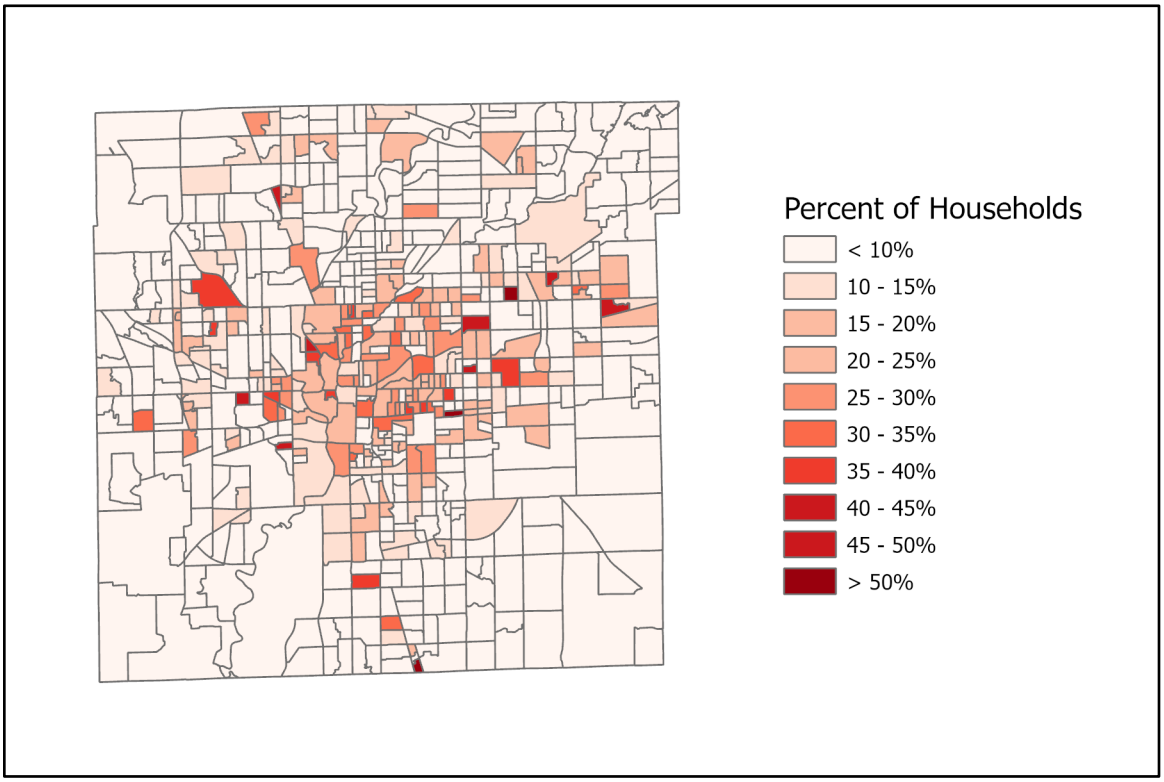


Figure 2: Prevalence of Households in Poverty, 2018

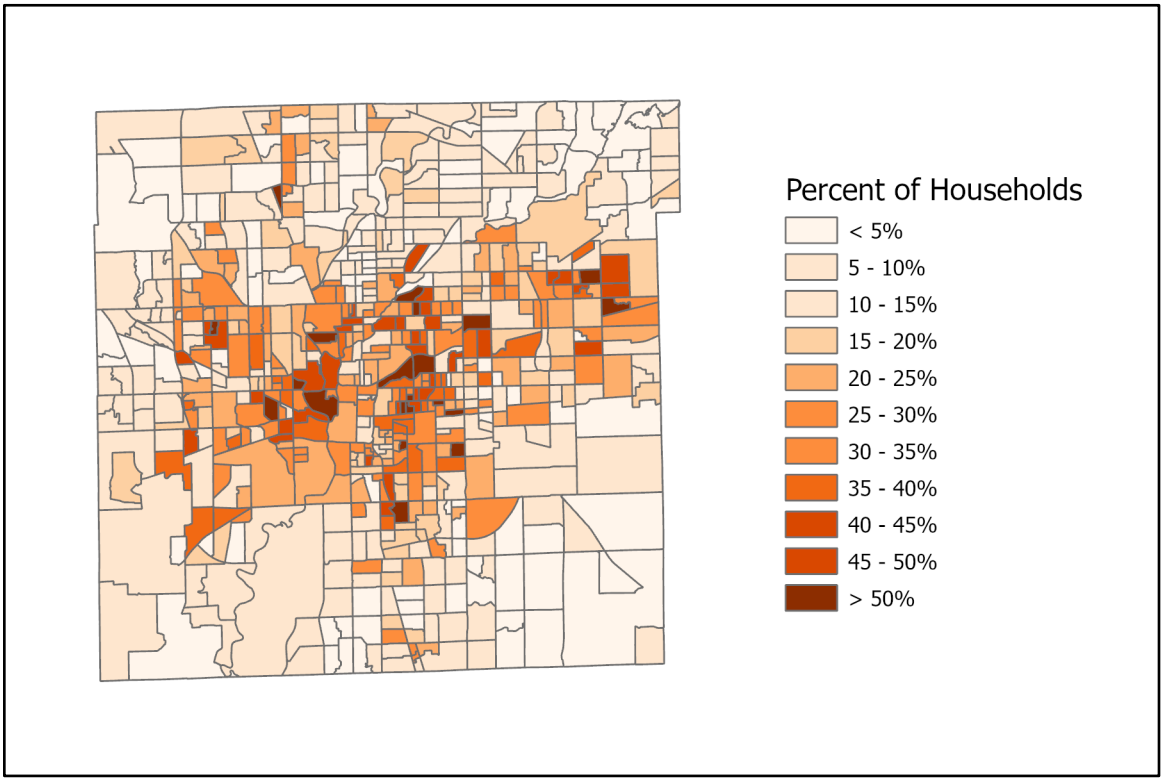


Figure 3: Prevalence of Single-Parent Families in Poverty, 2018

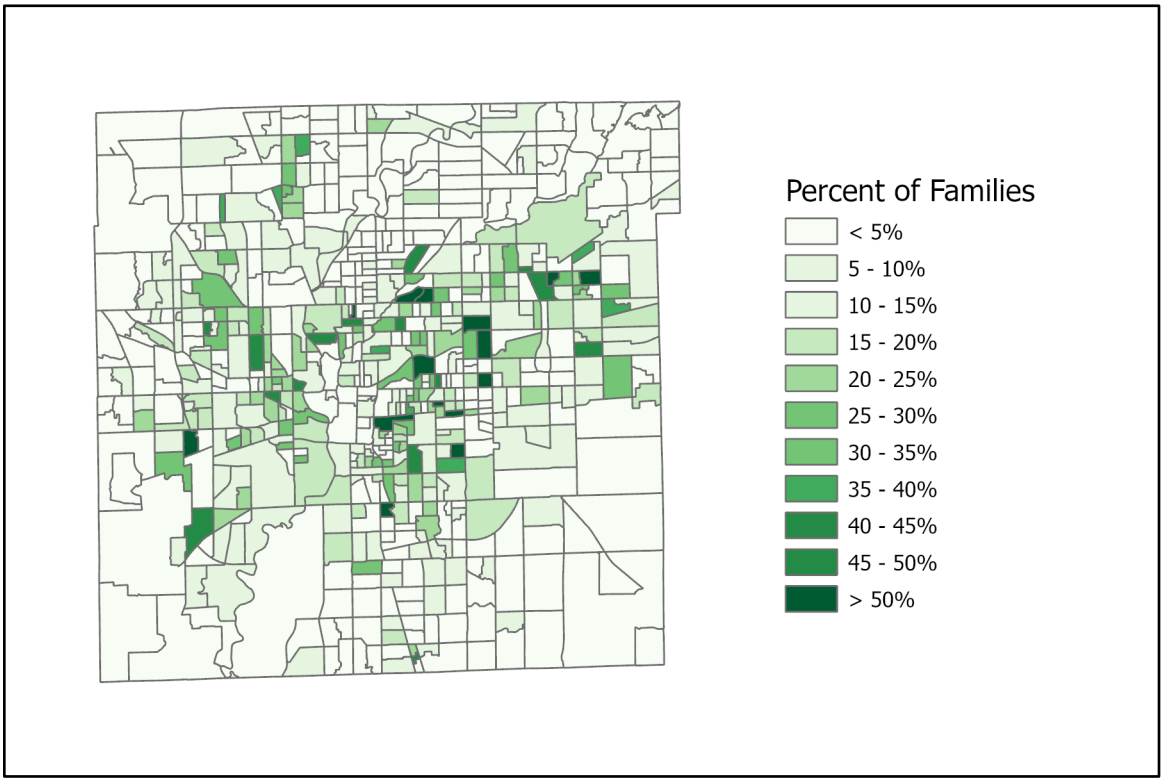


Figure 4: Prevalence of Households of People Age 65 and Older Living Alone, 2018

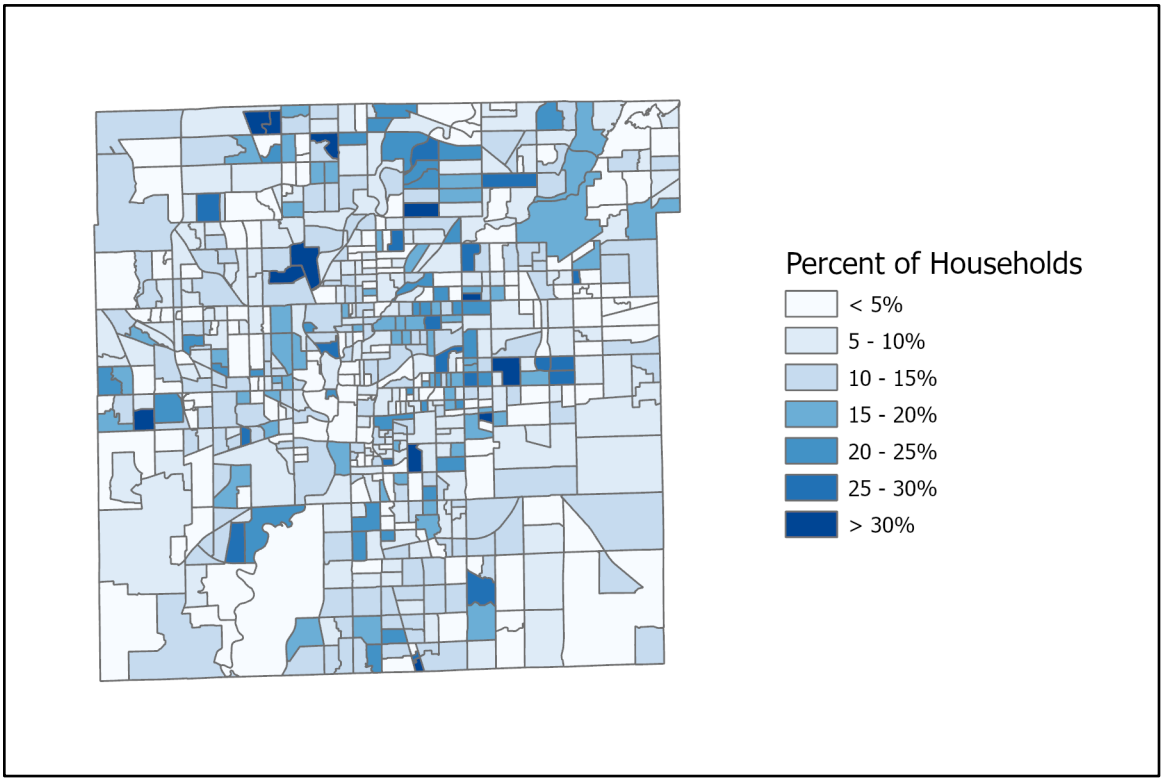
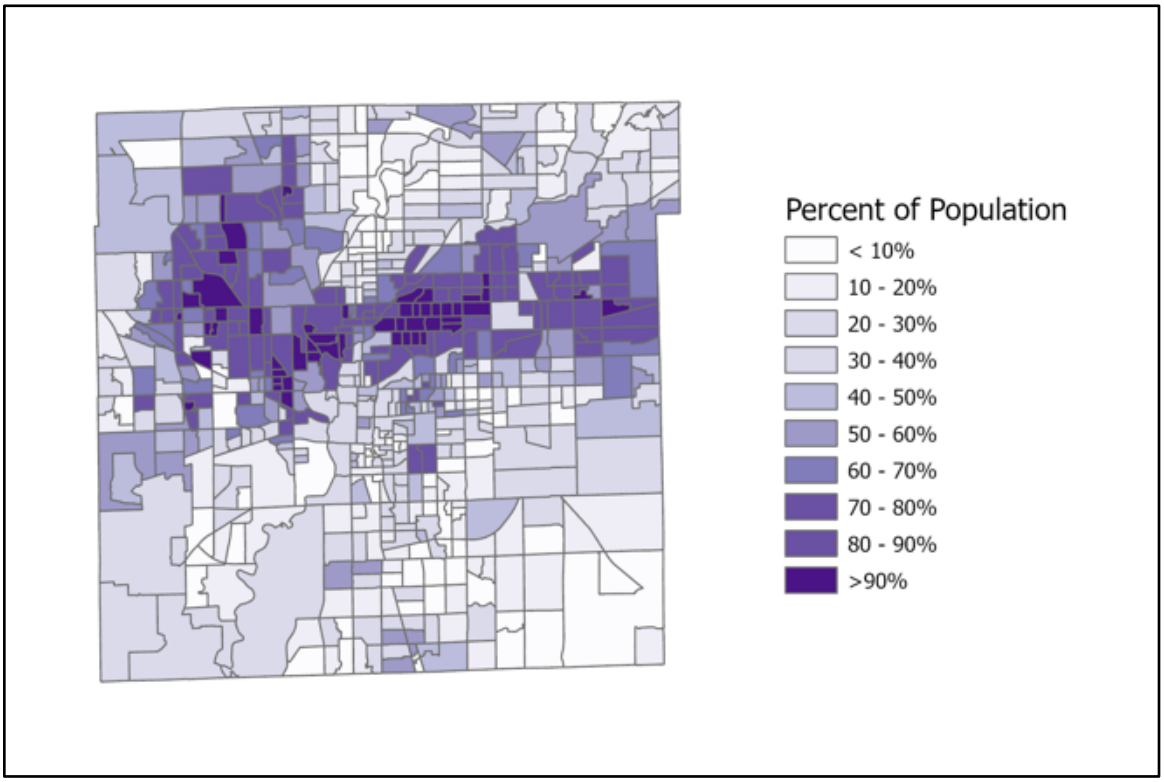


Figure 5: Prevalence of Racial and Ethnic Minority Populations, 2018



RESULTS

This section presents the findings of the analysis performed and describes the impact of public transit availability change on spatial access to food. Figures 6 and 7 show the outcome of the six service area analyses with results for both years superimposed to depict change in access to supermarkets via walking and/or bus within 30 minutes for weekdays and Sundays in Marion County, Indiana. All gains and losses in roads with access is a consequence of changes to the bus system alone, as the road network and supermarkets were held constant in the analyses. The totals of miles of road where access was gained and lost for the entire county is represented in Table 2, as well as those within USDA-designated low-access tracts, which encompass roughly a third of all gains and losses on both weekdays and Sundays and holidays.

The results reveal that miles of road where access was gained and lost were both highest on Sundays. The net change was also greatest for Sundays, with miles of road where access was gained being 3.75 times higher than miles of road where access was lost. A significant amount of road miles gained occurred on the East side of the county for both weekdays and Sundays, and a large portion of these gains were within USDA-designated areas of low access to food. While the Northwest part of the county lost some roads with access on weekdays, it also gained a significant amount of road with access on Sundays, a portion of which was also within a low access area as determined by the USDA. Significant losses of miles of road with access occurred in the Northeast part of the county on Sundays, which is also an area partially designated low access by the USDA.

Figure 2: Change in Access to Supermarkets within 30 Minutes via Walking and/or Bus on Weekdays from Summer 2018 to Summer 2020 in Marion County, Indiana

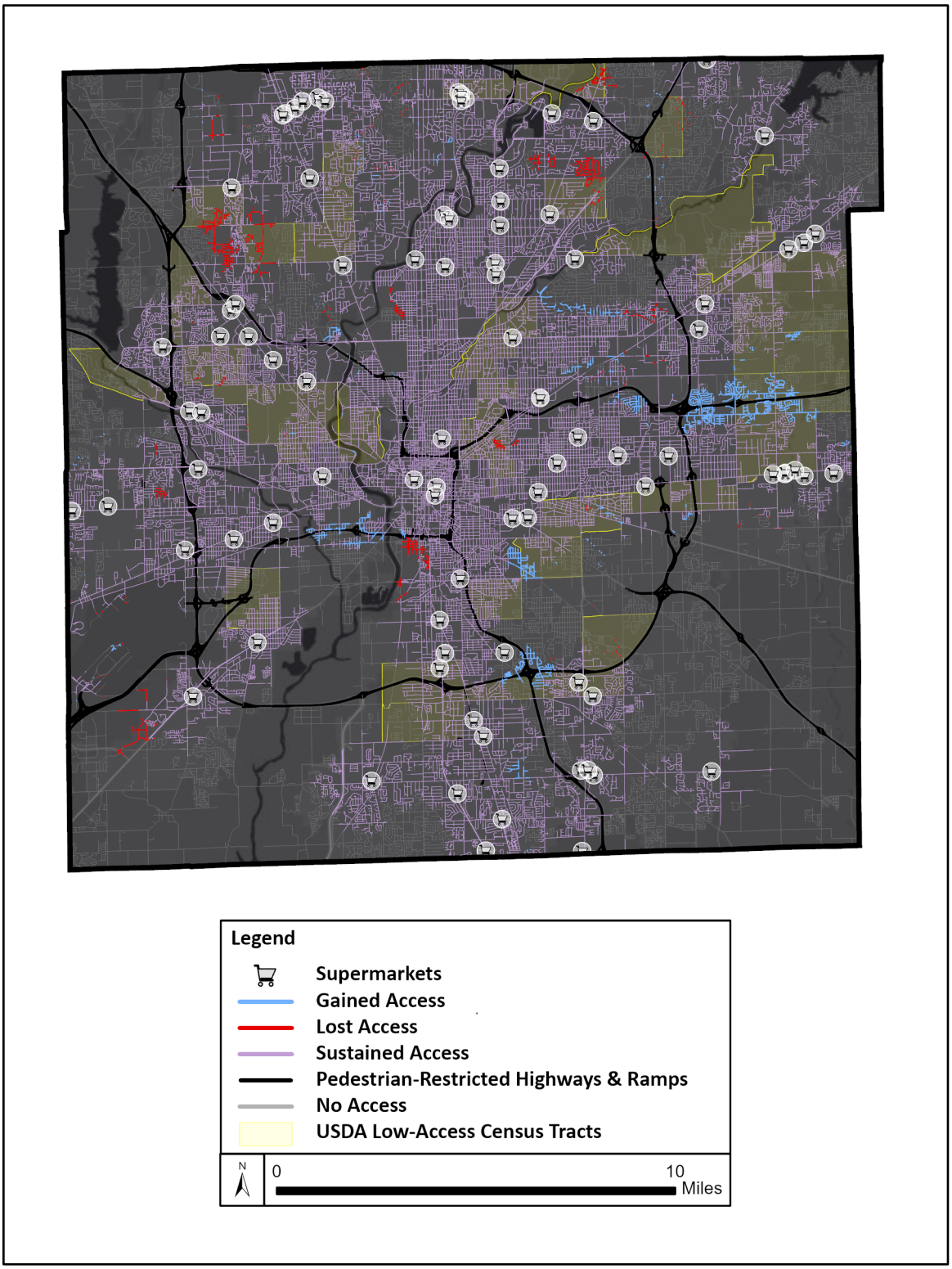


Figure 3: Change in Access to Supermarkets within 30 Minutes via Walking and/or Bus on Sundays/Holidays from Summer 2018 to Summer 2020 in Marion County, Indiana

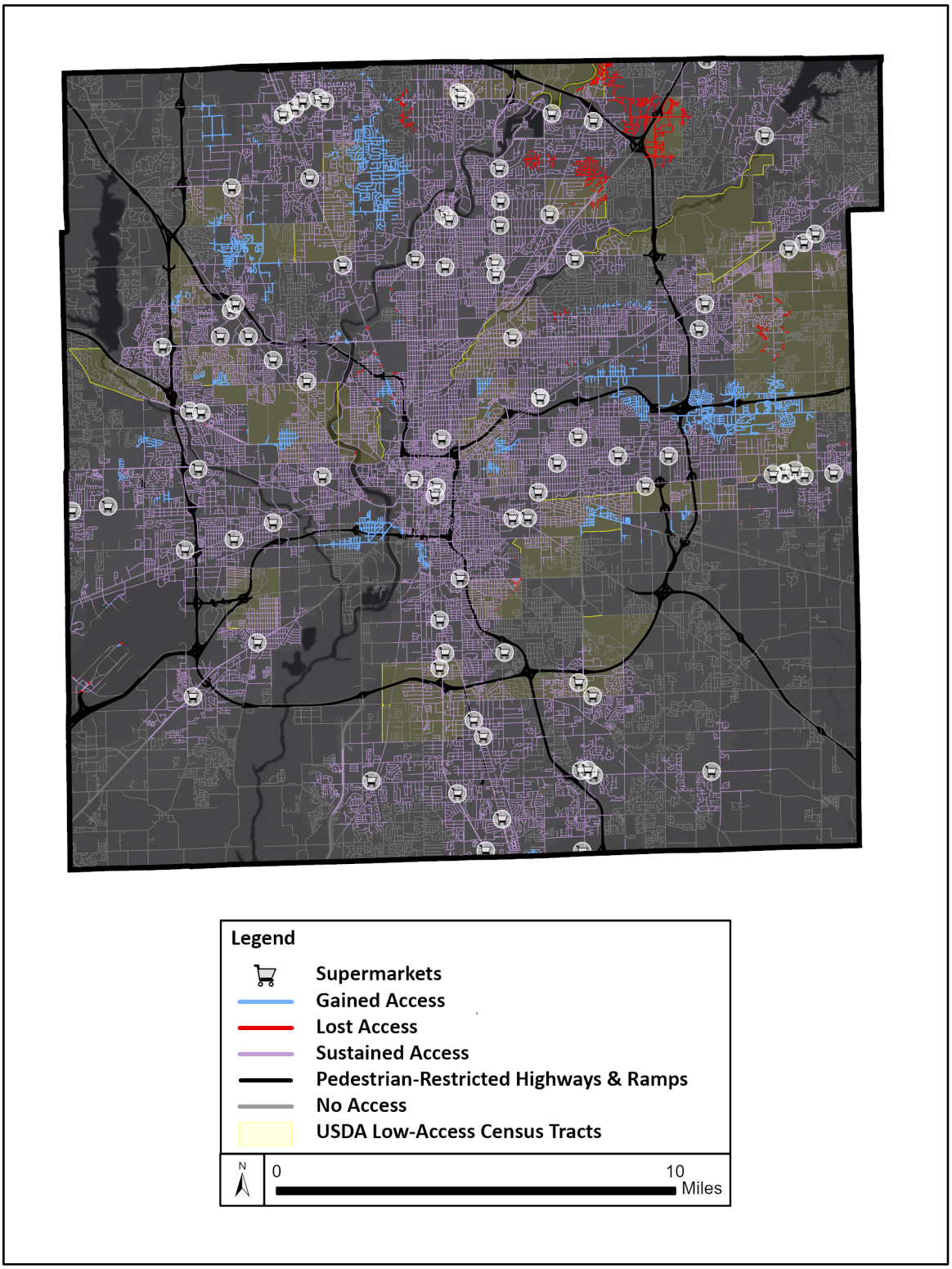


Table 2: Change in Miles of Road with Access to Supermarkets within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 in Marion County, Indiana

	Weekdays (County)	**Weekdays** (USDA Low-Access)	**Sundays/ Holidays** (County)	**Sundays/ Holidays** (USDA Low-Access)
Gained	+90.37 miles	+31.97 miles	+213.09 miles	+66.09 miles
Lost	-49.27 miles	-12.84 miles	-56.86 miles	-21.08 miles
Net Change	**+41.09 miles**	**+19.13 miles**	**+156.23 miles**	**+45.01 miles**

Households Without a Vehicle

Figure 8 (and Table 3 in the Appendix) presents the net change of miles of road with access to supermarkets by walking and/or bus within 30 minutes from summer 2018 to summer 2020 by prevalence of households without a vehicle among block groups. As can be seen in Figure 1, block groups with a higher prevalence of households without a vehicle are primarily concentrated at the center of the county. The general trend is that for block groups where the prevalence of households without a vehicle is higher, there is less net change of miles of road with access. Block groups with less than 10% of households without a vehicle had the largest net change for both days, however for Sundays it was more than five times higher than it was for weekdays. Block groups with the largest proportions of households without a vehicle saw minimal net change for both days, positive and negative.

Figure 8: Net Change in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 by Prevalence of Households without a Vehicle

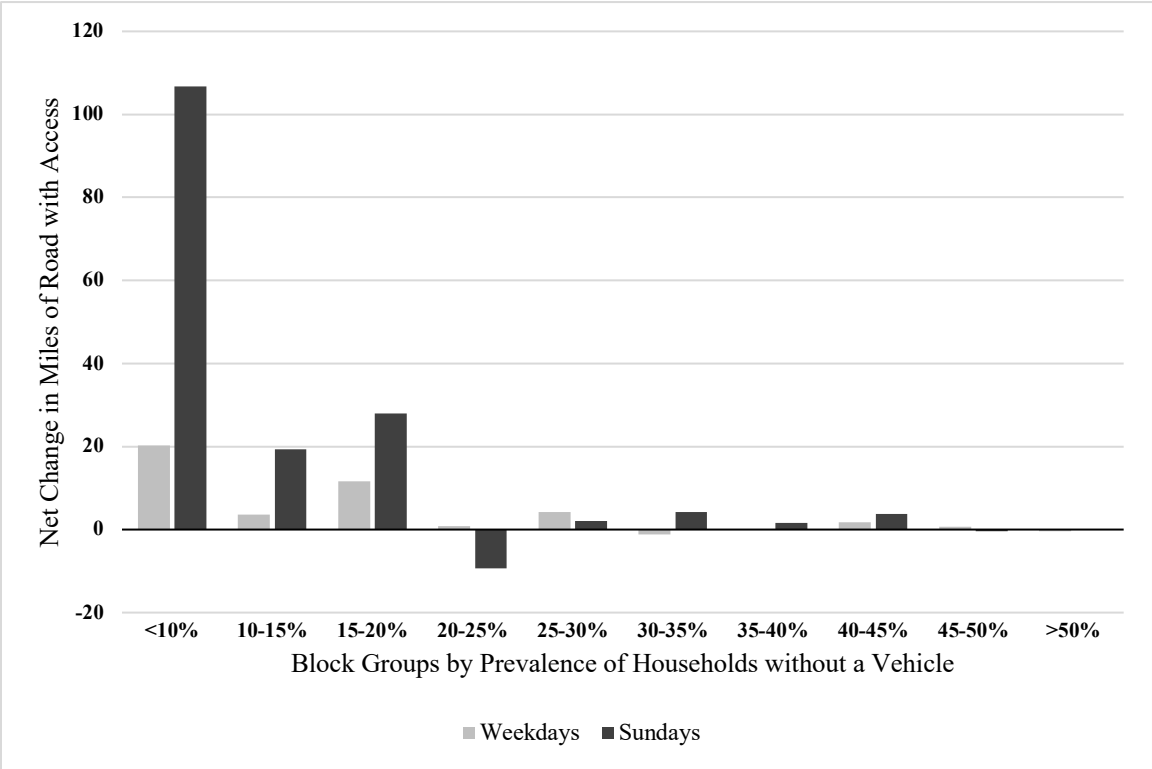
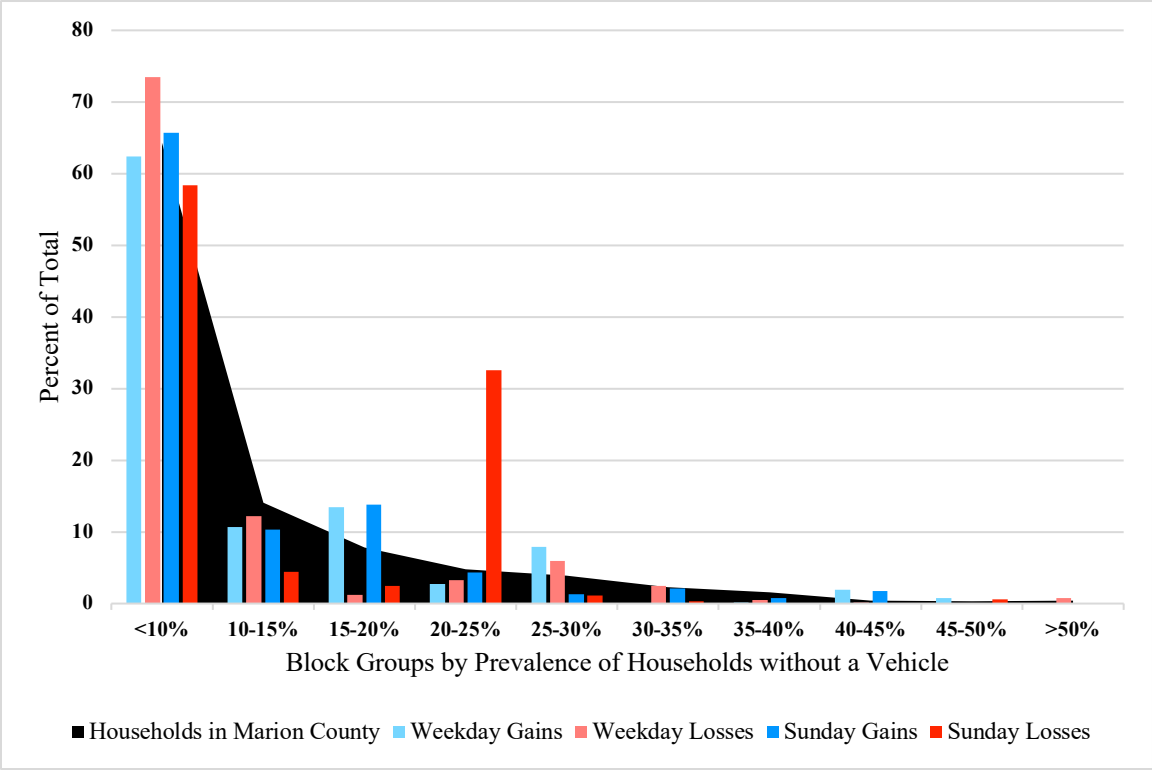


Figure 9 (and Table 4 in the Appendix) shows the distribution of total county gains and losses of miles of road with access to a supermarket via walking and/or bus within 30 minutes from Summer 2018 to Summer 2020 according to the prevalence of households without a vehicle among block groups, compared to the distribution of all-county households within. Much of the distribution of gains and losses follows the distribution of households, with a few exceptions. For example, the share of gains and losses for block groups with 10-15% and 35-40% of households without a vehicle were less than the proportions of their share of the county households for both weekdays and Sundays. Also, the share of gains alone for block groups with 15-20% and 40-45% of households without a vehicle were greater than their share of county households, while the share of losses were lower. For block groups with greater than 10% of households

without a vehicle, none showed that their share of miles of road where access was gained was significantly greater (+5%) or less (-5%) than their share of county households, on either day. While this is also mostly true for miles of road where access was lost, block groups with 20-25% of households without a vehicle had a result roughly six times higher than their share of county households on Sundays.

Figure 9: Distribution of Total County Gains and Losses in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 by Prevalence of Households without a Vehicle



Households in Poverty

Figure 10 (and Table 5 in the Appendix) shows the net change of miles of road with access to supermarkets by walking and/or bus within 30 minutes from summer 2018 to summer 2020 by prevalence of households in poverty among block groups. Figure 2 reveals that block groups with a higher prevalence of households in poverty, similar to households without a vehicle, are concentrated toward the center of the county.

Generally, except for block groups with less than 5% of households in poverty, net changes decreased as prevalence of households in poverty increased. While block groups with less than 5% of households in poverty saw negative net change for both weekdays and Sundays, there were no other occurrences of negative net change on both days. The only incidence of negative net change was for weekdays for block groups with 10-15% of households in poverty, the remainder of block groups for both weekdays and Sundays were positive.

Figure 10: Net Change in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020by Prevalence of Households in Poverty

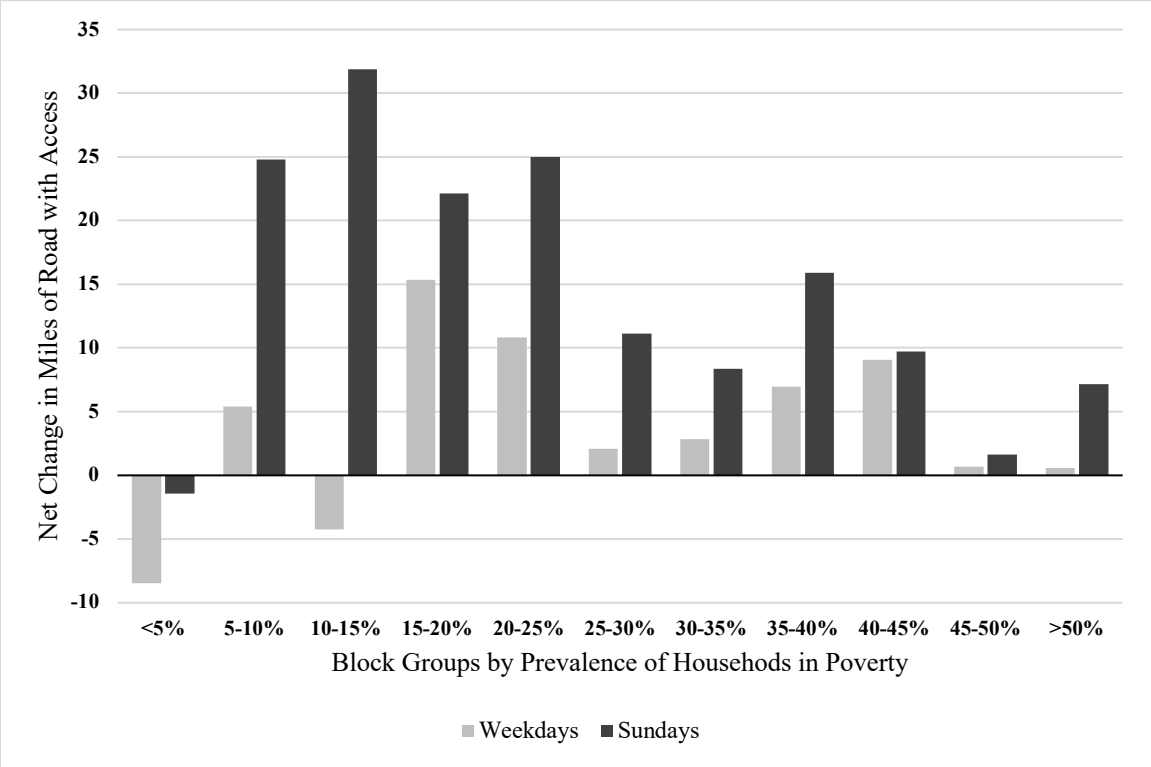
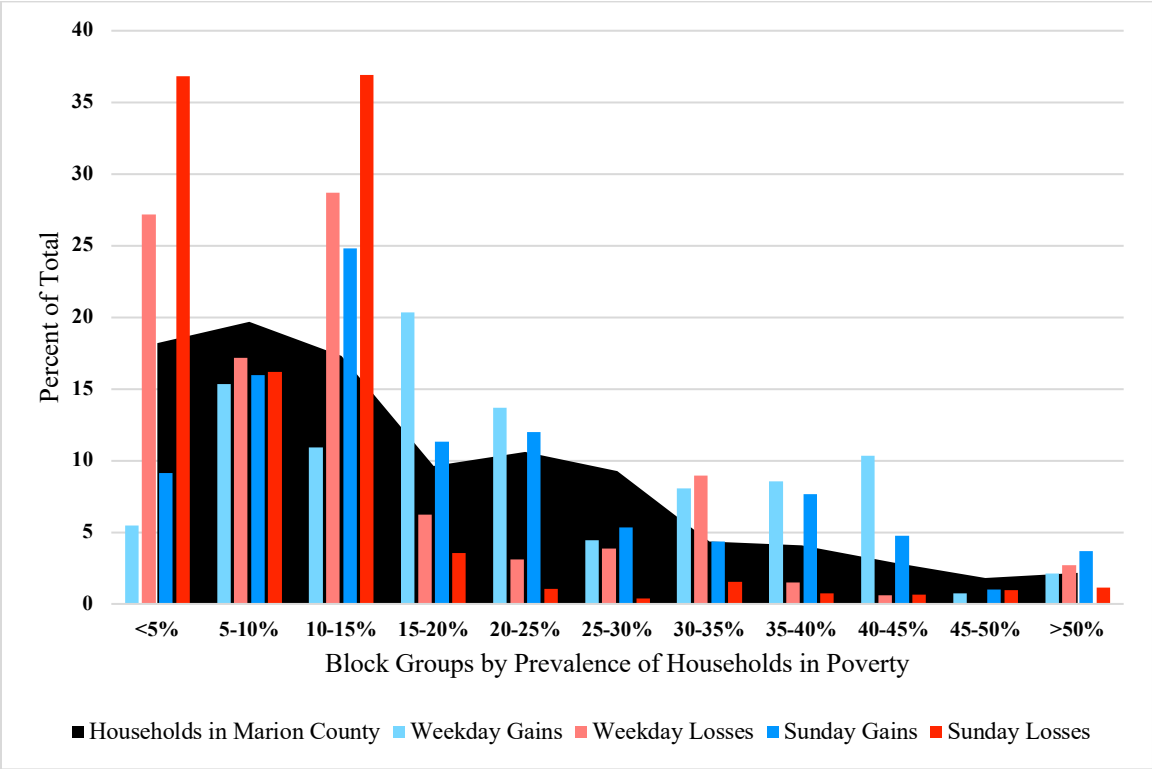


Figure 11 (and Table 6 in the Appendix) shows the distribution of total county gains and losses of miles of road with access to a supermarket via walking and/or bus within 30 minutes from Summer 2018 to Summer 2020 according to the prevalence of households in poverty among block groups, compared to the distribution of all-county

households within. The share of gains and losses loosely fit the distribution of county households, with several instances of difference greater than 5%. For share of losses in access being greater than the share of the population, this was mostly among block groups with less than 15% of households in poverty. However, this also occurred on weekdays for block groups with 30-35% of households in poverty and on Sundays for block groups with greater than 50% of households in poverty. Gains in access greater than the share of the population were observed for several block groups by prevalence of households in poverty, on both weekdays and Sundays, though less often by a difference of greater than 5%.

Figure 11: Distribution of Total County Gains and Losses in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 by Prevalence of Households in Poverty



Single-Parent Families in Poverty

Figure 12 (and Table 7 in the Appendix) shows the net change of miles of road with access to supermarkets by walking and/or bus within 30 minutes from summer 2018 to summer 2020 by prevalence of single-parent families in poverty among block groups. Net change for Sundays was often higher than net change for weekdays. Figure 3 identifies that block groups with a higher prevalence of single-parent families are loosely concentrated centrally in the county, but the highest prevalence block groups are skewed to the east. Net change was positive for most block groups on weekdays, however there were a few instances of negative net change. Sundays had consistently positive or null net change. While net change was minimal for weekdays for most block groups with a prevalence of single-parent families in poverty greater than 30%, the highest net change occurred for block groups with 40-45%.

Figure 12: Net Change in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 by Prevalence of Single-Parent Families in Poverty

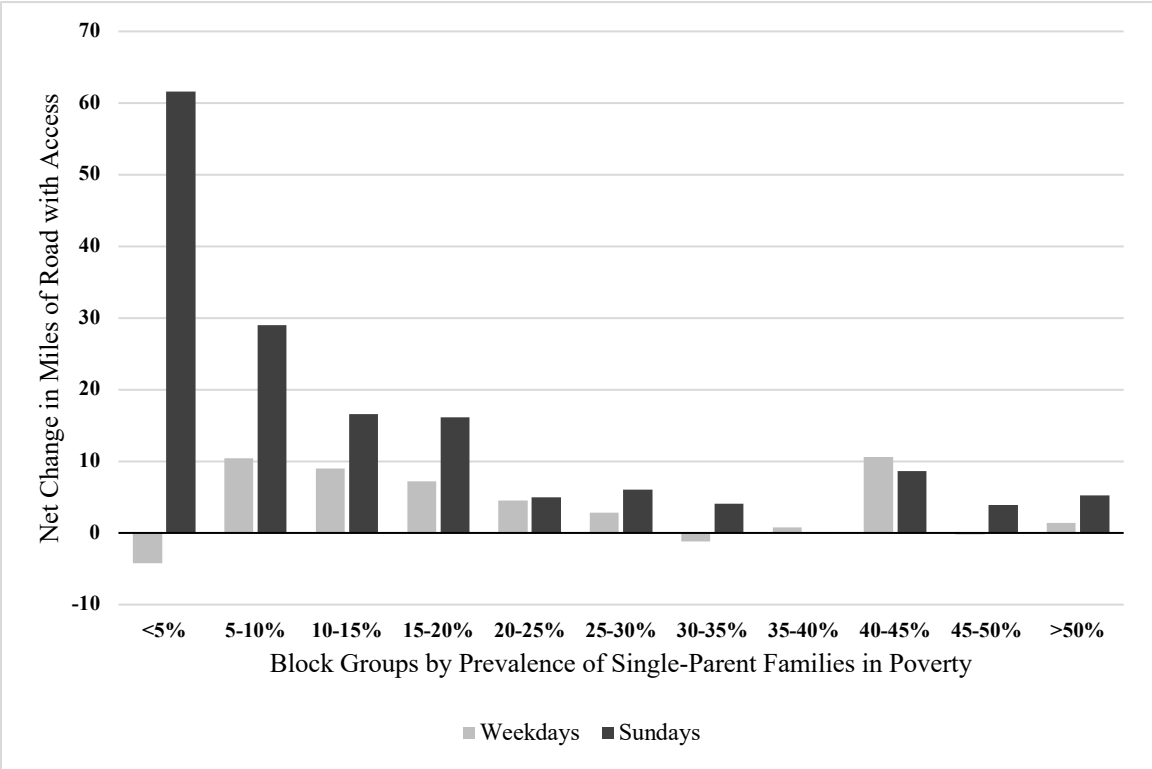
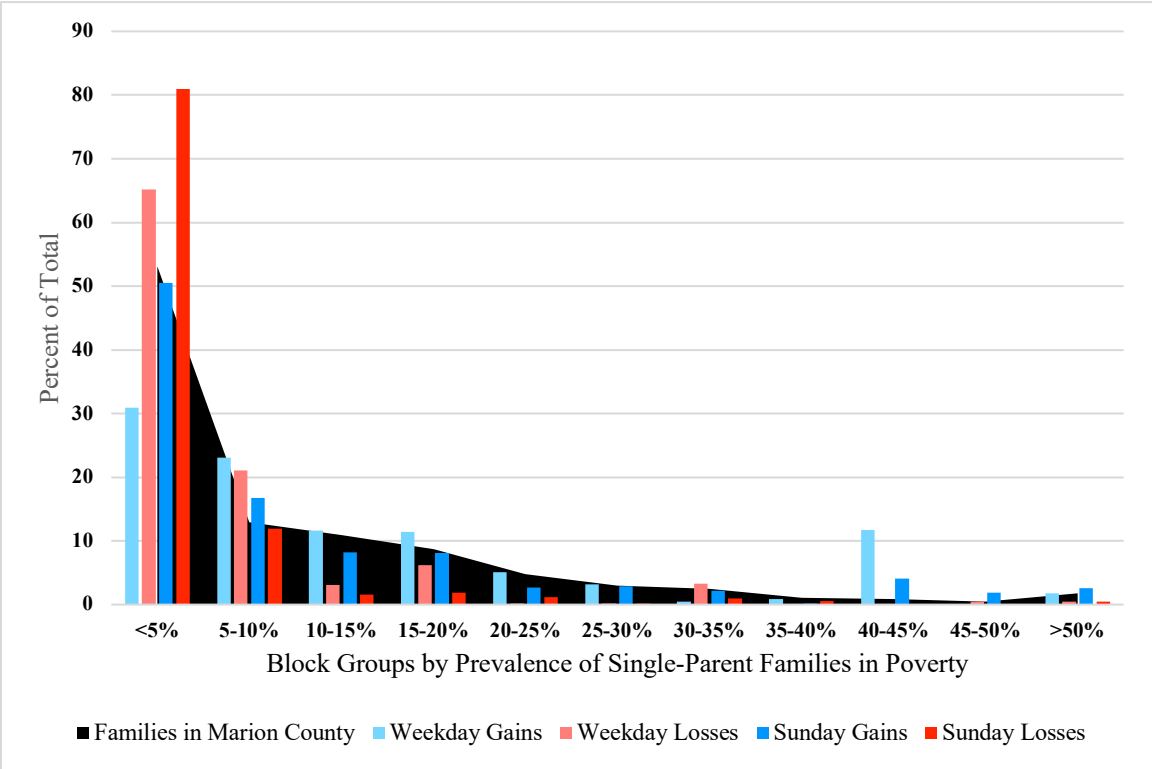


Figure 13 (and Table 8 in the Appendix) shows the distribution of total county gains and losses of miles of road with access to a supermarket via walking and/or bus within 30 minutes from Summer 2018 to Summer 2020 according to the prevalence of single-parent families in poverty among block groups, compared to the distribution of all-county families within. There were minimal occurrences of the share of gains or losses being higher than the share of the population by greater than 5%. These include block groups made up less than 20% and 40-45% of single-parent families in poverty. Except for block groups with a rate less than 5% of single-parent families in poverty, share of losses were consistently lower than the share of families for Sundays. Similarly, except for block groups with a rate less than 10% of single-parent families in poverty, share of losses were consistently lower than the share of families for weekdays.

Figure 13: Distribution of Total County Gains and Losses in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 by Prevalence of Single-Parent Families in Poverty



Households of People Age 65 and Older Living Alone

Figure 14 (and Table 9 in the Appendix) shows the net change of miles of road with access to supermarkets by walking and/or bus within 30 minutes from Summer 2018 to Summer 2020 by prevalence of households of people age 65 and older who live alone. Unlike the previous three variables, Figure 4 shows that block groups with a higher prevalence of households of people age 65 and older living alone are spread across the county and not concentrated in any specific area. Overall, Sundays saw greater net change across all block groups. Net change was consistently positive for Sundays for block groups with less than 30%, but block groups with greater than 30% had zero net change. Net change was mostly positive for weekdays, except for block groups with 15-25% of households of people age 65 or older living alone.

Figure 14: Net Change in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 by Prevalence of Households of People Age 65 or Older Living Alone

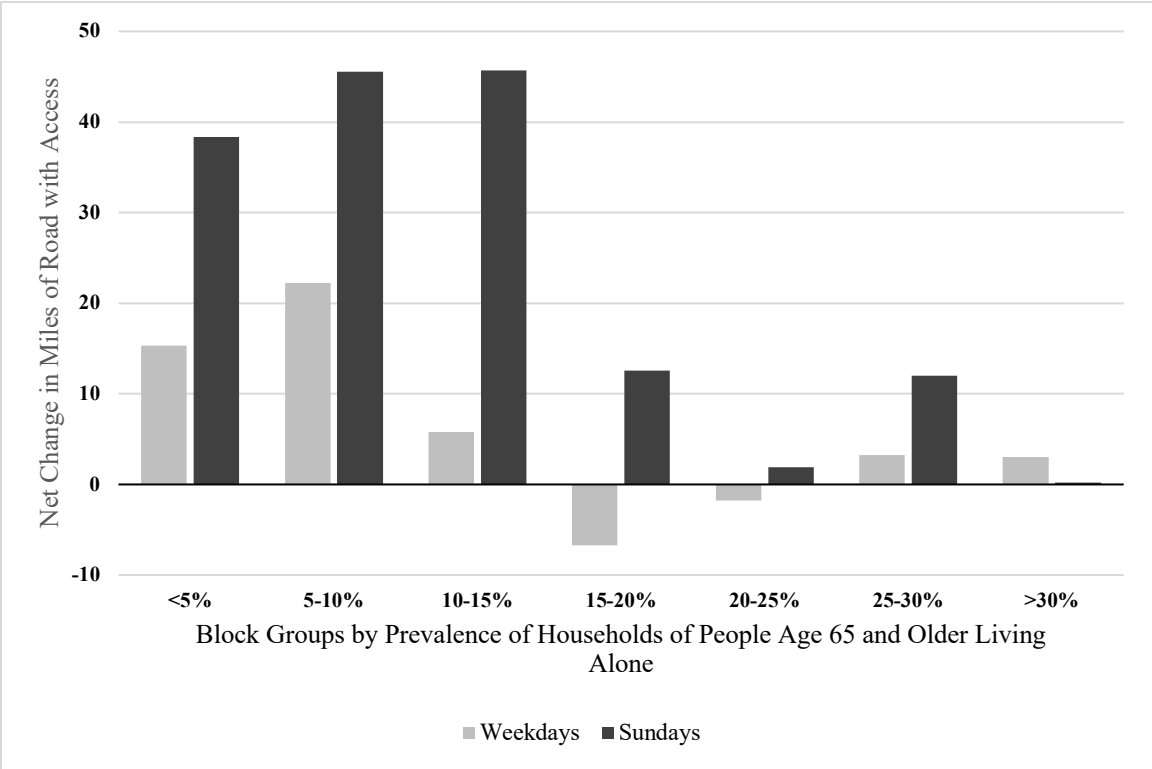
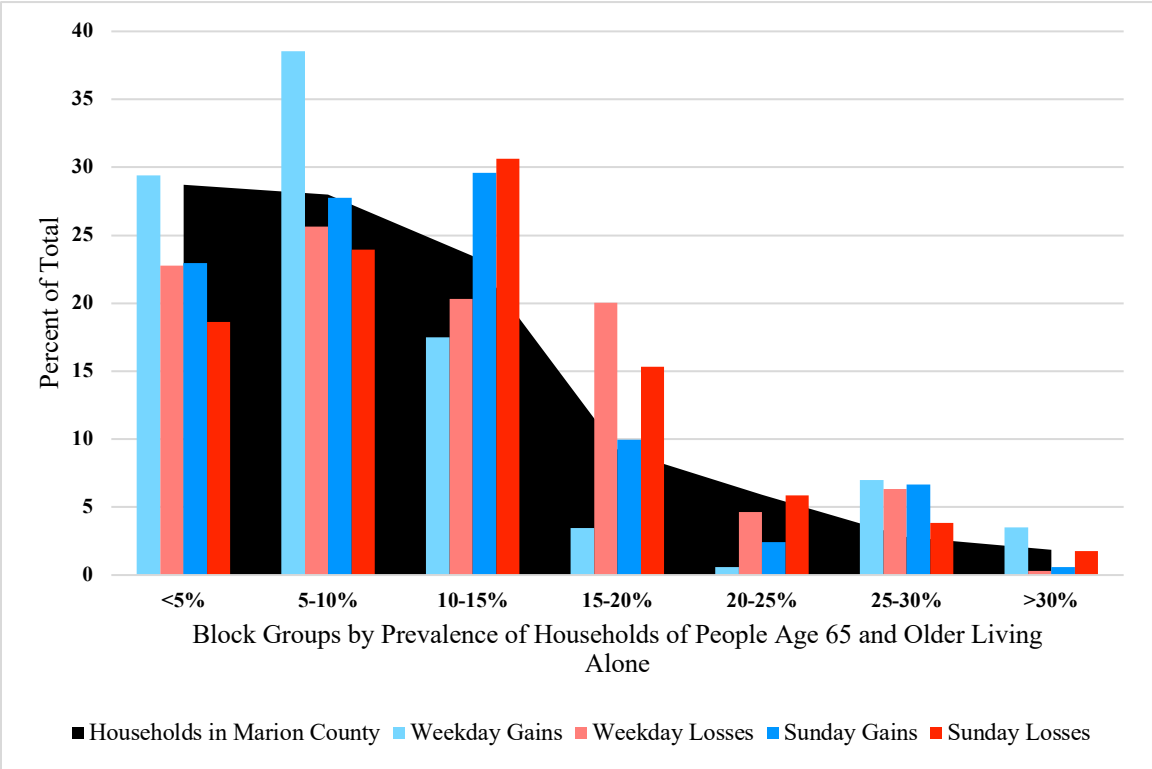


Figure 15 (and Table 10 in the Appendix) shows the distribution of total county gains and losses of miles of road with access to a supermarket via walking and/or bus within 30 minutes from Summer 2018 to Summer 2020 according to the prevalence of households of people age 65 and older living alone among block groups, compared to the distribution of all-county households within. Instances of the share of gains or losses exceeding the share of households by greater than 5% were concentrated among block groups with lower prevalence. The share of gains on weekdays was significantly lower than the share of households for block groups with 10-25% of households of people age 65 and older living alone, and for block groups with 20-25% and greater than 30% for Sundays.

Figure 15: Distribution of Total County Gains and Losses in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 by Prevalence of Households of People Age 65 or Older Living Alone



Racial and Ethnic Minority Populations

Figure 16 (and Table 11 in the Appendix) shows the net change of miles of road with access to supermarkets by walking and/or bus within 30 minutes from Summer 2018 to Summer 2020 by prevalence of racial and ethnic minority populations among block groups. Figure 5 reveals that block groups with a higher prevalence of racial and ethnic minority populations are highly concentrated in the northeast and northwest of the county. For block groups with greater than 10% of a minority population, net change on Sundays was consistently positive and greater than that for weekdays. There were several incidences of negative net change for weekdays, especially for block groups with lower prevalence of racial and ethnic minority populations, and for block groups with greater than 90%.

Figure 16: Net Change in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 by Prevalence of Racial and Ethnic Minority Populations

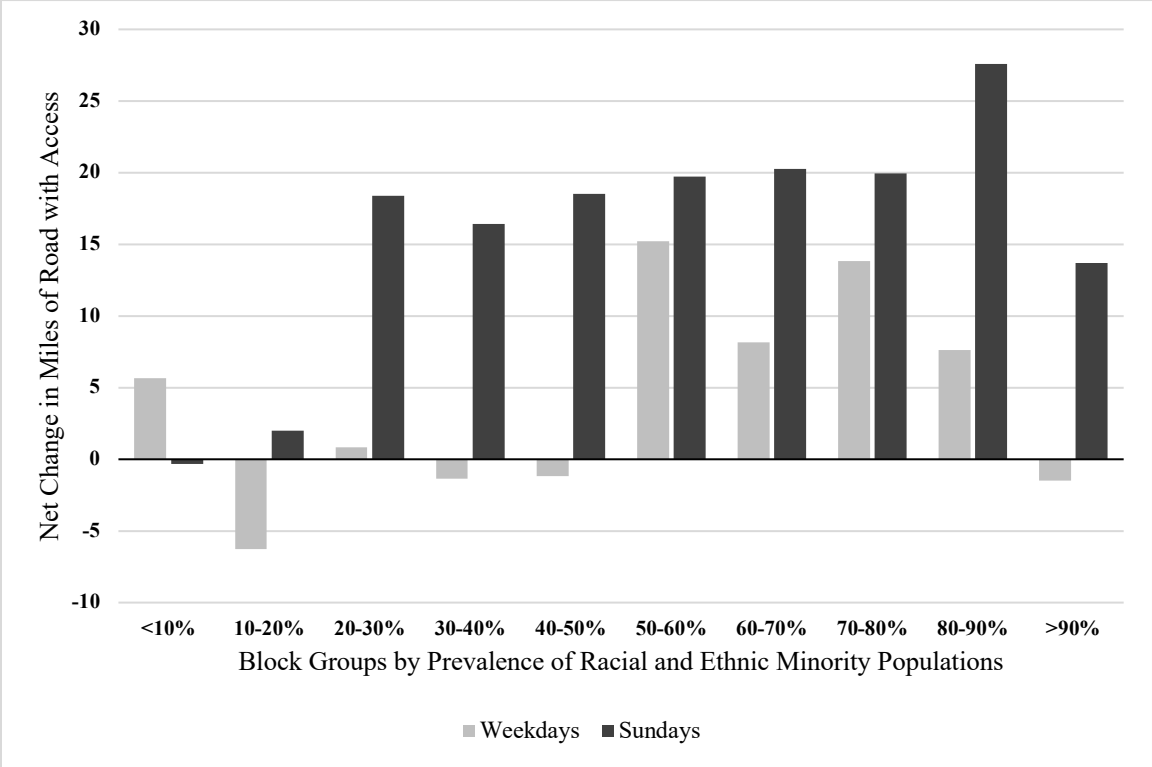
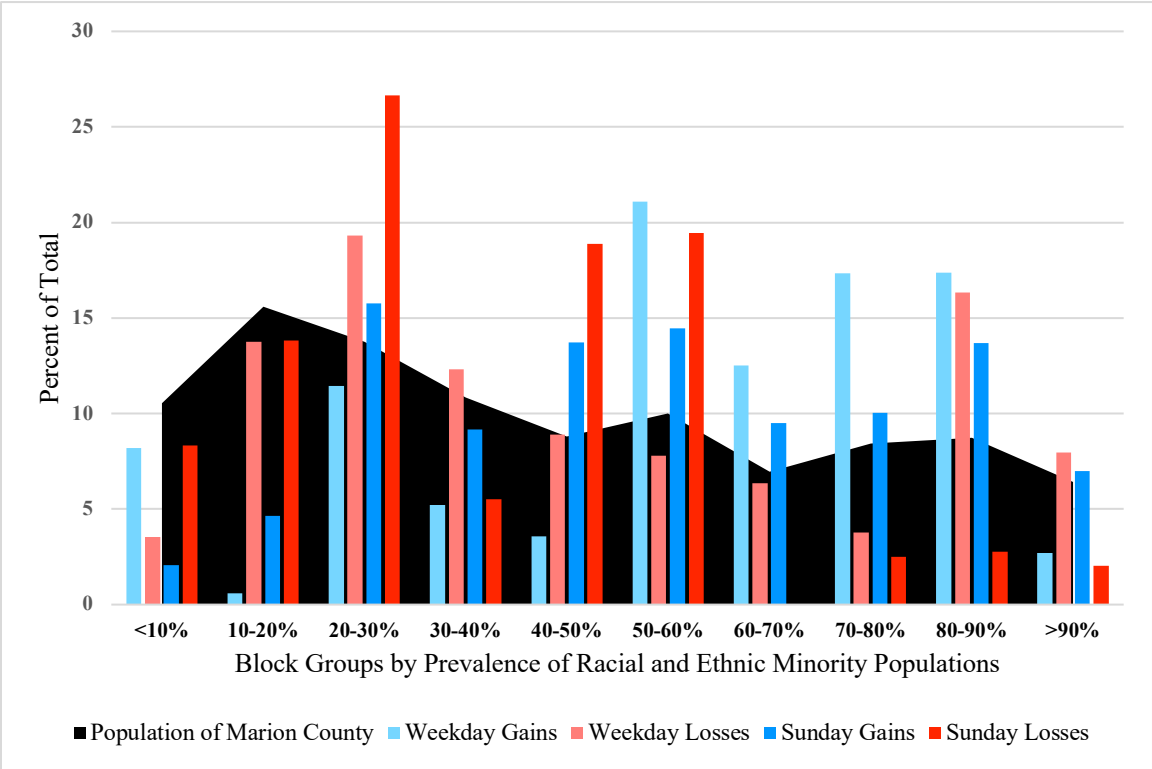


Figure 17 (and Table 12 in the Appendix) shows the distribution of total county gains and losses of miles of road with access to a supermarket via walking and/or bus within 30 minutes from Summer 2018 to Summer 2020 according to the prevalence of racial and ethnic minority populations among block groups, compared to the proportional distribution of the county population within. There were several instances of the share of gains and losses differing from the share of households by greater than 5%, especially among block groups with higher racial and ethnic minority populations. Weekday gains were significantly higher for block groups with 50-90%. Sunday losses were low for block groups with greater than 60%, however, for block groups with 20-30% and 40-60% Sunday losses were high. Weekday losses were high for block groups with 80-90%.

Figure 17: Distribution of Total County Gains and Losses in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 by Prevalence of Racial and Ethnic Minority Populations



DISCUSSION

The development and proliferation of the food desert metaphor resulted in an increased focus by governments on inequalities in spatial access to food, situating it within the greater fight against food insecurity. As discussed in the background section, after the metaphor's origin in late 1990s British politics and its export to the United States, it became a widely accepted concept among academics and policymakers for studying spatial access to food and identifying where inequalities exist. Despite lacking a universal definition and systematic method of determination, governments across the US introduced the concept into policy, often based off the USDA's definition and method. Although the concept of food deserts can reveal broad geographic trends in spatial access to food, it is limited in its ability to model it with accuracy and precision, being that it succumbs to various geographic measurement problems and fails to account for mobility and temporal variability, as described in the background section.

As studies related to spatial access to food have grown in complexity over recent years, the identification of food deserts has become less of an overall priority for scholars. Instead, the focus has shifted toward development and assessment of intervention strategies intended to mitigate inequalities. Intervention strategies around spatial access to food generally fit into two categories: bringing food to people and bringing people to food, a contrast identified by Lang (1999) as one of several tensions in regarding the vision for the future of the food system. Since the food desert concept heavily emphasizes the proximity to grocery stores, initial attempts to mitigate inequalities centered around provision of new food retail, most commonly, the introduction of new grocery stores in areas with low access to existing ones. This

strategy, however, has had mixed results in both simulations (Abel & Faust, 2020; Clarke et al., 2002) and natural experiments (Allcott et al., 2019; Cummins, 2005; Cummins et al., 2014; Dubowitz et al., 2015; Wrigley, Warm, et al., 2002). Issues that can potentially result from the introduction of new grocery stores include the creation of 'food mirages', or areas where only unaffordable food retail outlets are accessible (Breyer & Voss-Andreae, 2013; Sullivan, 2014), as well as disruption to existing food retail nearby (Allcott et al., 2019; Bonanno & Li, 2012; Clarke et al., 2002). However, it is important to note that without access the choice to purchase and consume healthy food cannot be made (Hendrickson et al., 2006), therefore in some cases the introduction of a grocery store is warranted, and the loss of a store can be problematic (Russell & Heidkamp, 2011; Yeager & Gatrell, 2014; Zhang & Ghosh, 2016). Other 'food to people' strategies that have been attempted include provision of mobile market systems (Widener et al., 2012), farmers' markets and urban gardens (Corrigan, 2011; Kisner, 2011; Larsen & Gilliland, 2009; Lowery et al., 2016; Mack et al., 2017; McCracken et al., 2012; Sadler, 2016), and policies directed at increasing the availability of fresh produce at small retailers (Bodor, Rice, et al., 2010; Bodor, Ulmer, et al., 2010; Bonanno & Li, 2015; Dannefer et al., 2012; Halliday et al., 2019; Martin et al., 2014; Neumeier, 2015; Pinard et al., 2016; Song et al., 2009) and non-traditional retail locations, such as public transportation stops and other community sites such as libraries and schools (Halliday et al., 2019; Kisner, 2011; Sharma et al., 2017). Also, while not a 'food to people' strategy per se, policies have been implemented to keep certain types of food away from people, such as zoning regulations that prevent development of new fast-food establishments (Boone-Heinonen, 2011; Richardson et al., 2011; Sturm & Cohen, 2009) to fight the production of 'food

swamps', or areas with an abundance of unhealthy food, which is a growing body of research (Balcaen, 2020; Bridle-Fitzpatrick, 2015; Burns & Inglis, 2007; Eckert & Vojnovic, 2017; Fielding, 2011; Osorio et al., 2013; Yang et al., 2020). Strategies adhering to the 'people to food' intervention model are less abundant and inherently related to transportation. One strategy is to increase access to public transportation through fare subsidies and provision of specialized routes (Halliday et al., 2019). Another strategy is the provision of no- or low-cost vehicles to qualifying low-income families (Wright et al., 2016). A third strategy, currently operating or planned in many US cities, is subsidized trips with the popular ride-sharing platforms Lyft through public-private partnership ("Access to Healthy Food," n.d.).

As governments implement various 'food to people' and 'people to food' intervention strategies aimed at reducing inequalities in spatial access to food, consideration is necessary for simultaneously occurring changes to the structure of the urban environment that can also affect access, such as projects planned or completed by community and economic development and public transportation planning agencies. These structural changes can have a positive or negative impact on spatial access to food, or a combination of both distributed geographically. To increase the efficacy of intervention strategies, awareness of their impacts on these structural changes on spatial access to food can aid in better targeting of areas with populations most vulnerable to food insecurity and can result in more effective use of public resources.

While the changes to the IndyGo bus system in Marion County were not specifically intended to improve spatial access to food, they did have an impact on it, as the results show. The analysis performed provides insights into these impacts for the

entire county as well as segments of the population most vulnerable to food insecurity within. For the entire county, the impact of the public transit availability changes on spatial access to food were positive overall, with a net change of +41.09 miles of road with access on weekdays, the days with the greatest availability of bus service, and +156.23 miles of road on Sundays, the days with the least availability of bus service. When observing the net changes in access for the entire county and across block groups based on the prevalence of each of the five sociodemographic variables, a positive net change reflects an overall improvement in access and a negative net change reflects an overall worsening of food access. Positive or negative, the magnitude of the net change for block groups by prevalence of each socioeconomic variable provides additional insight, however, because it is not standardized to the distribution of the population, interpretation of it is difficult. To overcome that, a comparison of the share of gains and losses in miles of road with access across block groups by prevalence of each of the five sociodemographic variables to the share of the population within reveals more about the impact of public transit availability change on spatial access to food. In doing so, identification of where the distributions do not align can answer for whether public transit availability changes are helping or hurting spatial access to food for vulnerable groups.

A 5% threshold was used to identify among which block groups there was significant difference in the share of gains and losses to miles of road with access and the share of the county's total households, families, or population. For gains in miles of road with access, it is ideal if the share is significantly greater than the share of the county's households, families, or population because it indicates an above average benefit to access. However, if the share of gains is significantly less than the share of the

population, it can imply a widening need for intervention. Conversely, if the share of losses is significantly greater than the share of the population, need for intervention widens, but if the share of losses is significantly less than the share of the population, it is of less concern, relatively.

Households Without a Vehicle

For households without a vehicle, the public transit availability changes had a relatively neutral impact on spatial access to food. While there are various ways for people without a vehicle of their own to get to supermarkets, including borrowing a vehicle, carpooling, biking, taking a taxi, and ride sharing, this population represents a group among the most dependent on walking and public transportation, though it should be considered that just because a household has a vehicle it does not necessarily negate the need for public transportation, as the vehicle could be shared among individuals within the household or restricted for use from some. The measure of net change did not reveal much beyond a general trend of decrease as the prevalence of households without a vehicle increased (see Figure 8 and Table 3). One exception to this trend was the negative net change measured for block groups with 20-25% of households without a vehicle for Sundays. When looking at the shares of gains and losses compared to the share of households for these block groups (see Figure 9 and Table 4), the negative net change is the outcome of a share of losses that significantly exceeds the share of the population. As evident when comparing Figures 1 and 7, this is related to the large losses in miles of road with access in the northeast side of the county. For block groups with the highest prevalence of households without a vehicle though, there are no significant differences between the share of access gained and lost and the share of households.

While there was not a significant positive impact on spatial access to food for households without a vehicle, a neutral impact is better than a negative one.

Households in Poverty

For households in poverty, the impact of public transit availability change on spatial access to food was relatively positive overall. Although poverty is a measure of deprivation that relates primarily to inequality in economic access to food, it is exacerbated by inequality in spatial access to food (Sadler et al., 2015). Further, households in poverty are more likely to also be without a vehicle. Even if a household in poverty has a vehicle though, access based off dependence on it is vulnerable to loss. For example, if the vehicle is damaged, stolen, or repossessed, households in poverty may not have the economic means to immediately replace it. If this is the case, need arises for alternative means of access such as by walking or public transportation, which is challenging given the greater distance to grocery stores for low-income areas (Dutko et al., 2012). The net change in road miles of road with access was positive for block groups with greater than 15% of households of in poverty on both weekdays and Sundays. The share of gains and losses compared to the share of the population show this is the result of many instances where the share of gains exceed the share of the population, sometimes significantly (greater than 5%), and where the share of losses is lower than the share of the population, sometimes significantly as well. As can be seen in Figure 1, these block groups are concentrated toward the central and eastern parts of the county. For block groups with lower prevalence of households in poverty, there were several instances where the share of losses is higher than the share of the population, meaning the overall

impact of public transit availability change on spatial access to food favored block groups with greater households in poverty.

Single-Parent Families in Poverty

The impact of public transit availability change on spatial access to food for single-parent families in poverty was somewhat similar to the results for households without a vehicle, relatively neutral. Single-parent families in poverty experience the same economic constraints to food access as households in poverty, but they may also face greater time constraints associated with childcare. The impact of change in public transit availability change on this population measured by net change in access followed a decreasing trend as the prevalence of single-parent families increased (see Figure 12 and Table 5). The largest outlier to this trend was for share of gains on weekdays and Sundays for block groups with a single-parent family prevalence of 40-45% (see Figure 13 and Table 6). According to Figure 3, these block groups are scattered across the county and the gains are not related to any specific cluster of roads where access was gained.

Households of People Age 65 and Older Living Alone

For households of people age 65 and older living alone, the impact of public transit availability change on spatial access to food was more negative than it was positive. This segment of the population is vulnerable to food insecurity due to a greater likelihood of mobility constraints associated with older age, and because they live alone, it is likely that they are responsible for their own food procurement, so driving or walking long distances may not be feasible (Fitzpatrick et al., 2019; Shannon et al., 2015). This subgroup of the population also often survives off fixed incomes, which poses a potential

economic barrier to healthy food access and which is exacerbated by spatial inaccessibility. The results of the analysis show that net change was significantly lower for block groups with a greater prevalence of households of people age 65 or older living alone. When looking at the share of gains and losses compared to the share of the population, there are several instances where the share of losses is higher than the share of the population and only few where the share of gains is higher. Figure 4 shows that block groups with higher prevalence of households of people age 65 or older living alone are distributed across the county and not concentrated in any specific part.

Racial and Ethnic Minority Populations

The impact of public transit availability change on spatial access to food for racial and ethnic minority populations was relatively positive overall. This group of the population faces an abundance of inequalities beyond access to food, including rates of diet-related chronic disease. In addition, they are more likely to face the burdens of residential segregation, which often comes with greater distance to grocery stores and greater availability of unhealthy food (Berg & Murdoch, 2008; Dutko et al., 2012; C. Gordon et al., 2011; Kwate, 2008; Li & Ashuri, 2018; Moore & Diez Roux, 2006; Powell et al., 2007; Zenk et al., 2005). The measure of net change shows consistently positive and high results for groups with the greatest prevalence of racial and ethnic minority populations on Sundays. The share of gains and losses compared to the share of the population confirm this, but also reveals that many instances where this is also true for weekdays. Figure 5 shows that block groups with a higher prevalence of racial and ethnic minority populations are concentrated in the central, northwest, and northeast parts of the county.

Implications for Policymakers and Planners

The implications of this study for policymakers and planners, especially those involved with the implementation of strategies to reduce inequalities in spatial access to food, are that more than just proximity to food retail determines spatial access. To go further than the food desert metaphor can for conceptualizing spatial access to food and identifying inequalities, the structure of the urban environment requires a more comprehensive evaluation to understand how and when people can access food. The method explored in this thesis measures spatial access to food according to the road and public transportation networks to avoid boundary issues, how people move throughout the city without a vehicle, and acknowledges the dynamic nature of spatial access. Because any urban environment will change structurally over time, multi-agency coordination can guide the planning and implementation of intervention strategies to have the greatest possible outcome and meet the greatest need. Further, an agenda to improve spatial access to food can be adopted by policymakers and planners at agencies responsible for community and economic development and transportation. Even though food insecurity is ultimately a health issue, its causes are not, and prevention of them would likely result in better health outcomes over time. Multi-agency coordination on spatial access to food may lead to better-informed decision making so that policy and projects do not negatively impact spatial access to food, therefore lessening the impact of another agency's efforts to improve it. Should a negative impact be unavoidable by a project or program for certain areas, the methods used in this thesis can also help to identify need for geographically or demographically targeted intervention strategies to offset them. While the structural changes to the urban environment observed in this thesis

relate to public transportation availability, the approach can extend to include other structural changes that impact spatial access to food such as those related to the road network or to the food retail landscape. Furthermore, the approach taken in this study can be applied to other access measures unrelated to food, such as to public services or healthcare.

For Marion County specifically, the implications of this study relate directly to current projects. While the analysis measured change from the summer of 2018 to the summer of 2020, changes to the IndyGo bus system are ongoing. The analysis included the introduction of the first BRT route, the Red Line, but construction on two more BRT routes is due to begin within the next few years CIRTA, 2016). The Red Line was completed first because it was anticipated to have the greatest potential for success as far as ridership, economic development, and federal funding are concerned (CIRTA, 2016). However, the Blue Line and the Purple Line are both planned to pass through areas designated as low access to food by the USDA, and therefore may have greater impact on spatial access to food, although not specifically intended to. The planned transformation of IndyGo bus routes from a hub-and-spoke model to a grid-based system are also likely to have a significant impact on spatial access to food across the entire city and not localized like the impacts of the new BRT routes will be. For instance, it will allow for easier transfer between routes, potentially making it possible for some to reach stores they currently do not have timely access to.

Strategies specifically intended to improve spatial access to food are also being explored by the county, such as those that are part of a $780,000 initiative launched in 2019 and administered by the Marion County Department of Public Health ("City-County

Fiscal Ordinance No. 13," 2019), which include a partnership with the ride-sharing service Lyft to launch a pilot program that subsidizes trips to and from select food retailers for residents with incomes below a certain level and who live within certain areas, as well as development of a mobile market system to bring groceries into various neighborhoods and other plans. The strategies of this initiative did not include plans for public transportation, however, should these efforts continue or grow, coordination between public health and transportation agencies could be beneficial for strategies implemented.

While the analysis performed sought to go beyond the identification of food deserts and the limitations involved with the methodology behind it, it has its own limitations which also offer opportunity for future study. Except for public transportation data, the data used were temporally inconsistent and were kept constant for both the summer of 2018 and summer 2019. This included the road network, the location of supermarkets, and sociodemographic measures, which in real life are all subject to change. Although this study challenged some structural limitations that food desert identification faces, such as the boundary problem, the MAUP, and the UGCoP, there is opportunity for increasing the accuracy and precision of the results. One way could be to incorporate stronger population referencing methods such as through use of Census blocks or parcel data rather than block groups to relate miles of road gained and lost to affected populations. With this, non-residential areas can also be eliminated from the analysis, which is not as easy to accomplish with use of larger areal units.

As can be seen in Figures 6 and 7, use of the road network to measure spatial access to food produces results that conflict with generalizations made when the USDA

method is used. The road network is how people move across the city, by walking or in a vehicle, and therefore it is a more accurate depiction of spatial access than one dependent on Cartesian distance measures from areal unit centroids. Still, there is room for better representation of how people travel. For example, consideration for the walkability of the road network and other pedestrian-accommodating infrastructure can present more accurate models of access. While highways, ramps, and service roads were restricted for pedestrians in the analysis, other roads in the city are likely also unwalkable, including those without sidewalks that are not side streets, or those in unsafe environments. Sidewalk data can be obtained rather easily but measuring safety and comfort around walkability could provide an opportunity for inclusion of qualitative data from surveys or interviews with city residents. Another opportunity to build on this study is using different sources for food procurement and not just supermarkets. As described in the methods section, supermarkets were chosen intentionally, but other sources for food procurement also contribute meaningfully to various populations. For example, smaller ethnic specialty stores are likely influential to the food shopping behaviors of ethnic and racial minority groups and food pantries to low-income populations.

While food desert identification methods are static in time, the reality is that spatial access to food is temporally dynamic. The main objective of this study was to measure change, therefore, time was intrinsically relevant, however, another way that the analysis considered time was in its comparison between days when bus service runs most frequently, on weekdays, to days when bus service runs least frequently, on Sundays and holidays. This offers a glimpse at the range of access across a given week. More can be studied to better understand the temporal variability of spatial access to food though. For

example, fluctuations in access throughout the day can be observed if various hours of the day are included. Similarly, access can be calculated for times when public transit is not in service, such as past midnight, which would essentially be a solely walking-based access measure. The hours of operation of food retailers must also be considered. It is also important to note that the analysis performed assumed buses consistently run according to schedule, so methods to account for this should be leveraged in future work.

Another way that the method of this study can be improved upon, which it fails to do just like food desert identification methods, is to move beyond a binary conceptualization of spatial access to food. Through use of methods that measure the extent of access, rather than simply the existence of it, it can provide a more detailed picture and can identify areas that are more vulnerable to losing access if there is a change in the availability of public transit or food retail. Because inequalities in spatial access to food are a health-related concern, the analysis can also be enriched with inclusion of health-related data. Although it is difficult to obtain such data at a local level smaller than the county, the inclusion of it could be helpful for better understanding the relationship between spatial access to food and health outcomes related to chronic diet-related diseases.

CONCLUSION

This thesis describes how spatial access to food, a determining factor of food security, came to be an area of study that has grown in complexity throughout the last quarter of a century. While the introduction of the food desert metaphor led to an era of inspiration for scholars and policymakers to address inequalities in spatial access to food, the simplicity of methodology based off it fails to account for much of what determines spatial access, such as mode of transportation and time. As public entities across the US are increasingly delegating attention and resources to intervention strategies intended to mitigate these inequalities, the need for accurate modelling of spatial access to food, especially for those most vulnerable to food insecurity, is critical for planners and policymakers to efficiently target efforts. Network analyses, such as those performed in this thesis, offer an opportunity to add complexity to the measurement of spatial access to food to better capture where inequalities exist.

In addition to the need for accurate representation of spatial access to food, there is also a need for greater coordination among public agencies to support efforts put forth to mitigate inequalities. This study assesses the impact of public transit availability change over a two-year period on spatial access to food in Marion County, Indiana. The results of the analysis show that these changes had an overall beneficial impact on spatial access to food for the county as a whole, indicated by positive net changes in miles of road where supermarkets can be accessed within thirty-minutes via walking and/or bus on days with the highest availability of bus service, weekdays, and the lowest availability of bus service, Sundays and holidays. The analysis also reveals how these changes to the availability of buses specifically impacted segments of the population that are among the

most vulnerable to food insecurity. While the changes to the public transit system in Marion County were not detrimental to spatial access to food, and therefore occurred in harmony with the county's agenda to improve food access, improvement plans for the bus system are set to continue over the coming years and a similar analysis can be useful in the future to monitor whether changes to the bus system continue to have a positive impact on spatial access to food or if the trends turn the oppositive direction. Similar analyses can also be performed to observe how other changes within urban environments, not just public transportation, impact spatial access to food, and even spatial access to other services, such as healthcare, education, and recreation facilities. Performing analyses such as these can help to ensure that planning and policy decisions intended to have a positive impact in one way do not have a negative impact in another.

With food insecurity affecting so many across the world, mitigating inequalities in spatial access to food is a meaningful act, even in high-income countries such as the US. However, to be successful at improving spatial access to food, more than the identification of food deserts is necessary. Various intervention strategies can be attempted, but consideration of the complexity involved with spatial access to food is critical.

APPENDIX

Table 3: Net Change in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 by Prevalence of Households without a Vehicle

Block Groups by Prevalence of Households without a Vehicle	Net Change in Miles of Road with Access on Weekdays	Net Change in Miles of Road with Access on Sundays/Holidays
<10%	+20.20 miles	+106.76 miles
10-15%	+3.64 miles	+19.39 miles
15-20%	+11.56 miles	+27.94 miles
20-25%	+0.85 miles	-9.30 miles
25-30%	+4.21 miles	+2.10 miles
30-35%	-1.22 miles	+4.20 miles
35-40%	-0.15 miles	+1.67 miles
40-45%	+1.70 miles	+3.82 miles
45-50%	+0.68 miles	-0.35 miles
>50%	-0.38 miles	0.00 miles

Table 4: Distribution of Total County Gains and Losses in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 by Prevalence of Households without a Vehicle

Block Groups by Prevalence of Households without a Vehicle	Distribution of Total County Households	Distribution of Miles of Road where Access was Gained on Weekdays	Distribution of Miles of Road where Access was Lost on Weekdays	Distribution of Miles of Road where Access was Gained on Sundays/Holidays	Distribution of Miles of Road where Access was Lost on Sundays/Holidays
<10%	60.13%	62.42%	73.47%	65.68%	58.39%
10-15%	14.08%	10.69%	12.23%	10.28%	4.43%
15-20%	9.02%	13.45%	1.21%	13.77%	2.46%
20-25%	5.38%	2.74%	3.31%	4.34%	32.60%
25-30%	5.22%	7.91%	5.96%	1.29%	1.15%
30-35%	2.69%	0.00%	2.48%	2.07%	0.36%
35-40%	1.74%	0.10%	0.49%	0.78%	0.00%
40-45%	0.63%	1.94%	0.10%	1.79%	0.00%
45-50%	0.47%	0.75%	0.00%	0.00%	0.61%
>50%	0.63%	0.00%	0.76%	0.00%	0.00%

Table 5: Net Change in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 by Prevalence of Households in Poverty

Block Groups by Prevalence of Households in Poverty	Net Change in Miles of Road with Access on Weekdays	Net Change in Miles of Road with Access on Sundays/Holidays
<5%	-8.47 miles	-1.45 miles
5-10%	+5.41 miles	+24.80 miles
10-15%	-4.26 miles	+31.86 miles
15-20%	+15.33 miles	+22.12 miles
20-25%	+10.83 miles	+25.00 miles
25-30%	+2.10 miles	+11.12 miles
30-35%	+2.86 miles	+8.36 miles
35-40%	+6.98 miles	+15.90 miles
40-45%	+9.07 miles	+9.72 miles
45-50%	+0.67 miles	+1.61 miles
>50%	+0.58 miles	+7.18 miles

Table 6: Distribution of Total County Gains and Losses in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 by Prevalence of Households in Poverty

Block Groups by Prevalence of Households in Poverty	Distribution of Total County Households	Distribution of Miles of Road where Access was Gained on Weekdays	Distribution of Miles of Road where Access was Lost on Weekdays	Distribution of Miles of Road where Access was Gained on Sundays/Holidays	Distribution of Miles of Road where Access was Lost on Sundays/Holidays
<5%	18.20%	5.45%	27.20%	9.15%	36.84%
5-10%	19.69%	15.34%	17.16%	15.97%	16.21%
10-15%	17.31%	10.93%	28.70%	24.80%	36.91%
15-20%	9.63%	20.35%	6.21%	11.33%	3.56%
20-25%	10.62%	13.68%	3.11%	12.01%	1.05%
25-30%	9.28%	4.44%	3.88%	5.32%	0.37%
30-35%	4.35%	8.04%	8.94%	4.34%	1.56%
35-40%	4.07%	8.54%	1.50%	7.66%	0.74%
40-45%	2.88%	10.36%	0.59%	4.74%	0.65%
45-50%	1.81%	0.74%	0.00%	1.01%	0.97%
>50%	2.16%	2.12%	2.71%	3.68%	1.14%

Table 7: Net Change in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 by Prevalence of Single-Parent Families in Poverty

Block Groups by Prevalence of Single-Parent Families in Poverty	Net Change in Miles of Road with Access on Weekdays	Net Change in Miles of Road with Access on Sundays/Holidays
<5%	-4.19 miles	+61.64 miles
5-10%	+10.44 miles	+28.96 miles
10-15%	+9.00 miles	+16.57 miles
15-20%	+7.25 miles	+16.12 miles
20-25%	+4.55 miles	+4.99 miles
25-30%	+2.81 miles	+6.07 miles
30-35%	-1.21 miles	+4.07 miles
35-40%	+0.73 miles	+0.06 miles
40-45%	+10.56 miles	+8.60 miles
45-50%	-0.22 miles	+3.90 miles
>50%	+1.38 miles	+5.26 miles

Table 8: Distribution of Total County Gains and Losses in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 by Prevalence of Single-Parent Families in Poverty

Block Groups by Prevalence of Single-Parent Families in Poverty	Distribution of Total County Households	Distribution of Miles of Road where Access was Gained on Weekdays	Distribution of Miles of Road where Access was Lost on Weekdays	Distribution of Miles of Road where Access was Gained on Sundays/Holidays	Distribution of Miles of Road where Access was Lost on Sundays/Holidays
<5%	53.11%	30.92%	65.20%	50.53%	80.98%
5-10%	12.93%	23.04%	21.08%	16.78%	11.96%
10-15%	10.91%	11.63%	3.06%	8.21%	1.62%
15-20%	8.74%	11.39%	6.18%	8.07%	1.91%
20-25%	4.75%	5.12%	0.16%	2.66%	1.19%
25-30%	2.97%	3.19%	0.14%	2.89%	0.16%
30-35%	2.49%	0.44%	3.26%	2.17%	0.97%
35-40%	1.03%	0.82%	0.02%	0.19%	0.61%
40-45%	0.91%	11.69%	0.00%	4.06%	0.09%
45-50%	0.43%	0.00%	0.46%	1.85%	0.08%
>50%	1.73%	1.77%	0.44%	2.59%	0.44%

Table 9: Net Change in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 by Prevalence of Households of People Age 65 or Older Living Alone

Block Groups by Prevalence of Households of People Age 65 or Older Living Alone	Net Change in Miles of Road with Access on Weekdays	Net Change in Miles of Road with Access on Sundays/Holidays
<5%	+15.35 miles	+38.38 miles
5-10%	+22.22 miles	+45.57 miles
10-15%	+5.79 miles	+45.66 miles
15-20%	-6.73 miles	+12.55 miles
20-25%	-1.77 miles	+1.87 miles
25-30%	+3.22 miles	+11.99 miles
>30%	+3.01 miles	+0.23 miles

Table 10: Distribution of Total County Gains and Losses in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 by Prevalence of Households of People Age 65 or Older Living Alone

Block Groups by Prevalence of Households of People Age 65 and Older Living Alone	Distribution of Total County Households	Distribution of Miles of Road where Access was Gained on Weekdays	Distribution of Miles of Road where Access was Lost on Weekdays	Distribution of Miles of Road where Access was Gained on Sundays/Holidays	Distribution of Miles of Road where Access was Lost on Sundays/Holidays
<5%	28.72%	29.40%	22.78%	22.98%	18.62%
5-10%	28.01%	38.56%	25.62%	27.77%	23.93%
10-15%	23.46%	17.49%	20.33%	29.60%	30.65%
15-20%	9.27%	3.47%	20.02%	9.98%	15.33%
20-25%	5.90%	0.58%	4.65%	2.44%	5.86%
25-30%	2.80%	7.01%	6.32%	6.65%	3.84%
>30%	1.85%	3.49%	0.29%	0.58%	1.77%

Table 11: Net Change in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 by Prevalence of Racial and Ethnic Minority Populations

Block Groups by Prevalence of Racial and Ethnic Minority Populations	Net Change in Miles of Road with Access on Weekdays	Net Change in Miles of Road with Access on Sundays/Holidays
<10%	+5.67 miles	-0.32 miles
10-20%	-6.25 miles	+2.01 miles
20-30%	+0.82 miles	+18.40 miles
30-40%	-1.36 miles	+16.41 miles
40-50%	-1.16 miles	+18.50 miles
50-60%	+15.23 miles	+19.72 miles
60-70%	+8.17 miles	+20.25 miles
70-80%	+13.81 miles	+19.96 miles
80-90%	+7.64 miles	+27.59 miles
>90%	-1.47 miles	+13.72 miles

Table 12: Distribution of Total County Gains and Losses in Miles of Road with Access to a Supermarket within 30 Minutes via Walking and/or Bus from Summer 2018 to Summer 2020 by Prevalence of Racial and Ethnic Minority Populations

Block Groups by Prevalence of Racial and Ethnic Minority Populations	Distribution of Total County Households	Distribution of Miles of Road where Access was Gained on Weekdays	Distribution of Miles of Road where Access was Lost on Weekdays	Distribution of Miles of Road where Access was Gained on Sundays/Holidays	Distribution of Miles of Road where Access was Lost on Sundays/Holidays
<10%	10.52%	8.20%	3.53%	2.07%	8.33%
10-20%	15.59%	0.59%	13.76%	4.63%	13.81%
20-30%	13.75%	11.43%	19.30%	15.75%	26.66%
30-40%	10.85%	5.21%	12.33%	9.17%	5.52%
40-50%	8.78%	3.56%	8.88%	13.72%	18.89%
50-60%	10.01%	21.09%	7.78%	14.45%	19.46%
60-70%	6.95%	12.51%	6.35%	9.51%	0.03%
70-80%	8.41%	17.35%	3.78%	10.03%	2.48%
80-90%	8.72%	17.36%	16.33%	13.69%	2.76%
>90%	6.40%	2.71%	7.95%	6.98%	2.05%

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