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MODELING AND ANALYSIS OF ACCESSIBILITY TO THE FOOD OPPORTUNITY  
SYSTEM IN SEDGWICK COUNTY, KANSAS

A Thesis by

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Bachelor of Science, Tecnológico de Monterrey, 2021

Submitted to the Department of Industrial, Systems and Manufacturing Engineering  
and the faculty of the Graduate School of  
Wichita State University  
in partial fulfillment of  
the requirements for the degree of  
Master of Science

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MODELING AND ANALYSIS OF ACCESSIBILITY TO THE FOOD OPPORTUNITY  
SYSTEM IN SEDGWICK COUNTY, KANSAS

The following faculty members have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirement for the degree of Master of Science, with a major in Industrial Engineering.

Laila Cure, Committee Chair

Nikki Keene Woods, Committee Member

Ehsan Salari, Committee Member

## DEDICATION

To my parents, my late father J. Francisco Maldonado Monje, and my mother Maria de Lourdes Mundo Berber for being the guiding lights of my life, your unconditional love and support helped me navigate this journey

## ACKNOWLEDGEMENTS

I want to thank my research advisor, Laila Cure, for her guidance and patience in the stages of this project. She has contributed to my academic and personal growth and professional development. I extend my gratitude to the members of the committee, Nikki Keene Woods, and Ehsan Salari, for their suggestions and feedback.

## ABSTRACT

Food accessibility has been a growing interest by the United States government due to the negative impact on the population's health such as obesity, chronic illness, and premature death. This thesis investigated existing and potential quantitative food access measurement models to support decisions to improve food access. A gap was identified in research assessing food access measurement methods for policymakers to proactively support actionable decisions to improve accessibility. There was an opportunity to incorporate individual and community considerations that would reflect a more realistic measurement of food access. A proposed integer program was proposed for individual navigation of the food opportunity system in Sedgwick County, Kansas. The formulation considers potential requirements and limitations of individuals seeking food assistance and the food opportunities available to them. The output of the proposed formulation recommends a set of locations and times for individuals to acquire the food they need at minimal cost. Ultimately, the illustration of the use of the life-constrained accessibility in the food opportunity system with a hypothetical sample of individuals with varied characteristics generated from census data. The thesis compares the assessment of access to the conventional perspective. It was confirmed that conventional measures overestimate the individual's ability to obtain the food they need.

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## LIST OF ABBREVIATIONS

ABS	Agent-Based Simulation
API	Application Programming Interface
BMI	Body Mass Index
CBC	COIN-OR Branch-And-Cut
CINAHL	Cumulated Index To Nursing And Allied Health Literature
DALYS	Disability-Adjusted Life-Years
F&V	Fruits And Vegetables
GIS	Geographic Information Systems
ID	Identity Document
ICT	Information And Communication Technologies
MI	Marginalization Index
MEDLINE	Medical Literature Analysis And Retrieval System Online
MRFEI	Modified Retail Food Environment Index
PFIVI	Place-Based Food Insecurity And Vulnerability Index
PRISMA	Preferred Reporting Items For Systematic Reviews And Meta-Analyses
RAM	Random-Access Memory
RFEI	Retail Food Environment Index
SMIP	Supermarket Interaction Potential
SNAP	Supplemental Nutrition Assistance Program
TEFAP	The Emergency Food Assistance Program

LIST OF ABBREVIATIONS (continued)

TGDE	Time Geographic Density Estimation
USD	Unified School District
U.S.	United States
USDA	United States Department Of Agriculture
WIC	The Special Supplemental Nutrition Program For Women, Infants, And Children
WSU	Wichita State University

# CHAPTER 1

## INTRODUCTION

Food systems play a primary role in human functioning and development. They are “place specific clusters of agricultural producers along with consumers and institutions engaged in producing, processing, distributing, and selling foods”<sup>1</sup>. Food access is defined as the accessibility of individuals to healthy food sources within their food system<sup>2</sup> and it is considered a basic human right according to the United Nations<sup>3,4</sup>. Low food access areas have been defined by the United States Department of Agriculture (USDA) as “food deserts” with 53.6 million people in the United States (U.S.) living in them<sup>5</sup>. This has various consequences, such as an increased probability of developing chronic illnesses, obesity and in long term, death<sup>6-8</sup>. It is estimated that one third of Americans are affected by obesity<sup>9</sup>.

There are distinct aspects of the food system that can limit an individual’s food access such as distance and time<sup>10</sup>, as well as their characteristics like income, gender, ethnicity, disabilities, education level amongst others<sup>11-14</sup>.

The main hypothesis of this thesis is that there is insufficient research on using food access measurement methodologies to support actionable decisions to improve food accessibility.

The objectives of this thesis are:

1. To investigate existing and potential models for food access measurements used to support system decisions for food access improvement.
2. To investigate the maximum accessibility level achievable by individuals within their life and environment constraints using optimization techniques.

3. To provide a shared understanding of the food assistance opportunity system in Sedgwick County from two perspectives: centralized (conventional) perspective and the individual (proposed) perspectives.

Chapter II addresses objective 1 with a systematic literature review defining food systems, identifying state-of-the-art quantitative methodologies to model food accessibility and summarizing decision support instances and models for accessibility improvement. A search protocol based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines was developed, and 39 articles were included in the review. Four of the articles included decision support models to improve accessibility; one focused on determining the optimal location of food outlets using mathematical optimization; another focused on minimizing the travel cost for a target population to mobile markets, another article focused on minimizing the number of food deserts with independent grocers, and the other focused on selecting among candidate policies using computer simulation. The articles with no decision support focus comment on the usefulness of their results to inform decision making for accessibility improvement. Most of these articles used food accessibility measures based on the spatially nearest food outlet and on whether there is at least one food outlet in a geographical buffer. Fewer considered public indices, store's open time window, and consumers travel patterns. There was a lack of decision making for improvement of assessed accessibility. Some measures considered community's needs such as being low income, health (based on the healthiness of the food outlet), and outlets' time schedules. There is an opportunity to incorporate individual and community considerations, along with time constraints in accessibility measures. This comprehensive approach of measuring food access references real-life constraints and capabilities of individuals. It was found that resources like food assistance opportunities are understudied<sup>15</sup>.

It's important to consider food opportunities in the food system as these places aid individuals in socioeconomic need. One of the conclusions of the systematic review was that there is an opportunity to develop a recommendation system for individuals considering their personal needs and constraints in navigating their food environment.

Chapter III addresses objective 2 with a recommendation scheduling model for individuals potentially seeking food assistance. Specifically, an individual's seeks a schedule to collect food from food assistance opportunities according to their necessities and spatiotemporal constraints. The problem was formulated as a binary integer program. The model was illustrated with data from Sedgwick County, Kansas, with a focus on food opportunities. It investigated how to obtain the parameters needed for the proposed modeling approach including the list of food opportunities in Sedgwick County, their open times, location, average number of servings that can be obtained in one visit, their requirements like the areas they serve, student status, income, and documentation. There was an assumption of 3 meals per day and car transportation. A questionnaire was developed to obtain the individual-specific parameters. There was a guarantee of the individual scheduled to visit locations on the time frame the individual is available, when the opportunities are open, where the individual meets the eligibility requirements, at most once per day and hour, and one location per day. Additionally, the total of servings of food obtained was at least the required number of servings needed for the planning horizon. The model was illustrated with an example including the 58 food opportunities in Sedgwick County. The model can be implemented by stakeholders and organizations interested in individual food access improvement. Other urban or rural settings can be applied to the model by following the parameter and data collection methodology explained in this chapter.

Chapter IV addresses objective 3 with findings from the food accessibility review from Chapter II and the optimal food navigation model developed in Chapter III. They were used to study a measure of “life-constrained access to food opportunities” in Sedgwick County, Kansas. A set of hypothetical individuals with diverse characteristics was created needing the services of food opportunities for a period of 1 week. They were generated with Montecarlo sampling techniques based on census data and the Sedgwick County Food System Master Plan. Conventional food access measurements (nearest outlet, density and dichotomous with buffers of 1 and 10 miles) were obtained. The main hypothesis was that conventional food access measurements overestimate the ability of people to access the food they need when they can obtain it given their routines. Independent t-tests with 95% confidence intervals and correlations between measurements were performed to test the hypothesis.

## CHAPTER 2

### DECISION SUPPORT MODELS TO IMPROVE FOOD ACCESSIBILITY: A SYSTEMATIC REVIEW

#### 2.1 Abstract

This study investigates systems decisions to improve food accessibility, along with the existing and potential models used to support those decisions. A systematic review of studies quantitatively modeling accessibility and/or supporting accessibility improvement decisions was conducted. The literature databases searched were the Medical Literature Analysis and Retrieval System Online (MEDLINE), Cumulated Index to Nursing and Allied Health Literature (CINAHL), ProQuest Nursing & Allied Health Source, Consumer Health Complete, and Scopus and 39 articles were reviewed. Four articles focused on specific decisions such as determining the optimal location of food outlets using mathematical models and evaluating the impact of policies on well-defined accessibility measures using computer simulation models. The remaining articles did not focus on decisions, they presented 24 well-defined accessibility measures, many of which incorporated parameters beyond the traditional chain-supermarket and household locations. The parameters used by these measures were summarized and classified into the categories of “*Spatially nearest*,” “*Binary*,” “*Indices*,” “*Spatiotemporal*,” “*Travel-Based*,” and “*Others*.” These accessibility measures suggest variables that can be incorporated into decision support models to improve food systems and to help individuals navigate their food environments with their needs and constraints. The discussion on the model-based studies illustrates how to objectively integrate the findings from public health research to

support the design of accessibility improvement interventions and policies, allowing for strategy evaluation and prioritization prior to implementation.

## **2.2 Introduction**

This review investigates the use of quantitative methods in supporting actionable decisions to improve food accessibility. Food is an important aspect of human development, allowing us to function as individuals and as a society. Access to food is recognized by the United Nations as a basic human right<sup>3</sup>, and the consumption of the right types of food has been identified as a key factor to avoid chronic illnesses such as cardiovascular disease, heart disease, stroke, cancer, diabetes, and obesity<sup>6</sup>. In the United States, chronic diseases for which diet is a major risk factor are four of the ten leading causes of death<sup>7</sup>. The food environment has been found to be a key factor in individuals' diets<sup>16</sup>. Globally, diet was reported to cause 11 million deaths and 255 million disability-adjusted life-years (DALYs) in 2017<sup>8</sup>.

Nevertheless, 10.5 percent of U.S. households experienced food insecurity in 2020<sup>17</sup>. Areas with low access to food are often called "food deserts" and around 53.6 million people live in them in the U.S.<sup>5</sup>. Individuals living in food deserts have limited healthy food options and are likely to suffer a "substitution effect" where inexpensive, energy-dense foods substitute healthier foods, thus increasing Body Mass Index (BMI)<sup>9</sup> and making them more likely to develop those chronic diseases<sup>18</sup>. Furthermore, food insecurity has been linked to nonclinical outcomes, such as missed workdays, particularly for adults with diabetes<sup>19</sup>.

Even if there is food available, it may not be accessible to everyone<sup>11</sup>. Economic variables have been identified as key factors influencing people's access to healthy food<sup>11,12</sup>. Half of the people living in food deserts have low income<sup>5</sup> and may have limited ability to travel to food

outlet<sup>20</sup>. The USDA defines “low income” as families in the U.S with an annual income at or below 200% of the Federal poverty threshold according to family size<sup>2</sup>.

Other factors affecting food acquisition include food outlet operating hours, ethnicity, age, gender, physical ability, education, and time available for shopping<sup>11,13,14</sup>.

Interest in food access research has increased during the past decade, and includes developing methods for measuring accessibility, assessing disparities, and evaluating novel policies. However, the hypothesis is that there is insufficient research integrating published findings to proactively support actionable decisions.

A 2011 systematic review on fast food access showed how unhealthy food options are more accessible to low-income and non-white individuals<sup>21</sup>. A 2012 systematic review on the food environment-diet relationship categorized studies based on the type of measure used and found that geographic information systems (GIS) access measures were the most used while few studies assessed affordability, accommodation, or acceptability<sup>10</sup>. A 2017 review on the measures to assess the food environment concluded that there is a need to develop robust and sound measures of the food environment along with sophisticated study designs<sup>22</sup>.

Strategies to improve accessibility or objective methods to develop such strategies were not explicitly discussed in those reviews. Through the explored research, this is the first review that focuses on decisions to improve food accessibility and the methods used to support those decisions. This research defines decisions as well-defined strategies or actions to implement to change a quantitative measure in the desired direction.

### **2.3 Methods**

Modeled after the PRISMA 2020 statement, a search protocol was developed prior to conducting any searching. Five databases were searched on August 6<sup>th</sup> and 11<sup>th</sup>, 2021: MEDLINE,

CINAHL, ProQuest Nursing & Allied Health Source, Consumer Health Complete, and Scopus. Subject index terms or free text searching were used depending on the corresponding controlled vocabularies and semantic meanings. The search strategy and the counts of articles identified per database are shown in Appendix A.

These searches yielded 81 articles (see **Error! Reference source not found.**). Nineteen additional studies known in advance to the authors did not appear in the searches. Six duplicates were removed. From these 94 articles, an initial screening excluded publications not meeting the inclusion/exclusion criteria, including reviews, discussion articles, case studies, non-peer-reviewed studies, and unpublished manuscripts. This phase further excluded studies published in languages other than English, as well as studies examining non-adult population groups. Aspects of articles not considered for exclusion included article publication date, setting, and geographic location.

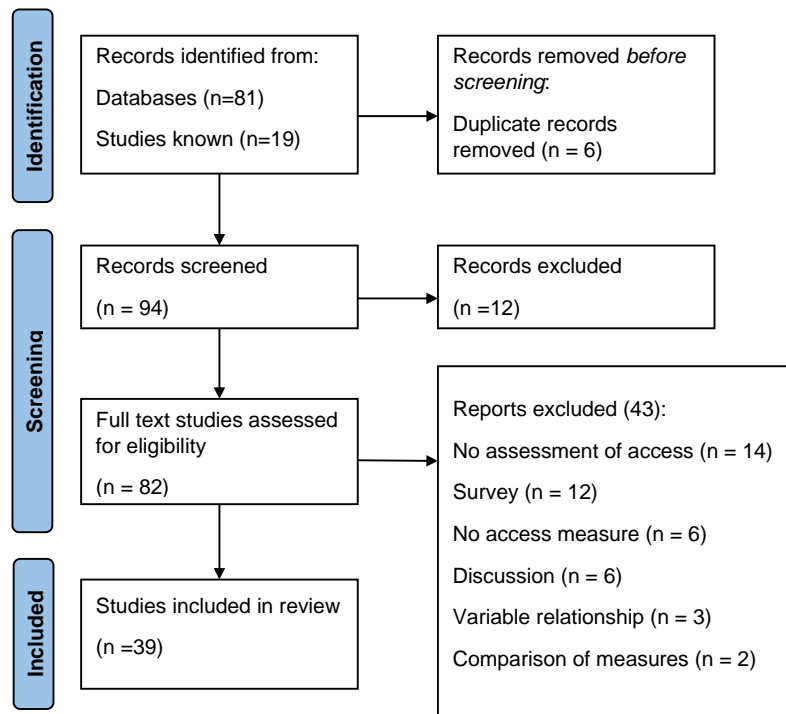


Figure 1. Flow diagram for review of accessibility studies in terms of decision support models.

Modeling approaches considered for inclusion had measurable quantities, statistical models, simulation models, visual/conceptual models, and maps. The studies excluded did not include a consumer (could be characterized as individuals or aggregated as communities), conducted a life cycle analysis or block chain/product traceability analysis, or used food accessibility as one predictor for other issues, such as obesity, inactivity, education, medication adherence, or others, without a thorough discussion and analysis of the accessibility measure. Papers focusing on food accessibility during disaster conditions, food literacy, food safety, and food chemistry or nutrition, were also excluded from the search. Twelve records were removed from the analysis after this screening.

For the final screening, the texts of all 82 remaining articles were reviewed independently by the primary author and advisor with disagreements being resolved by discussion analysis for appropriateness of inclusion in this thesis. Forty-three records were excluded and a final total of 39 articles were included in the analysis.

## **2.4 Results**

Fifteen of the reviewed papers focused on investigating the relationship between food accessibility and other variables, most predominantly obesity indicators<sup>9,15,18,23–25</sup> and fruit and vegetable consumption<sup>6,12,26,27</sup>. Other variables less studied included structure of agricultural systems<sup>28</sup>, walkability<sup>29</sup>, residents' perception of the food environment<sup>30</sup>, socio-economic and disability disparities<sup>11</sup>, and global diet measures<sup>11,31</sup>. The papers settings involved North America (27/39)<sup>5,7,12–14,18,20,24–29,31–44</sup>, Europe (6/39)<sup>16,30,45–48</sup>, Oceania (4/39)<sup>8,11,49,50</sup>, and Asia (2/39)<sup>6,51</sup>.

A considerable number (13/39) of papers proposed alternative measures of accessibility while discussing how their measure improves upon traditional approaches focusing on the number

of stores in a geographical radius<sup>13,20,36,39,41–45,48,51–53</sup>. Several papers studied food acquisition behaviors using individual level data from diverse sources<sup>14,37,50,54–56</sup>.

A few of the articles focused on measuring the accessibility of a specific community to identify food deserts<sup>46</sup>, assess racial disparities<sup>8</sup>, and study patterns of accessibility over time<sup>6</sup>. One paper defined the community of interest in terms of features not necessarily contained in a geographical area (e.g., formerly incarcerated)<sup>8</sup>.

#### **2.4.1 Decision Support Models**

Four of the 39 articles used mathematical optimization and computer simulation models to illustrate the potential benefits of interventions seeking to improve accessibility. The optimization models focused on strategically selecting the location of food vendors. For example, Widener et al. developed a mathematical model to optimize the locations of mobile markets<sup>33</sup>. The objective function here was to minimize travel costs for target populations within the area, modeled as demand nodes in a network. The constraints ensured that the demand nodes were served by one open mobile market, that the markets assigned to the demand nodes had the appropriate capacities, that demand nodes were assigned to the closest site, and that the maximum available number of markets was used. Demand locations were selected based on an inaccessibility measure (e.g., census blocks with inaccessibility measure above the 50<sup>th</sup> or 75<sup>th</sup> percentiles and a centroid network distance of more than one mile to the closest full-service grocery store). This model was illustrated using 2000 U.S. Census data from a medium-sized city (Buffalo, New York) and performing sensitivity analyses on demand node selection criteria, maximum capacity of a mobile market, and available number of mobile markets. The study concluded that it is possible to increase access to produce in food deserts by using mobile markets.

Bao et al. also used mathematical models<sup>34</sup>. They optimized the location of independent grocers to minimize the number of food deserts in an area. Locations were restricted to candidate sites. The objective was to maximize the food desert population that would be covered with the small grocers. The constraints ensured that the food dessert was served by the appropriate combination of stores given the desired number of stores to include in the analysis. While most of the parameters were defined at the census tract level, the accessibility measure used census block level data. The model was illustrated with data from Tucson, Arizona, where 45% of the food desert population is covered by 26 independent grocers. The optimization results showed that 25 strategically located small grocers could ensure coverage of up to 97% of the food desert population, given geographical characteristics of the area.

The simulation models focused on more complex, often unspecified, interventions potentially changing current consumer behaviors. For example, Widener et al. developed an agent-based simulation (ABS) model mimicking food shopping behaviors to study the number of households with fresh fruits and vegetables in stock at any point in time, given different scenarios<sup>35</sup>. The scenarios tested included implementing the following (1) unspecified efforts ensuring that consumers actively used farmers markets as the preferred shopping location when available, (2) a hypothetical program that changed a proportion of infrequent shoppers into weekly shoppers (e.g., transportation support, weekly Supplemental Nutrition Assistance Program (SNAP) benefits), (3) a hypothetical policy that ensured all convenience stores sell fruits and vegetables (e.g., incentives), and (4) an optimal mobile market distribution system designed using mathematical models<sup>33</sup>. The ABS model was illustrated with data from Buffalo, New York, for which the most promising intervention would be one motivating 50% of infrequent shoppers to increase their shopping frequency.

Abel and Faust developed a simulation model combining ABS, GIS, and discrete event simulation to study the impact of hypothetical policies on food accessibility<sup>32</sup>. The policies investigated included increasing the number of bus routes, improving pedestrian infrastructure to increase willingness to walk, increasing the number of grocery stores, and combinations of these policies. The model was used to analyze food deserts in Austin, Texas. The analysis found that increasing the willingness to walk would have the most impact in improving food access.

Articles with a less prominent focus on decision support either provided a very general comment on the usefulness of their findings as evidence to inform policy or mentioned general ideas to improve accessibility. Some of these ideas were in line with enhancing the locations of healthy food outlets, such as improving food access by encouraging existing food outlets, even fast-food restaurants, to increase their offerings of healthy options<sup>20,25,38</sup> or by adding new (preferably healthy) food outlets in low-access or economically disadvantaged locations<sup>7,20,24,25,38</sup>. The locations of more flexible food outlet options such as community-based food outlets<sup>36</sup> or mobile markets and food pantries<sup>25,38,43</sup> were also mentioned. In addition to increasing geographical accessibility to food, some authors mentioned the need for balancing the density of healthy to unhealthy food outlets in an area<sup>6,49</sup>.

Some ideas gravitated around transportation and included revising public transit routes based on current food outlet locations<sup>37</sup>, encouraging transit riders to include food shopping in their commute<sup>44</sup>, and locating healthy food outlets along transit and commuting routes<sup>14,29,37</sup>. Only one article suggested defining the operating hours of food outlets so that they would be consistent with the needs of the communities they serve<sup>20</sup>.

It was suggested that any interventions need to be culturally appropriate<sup>31</sup>. Most of the ideas mentioned would require a centralized food system planning and developing approach<sup>7,51</sup>

with the goal of supporting making the healthier choice the “easy one”<sup>8</sup>. Some ideas went beyond the food system, such as the need to reduce economic disparities<sup>7,24</sup> and strengthen the social network of low-access communities<sup>11</sup>.

#### 2.4.2 Measuring Accessibility

The methods used to assess food accessibility are summarized in **Error! Reference source not found.** References including more than one measure appear more than once in the table. **Error! Reference source not found.** summarizes the most common parameters and the notation used in **Error! Reference source not found.**

While most of the papers used measures involving traditional spatial access, alternative measures involved various interpretations, assumptions, and data sources. Twenty-four distinct accessibility measures were identified and grouped into spatially nearest, binary, indices, spatiotemporal, travel-based, and others. “*Spatially nearest*” (21 references) are measured as the distance(s) between a consumers’ location and their nearest food outlet(s). “*Binary*” (8 references) are measures indicating whether one or more other measures meet predefined thresholds, such as having a spatially nearest accessibility lower than a minimum distance. “*Indices*” (4 references) are measures available in public repositories and that were thoroughly discussed in the article. “*Spatiotemporal*” (2 references) are food access measures that consider the time window of stores being open. “*Travel-based*” (6 references) incorporate consumers’ (potential) travel patterns. “*Others*” (4 references) include unique measures developed for specific purposes. Some articles compared approaches to assess accessibility and compared results. Some, like Moore et al.<sup>31</sup> included both, a spatial measure, and a perception-based measure that they studied as potential factors in explaining diet quality.

##### **Parameters defined by analysts:**

$\delta$ : predefined threshold determining radius of analysis around a consumer (or buffer zone)

$t$ : time of the day

$T$ : time period selected

$\mathcal{F}$ : factors other than spatial considered in the analysis, indexed by  $f$ . Spatial accessibility is assigned  $f = 0$ .

$\omega_f$ : weight of factor  $f$

### Consumers and food outlets:

$\mathcal{J}$ : set of consumer points, indexed by  $i$

$\mathcal{C}$ : set of classes (types) of food outlets considered (healthy/unhealthy, large/small, free/paid, brand, etc.), indexed by  $c$

$\mathcal{J}_c$ : set of food outlets, indexed by  $j$ , where  $\mathcal{J}_c \in \mathcal{J}$  is the subset of food outlets of type/class  $c$

$\mathcal{M}$ : set of transportation modes considered, indexed by  $m$ ; adding the index  $m$  to any of the following parameters or measures implies considering transportation mode; omitting it implies that only one transportation mode is considered in the analysis.

$\mathcal{G}$ : Geographical movement data (i.e., observations or control points) from individuals

### Parameters obtained from data:

$d_{ij}$ : measure of distance between points  $i$  and  $j$ . If brackets are used around the second index (i.e.,  $d_{i[j]}$ ) then the distances are assumed to be ordered from smallest to largest with respect to  $i$ , thus  $[j]$  denotes the  $j^{th}$  closest store.

$s_{ij}$ : binary parameter indicating if  $d_{ij} \leq \delta$  ( $s_{ij} = 1$ ) or not ( $s_{ij} = 0$ )

$a_x$ : geographical area associated with  $x$

$r_i$ : probability of consumer point not having a vehicle

$p_i$ : population of the consumer point  $i$  (e.g., number of households in census tract  $i$ )

$p_{ij}$ : subpopulation that commutes between locations  $i$  and  $j$

$h_j$ : binary indicator of a food outlet offering healthy food options ( $h_j = 1$ ) or not ( $h_j = 0$ )

$v_j$ : linear shelf space dedicated to fruits and vegetables in store  $j$

$o_{jt}$ : binary indicator of a food outlet being open at time  $t$

$y_{[f],i}$ : value of factor  $f$  corresponding to consumer point  $i$

Figure 2. Parameters and variables used in accessibility formulas.

Consumers were represented by neighborhoods, census blocks or census tracts when publicly available datasets were used. They were represented by households when more tailored data was collected for the study. Food outlets included mostly full-service supermarkets; however, some studies also included healthy food outlets or ethnic stores.

Distances between consumers and grocery stores were calculated in several ways. Some studies simply used a Euclidean distance between the latitude and longitude coordinates of

locations of interest, while others used software, like GIS, to calculate Manhattan block or network travel distances, often transformed to average travel times. Mulrooney et al. proposed rasterizing images of an area and assigning a travel cost to each pixel (based on speed limits and distance estimates) to be used in spatially nearest accessibility assessments<sup>43</sup>.

Some studies recognized that it is not realistic to assume that food is only purchased close to people's residences<sup>14</sup>. Several authors considered the out-of-the-home aspects of daily life. For example, Shannon et al. used mobility data to analyze how food acquisitions are related to trips to destinations such as work, along with perceived neighborhood safety and availability of carpooling/ride sharing options<sup>37</sup>. They used a publicly available travel behavior inventory survey to describe the need, but they did not explicitly develop a new accessibility measure incorporating these other locations. Maguire et al. used both distance from home and distance from workplace to analyze exposure to supermarkets and fast-food retailers<sup>16</sup>. Similarly, Salze et al. extended the single consumer point measure to a home-work measure that incorporates the effect of commuting on accessibility<sup>45</sup>. Horner and Woods analyzed individual and aggregate accessibility to food shopping opportunities considering people's activity patterns and available time budgets<sup>13</sup>. Widener et al. proposed an accessibility score representing how easy or difficult it is for public transit users to acquire groceries using public transportation during their commute to work<sup>44</sup>. Zhang and Mao provided a taxonomy of food accessibility measures and proposed an '*n-n-n*' measure incorporating *n* origins, *n* destinations and *n* transit modes<sup>41</sup>.

Some articles simply used publicly available accessibility indices or proxies, such as the Food Environment Atlas by the USDA, which provides food desert designation for various consumer areas. The indices in the review that were fully described within the paper included the Retail Food Environment Index (RFEI) and its modified version, the Modified Retail Food

Environment Index (MRFEI). Galeana-Pizaña et al. based their accessibility assessment on a Marginalization Index considering population distribution, housing conditions, education, and income, which is computed by the Mexican National Population Council<sup>28</sup>.

Some articles proposed diverse ways to describe accessibility without formally defining measurable quantities. For example, Jürgens proposed a survey of consumer behaviors to identify what they called “mental food deserts”, depicted by shopping trip networks of consumers clusters<sup>48</sup>. Diez et al. used photographs taken by study participants to guide discussions on features of the food environment that are important to accessibility<sup>30</sup>. The identified features, mainly described qualitatively, included variety of food store types, poor access/built environment obstacles, marketing, economic crisis/poverty, cultural diversity, social relationships/support, food culture and tradition, unhealthy foods, cost barriers, availability of organic and dietetic food products, food hygiene and handling conditions.

The “time-budget” access of accessibility was mentioned in a small proportion of the articles. Some studies focused on the time-budget from the perspective of users. For example, Horner and Woods included a distance weighting function in their accessibility equation that ensures that only locations reachable by individuals within their travel budget are included<sup>13</sup>. Widener et al. included time windows available to shop as constrained by public transportation<sup>44</sup>. Zhang and Mao included a time-budget in the form of a travel cost threshold beyond which food accessibility is too low to be considered<sup>41</sup>. Other studies included the effect of store hours on accessibility. For example, Chen and Clark proposed adding a third dimension to the traditional accessibility maps in “3D space-time food access pillars”, which would be “sliced” to identify accessible areas at various times of the day<sup>40</sup>. In a different temporal perspective, Hobbs et al. studied the change in accessibility over ten years<sup>8</sup>.

Studies aggregating consumer point accessibility (e.g., county or census tract) mostly calculated a weighted average. Weights were primarily determined by population<sup>16,23,34</sup>. Logan et al. illustrated how to calculate an inequality index for the distribution of accessibilities of consumer points using the Kolm-Pollak approach<sup>39</sup>. In general, accessibility was visualized in two-dimensional heatmaps, and even three-dimensional space-time food access pillars<sup>40</sup>, highlighting accessibility disparities or potential food deserts.

In addition to the measurable quantities outlined in **Error! Reference source not found.**, some articles investigated food access or the broader concept of food security, using survey instruments. Two of the articles developed multivariate logistic regression models to assess the relationship between food security variables, including “restricted food access”, assessed through the “Food Purchasing Survey” (with questions, such as the following: “In the last 12 months, were there any times when you ran out of food and could not afford to buy more?”)<sup>11,50</sup>.

TABLE 1

METHODS TO ASSESS FOOD ACCESSIBILITY

<i>Category</i>	<i>Measure Name and Definition</i>	<i>Formulation per Consumer Point, i</i>	<i>References</i>
<i>Spatially nearest</i>	<b>Nearest outlet:</b> Distance between consumers' location and the nearest food outlet(s).	$A1_i = \min_{j \in \mathcal{J}} d_{ij} = d_{i[1]}$	5,7,8,14,16,24,27,29,33,34,37,39,42,43,46,47,49
<i>Spatially nearest</i>	<b>Density:</b> Number of food outlets in a buffer.	$A2_i = \sum_{j \in \mathcal{J}} s_{ij}$	12,14,16,26,29,41,47
<i>Spatially nearest</i>	<b>Distance to the closest three stores:</b> Sum of distances to the nearest three food outlet stores.	$A3_i = d_{i[1]} + d_{i[2]} + d_{i[3]}$	37
<i>Spatially nearest</i>	<b>Diversity:</b> Mean distance to the closest stores from three distinct brands.	$A4_i = \frac{A1_i  \mathcal{J}_{brand 1}  + A1_i  \mathcal{J}_{brand 2}  + \dots + A1_i  \mathcal{J}_{brand n} }{3}$ , where: $\mathcal{J}_{brand 1}, \mathcal{J}_{brand 2}, \dots, \mathcal{J}_{brand n} \subset \mathcal{J}$	34,47
<i>Spatially nearest</i>	<b>Spatial food access:</b> Percentage of area of geographic unit <i>i</i> served by the food outlets in $\mathcal{J}$ .	$A5_i = \frac{[\cup_{j \in \mathcal{J}} a_j(\delta)] \cap a_i}{a_i}$ , where $a_j(\delta)$ is the geographical area accessible to outlet <i>j</i> , when considering a buffer of $\delta$ .	40

TABLE 2 (continued)

Category	Measure Name and Definition	Formulation per Consumer Point, $i$	References
Binary	<b>Dichotomous:</b> Indication if there is a food outlet in a predetermined buffer.	$A6_i = \begin{cases} 1 & \text{if } A1_i \leq \delta \\ 0 & \text{otherwise} \end{cases}$	5,18,30,42,46,48 .51
Binary	<b>Food-desert:</b> Area with poverty rate of at least 20% and $\geq 33\%$ of the census tract population residing $>1$ mile from a supermarket for urban areas and $>10$ miles for rural areas.	$A7_i = \begin{cases} 1 & \text{if } \left( \frac{\sum_{i' \in CT_i} A2_{i'}}{p_i} > 0.33 \right) \wedge (y_{[pov],i} \geq 0.2), \\ 0 & \text{otherwise} \end{cases}$ where $CT_i$ is census tract $i$ and $y_{[pov],i}$ is the poverty rate of census tract $i$	34,56
Indices	<b>RFEI:</b> Ratio of describing the relative density of unhealthy food outlets to healthy food outlets.	$A8_i = \frac{\sum_{j \in J_{fast\ food}} S_{ij} + \sum_{j \in J_{convenience}} S_{ij}}{\sum_{j \in J_{grocery}} S_{ij}}$	6
Indices	<b>MRFEI:</b> Healthy food retailers as a percentage of all food retailers.	$A9_i = \frac{\sum_{j \in J} S_{ij} h_j}{A3_i}$	25,38
Indices	<b>Inverse marginalization:</b> Relationship of Marginalization Index (MI) and access has been acknowledged.	$A10_i = \frac{1}{MI_i},$ where MI is a marginalization index based on population, housing, education, and labor (indicators computed by the National Population Council in Mexico)	28
Spatiotemporal	<b>Temporal food access:</b> proportion of a period when food can be procured within a geographic unit.	$A11_{iT} = \frac{\max_{j \in J} [(t_{j,closed} - t_{j,open}) \times \delta_j(t)]}{T},$ where: $\delta_j(t) = \begin{cases} 1 & a_j(\delta) \cap a_i \neq 0 \\ 0 & a_j(\delta) \cap a_i = 0 \end{cases}$ , $t \in [0, T], j \in J$ and $a_j(\delta)$ is defined as in the spatial food access measure above.	40
Spatiotemporal	<b>Efficient access to food retailers at time t:</b> Accessible area at time $t$ for buffer-based consumer point $i$ .	$A12_{it} = \bigcup_{j \in J} \pi \delta^2 o_{jt}, \quad \forall j: d_{ij} \leq \delta$	20,40
Spatiotemporal	<b>Spatiotemporal food access:</b> Ratio of food access area to store operating hours per period $T$ .	$A13_{iT} = \frac{[\bigcup_{j \in J} a_j(\delta)(t_{j,closed} - t_{j,open})] \cap a_i T}{a_i T}$	40
Travel based	<b>n-n-n measure:</b> Population-weighted sum of reachable supermarkets.	$A14_i = \frac{\sum_{m \in M} \sum_{i' \in J \setminus \{i\}} p_{i'i'} S(i, i', m)}{\sum_{m \in M} \sum_{i' \in J \setminus \{i\}} p_{i'i'}},$ where: $S(i, i', m) = \sum_{j \in J} (A3_{im} + A3_{i'm})$	41

TABLE 3 (continued)

Category	Measure Name and Definition	Formulation per Consumer Point, $\mathbf{i}$	References
Travel based	<b>n-1-n measure:</b> The total number of people with low food accessibility in a neighborhood.	$A15_i = \sum_{m \in \mathcal{M}} \sum_{i' \in \mathcal{I} \setminus \{i\}} p_{ii'm} (1 - A16_{im}) (1 - A16_{i'm})$	31,41
Travel based	<b>Inaccessibility measure:</b> Estimated sum of distances traveled by households in a particular block group to reach their closest food outlet.	$A16_i = \sum_{i \in J} d_{i[1]} r_i p_i$	33
Travel based	<b>Potential accessibility index:</b> Potential for spatial interaction with possible destinations that can account for a global aspect of travel behavior.	$A17_i = \sum_{j \in J} f(d_{ij}),$ where: $f(\cdot)$ is an impedance function for travel between $i$ and $j$ .	45
Travel based	<b>Commuter potential accessibility:</b> Potential accessibility to food outlet $j$ for commuters living in $i$ and working in $i'$ .	$A18_{ii'} = (A17_i + A17_{i'}) \cdot (1 - \gamma(d_{ii'})),$ where $\gamma(\cdot)$ is a trip length weighting function that considers the commuting time budget.	45
Travel based	<b>Network-based time geographic density estimation (TGDE):</b> Individual's accessibility level to specific opportunities along a potential path tree, based on TGDE.	$A19_i = \sum_{j \in J}  \mathcal{G} ^{-1} \sum_{g \in \mathcal{G}} \hat{f}(x_{ij})' s_{jj'} O_j,$ where $\hat{f}(x_{ij})'$ : intensity for $i$ at $j$ . $s_{jj'}$ : topology correction factor. $O_j$ : attractiveness of $j$ .	13
Travel based	<b>Supermarket interaction potential (SMIP):</b> Level of access for transit riders in consumer location $i$ .	$A20_i = \sum_{i'} p_{ii'} \frac{\sum_{j=[1]}^{[5]} SMIP_{ii'j}}{n},$ where $SMIP_{ii'j}$ is a function of the latest possible departure time and the earliest arrival time at $j$ .	44
Others	<b>Place-based food insecurity and Vulnerability Index (PFIVI):</b> Linear combination of individual and environmental indices possibly affecting food accessibility.	$A21_i = \omega_0 A2_i + \sum_{f \in \mathcal{F}} w_f y_{[f],i}$	36

TABLE 4 (continued)

Category	Measure Name and Definition	Formulation per Consumer Point, $i$	References
Others	<b>F&amp;V stock level:</b> Number of households with fresh fruits and vegetables (F&V) in stock at a point in time.	$A22_{it} = y_{[F\&V],it}$ , where $y_{[F\&V]it}$ is the count of households in $i$ with stock of F&V at time $t$ (obtained through agent-based simulation)	35
Others	<b>Percentage walking as last resort:</b> Percentage of residents in a consumer area that do not have a car, live beyond a maximum walkable distance to a bus, and live beyond a maximum walkable distance to a store.	$A23_i = \frac{\sum_{i'} y_{[walking],i'}}{p_i}$ , where $y_{[walking]i'}$ indicates whether household $i'$ in consumer point $i$ meets conditions.	32
Others	<b>Neighborhood availability:</b> Shelf space dedicated to fresh fruits and vegetables in all stores within a buffer.	$A24_i = \sum_{j \in d_{ij} \leq \delta} v_j$	42

## 2.5 Discussion

This review found that there are opportunities to improve how accessibility is measured, but there is a lack of research using assessments to support actionable decisions for improvement. The few decision-oriented studies found, focused on either the location of food outlets or evaluating the potential effects of well-defined behavioral changes. In what follows, decisions that can impact accessibility and the methods that can be used to objectively study those decisions using data from assessment studies are discussed.

### 2.5.1 Food Opportunity Location

Both food vendor location studies formulated and solved a facility location problem, a well-known optimization problem arising in supply chain applications for which mathematical formulations can be tailored to a context. They modeled how to complement an existing network of full-service grocery stores with strategically located independent grocers or mobile markets.

Both showed potential improvement in spatial accessibility, thus motivating the use of similar techniques to inform incentive policies.

The spatially nearest measures imply that food accessibility can be improved by simply adding grocery stores or other food outlets to the area of interest. Since the new outlets are unlikely to be placed in the same exact location as an existing one, then there is undoubtedly one or more consumer points for which the minimum distance to a vendor is reduced. If the total accessibility of a set of consumer points is simply a weighted sum of distances, then the total accessibility measure is improved. Unfortunately, these types of measures do not account for the improvement of consumer points already having the best accessibility of the set, thus widening the gap between all the consumer points in an area. In addition to increasing overall accessibility, food system designers should seek to balance accessibility levels for all consumer points. Measures like the difference between the worst and best accessibilities (e.g.,  $\max_{i \in J} A1_i - \min_{i \in J} A1_i$ , when using  $A1_i$  as base measure), can help quantify disparities to inform new vendor location decisions and avoid trivial improvements.

The binary measures identified also imply that opening new food outlets is needed for accessibility improvement but requires the new locations to be within a predefined acceptable threshold in areas without a close food outlet to show a quantifiable change. The food-desert classification goes a step further to motivate new outlets to be placed close to low-income consumer points to have any quantifiable impact. Yet, none of the spatially nearest measures account for whether the type of food vendors being considered in the analysis meet the needs of the communities being represented as consumer points.

### **2.5.2 Food Opportunity System Configuration**

The RFEI and MRFEI indices incorporate information on whether the food outlets counted in accessibility measures are healthy, suggesting the need to include food outlet characteristics into improvement efforts. The inverse marginalization index does not directly measure accessibility in the traditional manner but implies that the characteristics of the communities served, particularly those deemed social determinants of health, should also be considered. The food opportunity system configuration decision involves determining the types of food opportunities that would be most beneficial for a community, along with the location of those food opportunities. Increased awareness of food disparities has motivated a local food movement with flexible alternatives such as farmers markets, food trucks, mobile markets, community gardens, and food lockers, among others. These alternatives can potentially better serve their communities since they are often started and operated by community members based on unmet needs. In addition, federal, state, and local governments, along with nonprofit organizations, have motivated the creation of food banks, food opportunities, and food sharing, aimed at providing hunger care to those in need. The coronavirus disease 2019 pandemic forced organizations to strengthen their online food acquisition platforms, which can also contribute to alleviating food access disparities. However, these alternative food opportunities are more difficult to map than large grocery stores, thus they are often excluded from analyses or recommendation systems<sup>37</sup>. Optimization models can be extended to incorporate goals and constraints related to community-specific characteristics such as population density, income level, and ethnic preferences, among others.

### **2.5.3 Food Opportunity Scheduling**

Alternative food outlets and hunger relief organizations tend to have more limited hours of operation and offerings. For example, a food opportunity may be located at a reasonable distance

from an individual's household, but given work or school schedules, individuals may not be able to obtain food through that outlet. The spatiotemporal measures identified have incorporated the outlets' opening and closing times, implying the need to include the question of when diverse types of food outlets should operate. Optimization models can be adapted to consider goals and constraints related to the time-budget constraints of the communities served. The travel-based measures identified allow for considering commuting information in the design of the food system.

In general, optimization techniques aim to support decisions by identifying a measurable quantity to improve as much as possible given some constraints (e.g., budget, geographical limitations, and resource/labor availability, among others). Mathematically optimal systems may still present challenges for some (or even many) individuals in the communities considered, particularly if the data used to formulate the model is aggregated into geographical units, such as census tracts. This implies a need to investigate the food system from the perspective of individuals. The travel-based indices provide different options to incorporate individual behaviors into food accessibility, particularly those related to commuting and travel. Nevertheless, it would be impossible to collect data from all individuals in a community to design a perfect food opportunity system. And even if it was possible, by the time it is implemented, individuals may have changed, or the nature of food may be different, resulting in similar "outlier" problems.

The decisions discussed above, and the perspective used in most of the reviewed research, are consistent with a top-down approach where the system is designed and analyzed in terms of "most" of the population, while individuals adapt to the resulting systems. The bottom-up complement is missing from these analyses. Policies like SNAP are intended to fill the gap between the system design and the individual experience by providing low-income individuals with

additional resources to procure food through traditional outlets. Still, there are opportunities in supporting individual-level decisions to take the best possible advantage of their food system.

#### **2.5.4 Food Acquisition and Preparation Schedule**

Given an existing food opportunity system with known operating schedule and food type constraints, a recommendation system can be developed for individuals. This recommendation system would match personal constraints and goals related to food preferences and needs, work schedules, family duties, income, and dwelling/other locations, among others, to efficiently select when and where to obtain the food they need. In addition, life circumstances may also cause food to be wasted if not prepared and eaten in a timely manner. The recommendation system could be extended to help individuals decide when raw vs prepared foods should be obtained. Nevertheless, individual-level decision support would require the availability of up-to-date data on food outlet locations, along with their operating hours, food offerings, and costs.

Mathematical optimization models often assume one or a combination of static scenarios. However, the optimal performance level cannot be ensured in a dynamic environment. Two of the articles used agent-based simulation to evaluate the anticipated impact of potential (unspecified) policies. Agent-based simulation allows for the combination of individual- and system-level information to evaluate, in different (still hypothetical) realities or scenarios, the impact of changes to the system or to individuals when uncertainty and variability play a significant role.

#### **2.5.5 Evaluating Hypothetical System Changes**

Identifying the most/least promising behavioral changes can guide policymakers in developing incentives. However, additional research would be needed to determine which policies would result in the desired behaviors. For example, if an increase in visits to a farmers' market was found to improve accessibility, then studies investigating promising interventions to motivate

those visits can be identified or developed. A study like Harris et al., which found that providing vouchers to older individuals with diabetes and food insecurity was associated with an increased number of visits to farmers markets<sup>57</sup> could further inform the incentives.

### **2.5.6 Evaluating Well-Defined Policies**

The alternative approach would be to select a policy and then study its anticipated impact on behaviors and then use this information to simulate the post-implementation system. In the farmer's market example, a simulation model could help investigate the anticipated effects on a community, should the results from the intervention-based study scale up. Computer-based simulation approaches allow for incorporating uncertainty into the effects of policies on the system and individuals.

## **2.6 Conclusion**

Current research assessing food accessibility and pointing to its disparities and relationship to health indicates a need to develop the evidence base needed to effect change. The literature review investigated actionable decisions aimed at improving food accessibility and the quantitative methods used to support these decisions. It identified state-of-the art accessibility measuring approaches that consider not only the traditional geographical locations of home and large grocery stores, but also individual and community aspects of the food system. These more comprehensive measures suggest decisions that can be studied to guide policymakers in effectively designing food systems that facilitate the consumption of the right types of food by considering various aspects of the daily lives of individuals, and to support individuals in navigating their food systems given their capabilities and constraints. The hope is that acting upon accessibility assessments and associations with morbidity and mortality improves the health of the communities and the quality of life of all individuals.

## CHAPTER 3

### SCHEDULING FOOD OPPORTUNITY RECOMMENDATIONS FOR INDIVIDUALS SEEKING FOOD ASSISTANCE

#### 3.1 Introduction

Food security is consistent access for sufficient, safe, and healthy food ensuring a high living standard<sup>2</sup>. Individuals without this consistent food access are considered food insecure<sup>58</sup>. Consistent access to food is a basic human right that could prevent detriments to health, nutrition<sup>4</sup>, and obesity. For example, obesity affects more than one-third of American adults and increases health risks of diabetes, heart disease, and mortality<sup>9</sup>. Low-income individuals are at a higher risk to encounter difficulties in food access which aggravates the already existing health outcome disparities<sup>34</sup>.

Food access research is focused on measuring or improving food systems but there has not been a focus on how to support individuals navigating their food systems in addition to other daily life demands. In the food accessibility literature, individuals were characterized as the individual's home geo-location<sup>6,11-13,24,26,27,31,35</sup>, as their census tract<sup>25,31,32,38,42,50</sup>, as the individual's home and work location<sup>14,37</sup> and by transportation analysis zone<sup>44</sup>. Individual based models allow a more refined and accurate representation of accessibility<sup>13,24,34,35,40,48,59-68</sup>. However, there is difficulty interpreting individual results for population-wide studies<sup>13,45,69,70</sup>.

Some studies do not focus on individuals but use an aggregated characterization at different scales; by census block level<sup>5,8,18,33,34,39,47</sup>, census tract level<sup>5,7,28,34,36,40,51</sup>, and region<sup>20,29,43,46,49</sup>. Aggregate data can help support policy decision making for area-based interventions<sup>34</sup> and to compare areas<sup>13</sup>. This is particularly helpful when no individual data is available and collecting it would be expensive. The aggregation assumes that all individuals in an area experience the same

accessibility level<sup>45</sup>. However, social context cannot be measured just with geographic units<sup>40</sup> because individuals have different characteristics and constraints such as time availability and budget<sup>13</sup>. Aggregated data is a common issue in the field as it can limit research<sup>44</sup> because it is too coarse to reflect the reality of consumers in detail<sup>5,70-72</sup> and it oversimplifies the dynamics of food access<sup>5,13,73,74</sup>.

There is a debate on individual vs aggregated measurements in food access<sup>60,75</sup>. Some journal articles have researched this comparison in a variety of ways including by census tract<sup>30,41</sup>, by the individual's home<sup>16,30,48</sup>, by the individual's home and work location<sup>16,41,45</sup>, by municipality<sup>45,48</sup> and by lower super output areas<sup>16</sup>. Maguire et al. found that aggregated groups showed a higher food access in general than by the individual measurement<sup>16</sup>. Zhang et al. found that aggregated approaches result in a lower food access than when individuals are considered with their different origins, food opportunities and travel modes<sup>41</sup>. Future research should consider doing both individual and aggregate characterizations<sup>13,40</sup> because it will allow subpopulations to be identified<sup>41</sup>, more flexibility in the design of policy decisions, and it would improve the cost effectiveness of policy implementations<sup>41</sup>.

This research focuses on the individual's perspective in accessing food. It explores the life-constrained food accessibility of individuals, which is proposed to be defined as the minimum distance to access the food needed by a household in a period of interest while considering spatiotemporal constraints. This chapter introduces the process of obtaining the parameters needed in a binary integer programming formulation to obtain a detailed schedule for food acquisition. The problem was formulated, and the parameters were collected to be inputted into the model. A subset of food assistance opportunities in Sedgwick County, Kansas was used as an example.

The results of this study are anticipated to be useful to individuals seeking assistance from organizations such as United Way 211, Information and Communication Technologies (ICT) Food Rescue, Kansas Food Bank, The Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), and the Salvation Army. The proposed parameter estimation and data collection method approach can be applied to other counties or geographical areas. The remainder of this chapter is organized as follows. Section 3.2 discusses the food navigation problem statement, section 3.3 introduces the problem formulation, section 3.4 describes the parameter estimation, section 3.5 explores an illustrative example, and section 3.6 presents the conclusion and future research.

### **3.2 Food Navigation Problem Statement**

An individual seeking a well-defined food acquisition schedule for a predefined time horizon. The schedule should provide a set of times and locations where they can obtain the food needed for their household with a minimum cost, measured as driving distance. It was assumed that the individual required a predefined number of servings of food per day, which was determined by the number of household members. The individual mainly dwelled in a household with a fixed and known location, but also frequently visited other locations, such as work and school. The dwelling and frequently visited locations were referred as the individual's locations. It was assumed that, for the period of interest, the time spent within and traveling between the individual's locations were known, assuming transportation by car.

The food navigation problem was to select some among the food opportunity locations available to the individual at various times, taking into consideration individual's locations schedule. For each food opportunity, the distance to individual locations, the distance to travel routes, the hours of operation and the amount of food (in number of servings) that can be obtained

in one visit, were known, or can be easily obtained. For each location, the suitability to fit the individual based on the location's requirements, such as address, poverty level, age, student status and documentation available were known.

The optimal schedule should make sure that:

- i. An individual is only scheduled to visit locations on days and times that the individual is available (not at work or performing other daily life activities).
- ii. An individual is only scheduled to visit locations on days and times that the locations are open for operation.
- iii. An individual is only scheduled to visit locations that are eligible to the individual (location requirements).
- iv. The total amount of food obtained from the scheduled visits to locations should be at least the required number of servings needed for the planning horizon.
- v. An individual is only scheduled to visit each location at most once per day.
- vi. An individual is only scheduled to visit a location at most once per day and hour.

The cost of the schedule was measured based on travel time or distance required to meet the schedule, (i.e., the objective was to minimize the amount of time or distance that individuals need to acquire the food).

### **3.3 Problem Formulation**

The scheduling model considered parameters to be provided by the individual seeking assistance, including date, time horizon, their time availability, frequently visited locations such as household, school, or work location, number of household members, address data, poverty level, age, student status and documentation availability. It assumed 3 meals per day, transportation by car and a maximum of 7 consecutive days.

The parameter  $T$  was divided into discrete periods indexed by  $t$  and the decision variables and problem parameters were defined accordingly. Table 2 summarizes the parameters that were used in formulating and solving the problem, along with the notation assigned. The decision variable,  $y_{tj} \in \{0,1\}$ , indicates whether food opportunity  $j$  should be visited at time  $t$ . The recommended schedule was thus determined by the optimal values of  $y_{tj}$  and found solving the following optimization problem:

TABLE 5  
PARAMETERS

<i>Parameters</i>	<i>Notation</i>
Time Horizon	Indexed by $t = 1, \dots, T$
Food opportunities	Indexed by $j = 1, 2, \dots, J$
Servings of food required for the time horizon.	$N$
Individual's available time slot indicator.	$a_t = \begin{cases} 1 & i \text{ is available at } t \\ 0 & \text{otherwise} \end{cases}$ $\forall 1 \leq t \leq T$
Distance cost it takes individual (or proxy) to acquire food at time $t$ from location $j$ .	$d_{tj}$ $\forall 1 \leq t \leq T, 1 \leq j \leq J$
Food opportunity location open time slot indicator.	$o_{tj} = \begin{cases} 1 & i \text{ is available at } t \\ 0 & \text{otherwise} \end{cases}$ $\forall 1 \leq t \leq T, 1 \leq j \leq J$
Amount of food (in average number of servings) that can be obtained from location $j$ in one day period.	$q_j$ $\forall 1 \leq j \leq J$
Suitability of $j$ to individual based on eligibility to the opportunity such as address, age, translation, documentation needed, etc.	$s_j = \begin{cases} 1 & j \text{ suits the individual} \\ 0 & \text{otherwise} \end{cases}$ $\forall 1 \leq j \leq J$

**Minimize:**

$$\sum_{j=1}^J \sum_{t=1}^T d_{tj} y_{tj} \quad (3.1)$$

**s.t**

$$y_{tj} \leq a_t, \forall j = 1, \dots, J, \forall t = 1, \dots, T \quad (3.2)$$

$$y_{tj} \leq o_{tj}, \forall j = 1, \dots, J, \forall t = 1, \dots, T \quad (3.3)$$

$$y_{tj} \leq s_j, \forall j = 1, \dots, J, \forall t = 1, \dots, T \quad (3.4)$$

$$\sum_{j=1}^J \sum_{t=1}^T q_j y_{tj} \geq N \quad (3.5)$$

$$\sum_{t=1}^{12} y_{tj} \leq 1, \forall j = 1, \dots, J \quad (3.6)$$

$$\sum_{t=13}^{24} y_{tj} \leq 1, \forall j = 1, \dots, J \quad (3.7)$$

$$\sum_{t=25}^{36} y_{tj} \leq 1, \forall j = 1, \dots, J \quad (3.8)$$

$$\sum_{t=37}^{48} y_{tj} \leq 1, \forall j = 1, \dots, J \quad (3.9)$$

$$\sum_{t=49}^{60} y_{tj} \leq 1, \forall j = 1, \dots, J \quad (3.10)$$

$$\sum_{t=61}^{72} y_{tj} \leq 1, \forall j = 1, \dots, J \quad (3.11)$$

$$\sum_{t=73}^{84} y_{tj} \leq 1, \forall j = 1, \dots, J \quad (3.12)$$

$$\sum_{j=1}^J y_{tj} \leq 1, \forall t = 1, \dots, T \quad (3.13)$$

$$y_{tj} \in \{0,1\} \quad (3.14)$$

The objective function (equation **Error! Reference source not found.**) minimizes the total cost, i.e., the total distance it takes for the individual to meet the schedule. Constraint set  $y_{tj} \leq a_t, \forall j = 1, \dots, J, \forall t = 1, \dots, T$  (3.2)

3.2) ensures that an individual is only scheduled to visit locations on times slots when the individual is available. Constraint set (3.3) ensures that only open food opportunity locations are included in the schedule. Constraint set (3.4) ensures that the individual is only scheduled to visit locations suiting the eligibility requirements of the food opportunities. Constraint (3.5) ensures that the total amount of food obtained from the scheduled locations is at least  $N$ . Constraint sets (3.6-3.12) ensures that the individual is only scheduled to visit each location at most once each day of the week (there is one set of  $J$  constraints per day of the week). Constraint set (3.13) ensures that the individual is only scheduled to visit at most one location per time slot. Constraint (3.14) states that the decision variable  $y_{jt}$  is binary; either food opportunity  $j$  is visited during time slot  $t$  ( $y_{jt} = 0$ ) or not ( $y_{jt} = 1$ ). The model is a binary integer programming which can be solved using the method Branch-and-Bound<sup>76</sup>.

There is an additional step for scenarios where the formulation recommends visiting food opportunities in consecutive time slots. The resulting schedules need to be adjusted by subtracting the distance from the individual's origin location to the food opportunity for each time the schedule suggests a trip between food opportunities, and then, the distance between the corresponding food opportunities should be added.

### **3.4 Parameter Estimation**

This section explains how each one of the parameters shown in Table 2 can be estimated within the food assistance opportunities in Sedgwick County, Kansas. The data about the individual's characteristics must be obtained directly from the individual seeking assistance using a questionnaire such as the one shown in Appendix B. In the questionnaire, the individual is asked about the time horizon for which they need food assistance (Questions 1-2), which informs the value of  $T$ . For the number of food servings required for the time horizon, it is assumed each person

eats 3 food servings per day, breakfast, lunch, and dinner. To obtain  $N$ , the days in the time horizon are multiplied by the number of people needing food assistance obtained from question 3, by 3 servings. The individual's availability is obtained from question 4. The parameter  $a_t$  is 0 or 1 depending on availability time at time  $t$ . If  $a_t = 0$ , the individual is not available, if  $a_t = 1$ , the individual is available. The individual's locations are obtained from questions 5 and 6.

A comprehensive list of food opportunities from Appendix C was mapped in Figure 3. Data to build this list was obtained from the websites of the Kansas Food bank<sup>77</sup>, Kansas 211 United Way<sup>78</sup>, Sedgwick County food resources<sup>79</sup> and Need Help<sup>80</sup> in Google. Food opportunities available were searched during August 2022 within Sedgwick County in Kansas. The search was done with the keywords “food pantries”, “free food”, and “food assistance”. Locations that offer free food items or food service to the community were included. The data extraction included the name, type of food opportunity, address, zip code, hours of operation, phone number, requirements, e-mail, and webpage. The resulting list contains 58 food opportunities, along with all the characteristics needed for the model. With the list of food opportunities, the value of  $J$  can be determined.

The parameter  $o_{tj}$  (i.e., the food opportunities availability at time  $t$ , in location  $j$ ) was determined based on the “Hours of operation” column of Appendix C. Only time frames from 8 am to 8 pm were included. Food opportunities were mostly open on Tuesdays and the most frequent time frame of the week was from 1 to 2 pm and they were least open on Sundays and the least frequent time frames of the week were from 10 pm to 5 am. On average they opened 6.95 hours per day and 49 hours per week as shown in Figure 4.

For the parameter  $q_j$ , information on serving sizes was determined by the food opportunity type and by calling a subset of them. Six categories were found, food trucks, soup kitchens, food

pantries, mobile food pantries, locations of the local program “ICT Community Fridge” and locations of the federal program "The Emergency Food Assistance Program (TEFAP) distribution site". A subset of food opportunities were called to ask the type of foods offered and an approximate number of food servings that an individual could obtain per visit. Given the information provided by the opportunities, an average number of food servings were assigned according to the type of opportunity.

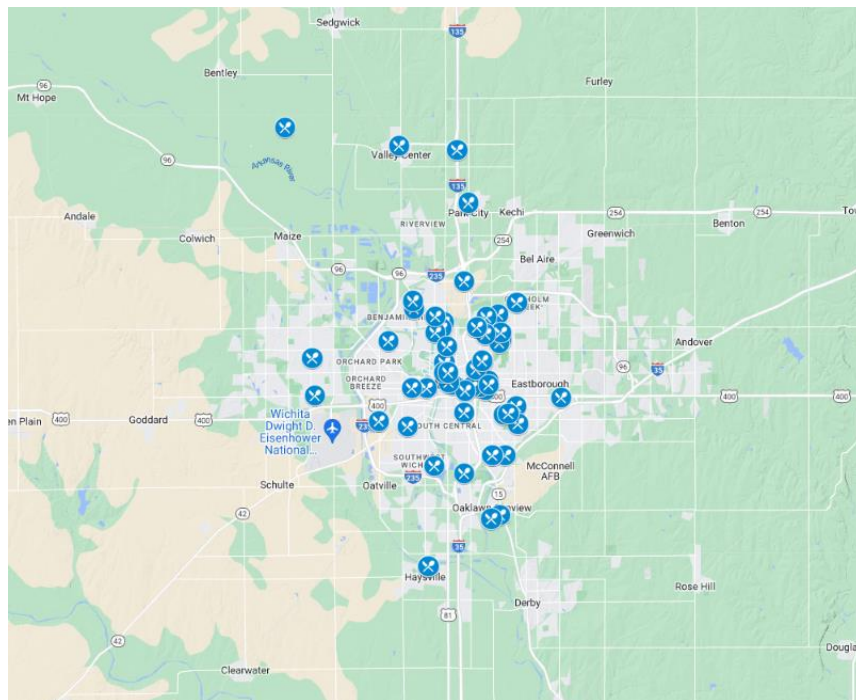


Figure 3. Food opportunities in Sedgwick County.

The average servings range between 2 and 10. Food trucks and soup kitchens were assigned two servings per person given that ready to eat meals were offered. The “ICT Community Fridge” was assigned six servings per individual as it was based on food donations from individuals. Food pantries and mobile food pantries were assigned eight servings per individual, as they were based on food donations from individuals and from the government. The "Emergency food assistance program Distribution Site" was assigned 10 as they receive donations from the Kansas Food Bank.

The values per food opportunity are shown in column “Average food servings per visit” in Appendix C.

Hour	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
12-1 am	2	2	2	2	2	2	2
1-2 am	2	2	2	2	2	2	2
2-3 am	2	2	2	2	2	2	2
3-4 am	2	2	2	2	2	2	2
4-5 am	2	2	2	2	2	2	2
5-6 am	3	2	2	2	2	2	2
6-7 am	4	3	3	3	3	3	3
7-8 am	4	4	4	4	4	4	3
8-9 am	10	14	12	11	10	5.25	3
9-10 am	14	18.25	16	15	13	5	4.25
10-11 am	13	20.25	17	18	14	7.25	5.25
11-12 am	17	22.25	19	20	17	8.5	7.25
12-1 pm	14	16	14	15	15	8	6
1-2 pm	17	21	21.25	21	19.5	9.25	7
2-3 pm	15	16	19	17.25	18	7	6
3-4 pm	12	13	14.5	14	14.5	7	6
4-5 pm	12	13.5	14.5	14	14.75	7	6
5-6 pm	9	9.5	11	11	12.25	8	5
6-7 pm	6	5	6	6	7	7	3
7-8 pm	6	5	6	6	6	5.5	3
8-9 pm	3	3	3	3	4	2.5	3
9-10 pm	3	2	3	3	4	3	2
10-11 pm	2	2	2	2	2	2	2
11-12 pm	2	2	2	2	2	2	2

Figure 4. Heatmap of the food opportunities’ open times.

The parameter  $s_j = 0$  when one requirement was not fulfilled by the individual with respect to the  $j^{th}$  food opportunity, such as home state, home county, home city, home zip code, home school district, federal poverty level, age, student at Wichita State University (WSU), Spanish translation need, photo identity document (ID), ID of all persons listed, proof of income, proof of address, social security card, presence of all household members.  $s_j = 1$  if all conditions required by the  $j^{th}$  food opportunity were met. The requirements of each food assistance opportunity can be found in the “Requirements” column in Appendix C and the individual’s eligibility was based on the responses to questions 7-21. These requirements were obtained by visiting the webpage of each food opportunity. Most food opportunities did not have requirements. Some ask individuals to show different combinations of recent personal records to confirm that the individual meets their

requirements, such as proof of address (18 out of the 58), official photo ID (11 out of the 58), proof of income (7 out of the 58), photo ID of each individual in the household (5 out of the 58), an application form (3 out of the 58), social security card of each individual in the household (2 out of the 58), WSU ID (1 out of the 58), and presence of all household members (1 out of the 58).

The cost of the individual getting to the food opportunity  $j$  at time  $t$ ,  $d_{tj}$ , was calculated based on distances between food opportunity locations and the individual's location at time  $t$ . The distance was calculated with Google Maps Application Programming Interface (API) assuming the user's transportation mode was by car. For the values of  $t$  when the individual was unavailable, a value of distance that was significantly larger than all other distances was assigned, so the model does not consider these unavailable  $t$ 's.

### **3.5 Illustrative Example**

To illustrate the use of the model using the Sedgwick County food assistance opportunity system (implying  $J = 58$ ), the responses to the questionnaire shown in Table 3 were assumed. The individual was a student from Wichita State University, living with one roommate on campus at "The Flats", and goes hiking to Chisholm Creek as seen on Table 5 and 6 and the mapped in Figure 5. Their address was in Sedgwick County in Wichita, Kansas, with the zip code 67208 within the Unified School District (USD) 259. They were 24 years old without a job, not under federal poverty, native English speaker, with a photo ID, proof of address, no social security card as they cannot find it, and their roommate had willingness to go in person and bring their photo ID. The individual was available on Monday from 4 to 8 pm as they're home after school and on Tuesday even though they're at school because it's flexible study time in the library. Wednesday through Friday from 8 am to 12 pm was also available as they have class in the afternoon.

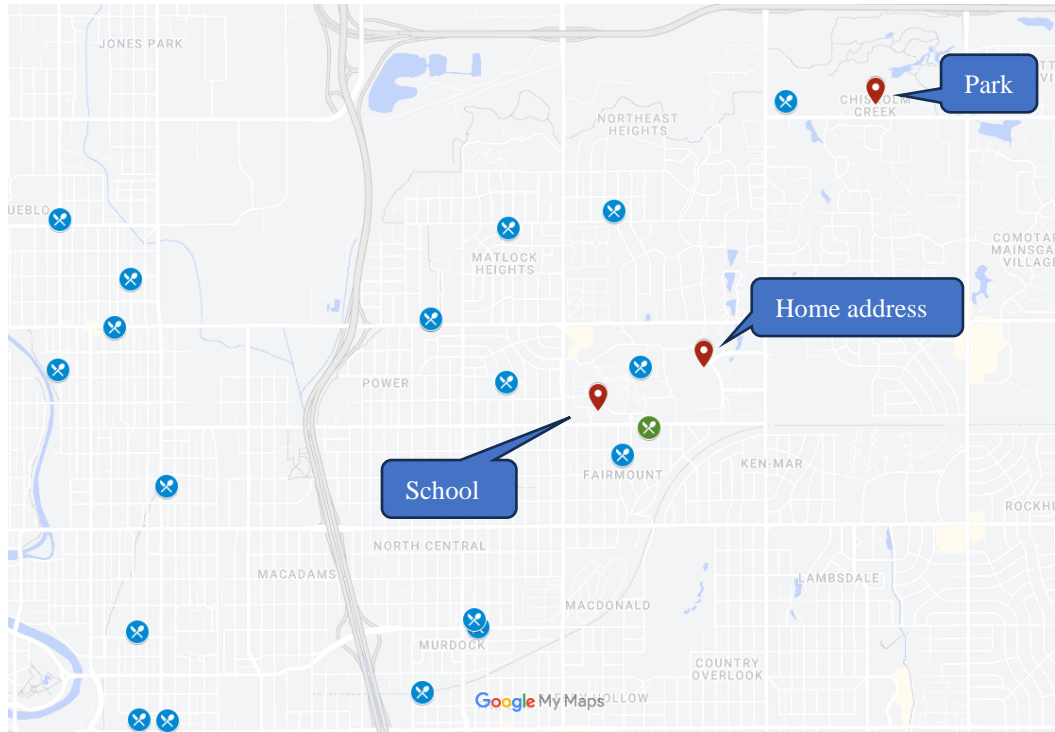


Figure 5 .Map of individual’s frequently visited locations.

It was assumed they seek food for their household ( $N = 30$ ) for 5 days ( $T = 60$ ). They were mainly available on the mornings of Wednesday through Friday and the afternoons of Monday and Tuesday as shown in Table 4 (i.e.,  $a_9 = a_{10} = a_{11} = a_{12} = a_{21} = a_{22} = a_{23} = a_{24} = a_{25} = a_{26} = a_{27} = a_{28} = a_{37} = a_{38} = a_{39} = a_{40} = a_{49} = a_{50} = a_{51} = a_{52} = 1$  and all other values of  $a_t = 0$ ).

Based on the United States Department of Agriculture’s “Food Access Research Atlas”<sup>81</sup>, the exemplified individual, had low food access based on the 1 and 10-mile buffer zones. Using minimum network distance to a food outlet as accessibility measure, the distance from their home was 2.2 miles to a grocery store and 1.14 miles to the closest food opportunity, “Shocker Support Locker”.

TABLE 6

EXAMPLE OF INDIVIDUAL'S RESPONSES

<i>Question</i>	<i>Example Response</i>
1. Date for the schedule in DD-Month-YYYY	25-Mar-2024
2. For how many days will you be needing food assistance?	5
3. How many people need food assistance?	2
4. For the food assistance horizon time slots, mark with an X the available times of the person driving to the food opportunities:	Table 4
5. For the food assistance horizon time slots, write the locations you will be at (home, work, school, etc.):	Table 5
6. Write the address of every location of question 6:	Table 6
7. Home state	Kansas
8. Home county	Sedgwick County
9. Home city	Wichita
10. Home zip code	67208
11. Home school district	USD 259
12. Are you in federal poverty level?	No
13. Age	24
14. Are you a student at WSU?	Yes
15. Do you need Spanish translation?	No
16. Do you have a photo ID?	Yes
17. Do you have ID of all persons listed?	Yes
18. Do you have proof of income?	No
19. Do you have proof of address?	Yes
20. Do you have social security card?	No
21. Do you have presence of all household members needing food?	Yes

TABLE 7

INDIVIDUAL’S ANSWER TO QUESTION: “FOR THE FOOD ASSISTANCE HORIZON TIME SLOTS, MARK WITH AN X THE AVAILABLE TIMES OF THE PERSON DRIVING TO THE FOOD OPPORTUNITIES:”

<i>Hour/Day</i>	<i>08:00-09:00 am</i>	<i>09:00-10:00 am</i>	<i>10:00-11:00 am</i>	<i>11:00-12:00 am</i>	<i>12:00-01:00 pm</i>	<i>01:00-02:00 pm</i>	<i>02:00-03:00 pm</i>	<i>03:00-04:00 pm</i>	<i>04:00-05:00 pm</i>	<i>05:00-06:00 pm</i>	<i>06:00-07:00 pm</i>	<i>07:00-08:00 pm</i>
<i>Monday</i>									X	X	X	X
<i>Tuesday</i>									X	X	X	X
<i>Wednesday</i>	X	X	X	X								
<i>Thursday</i>	X	X	X	X								
<i>Friday</i>	X	X	X	X								

TABLE 8

INDIVIDUAL’S LOCATION BY TIME SLOT

<i>Hour/Day</i>	<i>08:00-09:00 am</i>	<i>09:00-10:00 am</i>	<i>10:00-11:00 am</i>	<i>11:00-12:00 am</i>	<i>12:00-01:00 pm</i>	<i>01:00-02:00 pm</i>	<i>02:00-03:00 pm</i>	<i>03:00-04:00 pm</i>	<i>04:00-05:00 pm</i>	<i>05:00-06:00 pm</i>	<i>06:00-07:00 pm</i>	<i>07:00-08:00 pm</i>
<i>Monday</i>	Park	Park	School	School	School	School	Home	Home	Home	Home	Home	Home
<i>Tuesday</i>	Park	Park	School	School	School	School	Home	Home	School	School	School	School
<i>Wednesday</i>	Home	Home	Home	Home	Park	Park	School	School	School	School	Home	Home
<i>Thursday</i>	Home	Home	Home	Home	Park	Park	School	School	School	School	Home	Home
<i>Friday</i>	Home	Home	Home	Home	Park	Park	School	School	School	School	Home	Home

TABLE 9

INDIVIDUAL'S FREQUENTLY VISITED PLACES

<i>Location</i>	<i>Address (Street, City, State, Zip code)</i>
Home	2011 Innovation boulevard, Wichita, 67208
School	1845 Fairmount St, Wichita, 67260
Park	5610 East 29 <sup>th</sup> St N, Wichita, 67220

To solve this example, the coefficients were established in Excel and imported into Python to solve the problem using the COIN-OR Branch-and-Cut (CBC) solver method. It was implemented in Python version 3.11.1, and coded in Visual Studio Code version 1.78.2. The python libraries used were “panda”, “googlemaps”, “numpy”, “time”, “math” and “pulp”.

It took 0.67 seconds to run the code for these 58 opportunities and 60 time slots. The optimal solution suggested four trips for a total driving distance of 4.41 miles (Table 7). The routes of their origin and destination are shown in Figure 6. The food opportunity geographically closest to their home address was the Shocker Support Locker, with a distance of 1.14 miles. However, the Shocker Support Locker open times were Monday through Friday from 12 pm to 3 pm, when the individual was not available.

TABLE 10

RECOMMENDED SCHEDULE FOR ILLUSTRATIVE INDIVIDUAL

$y_{tj}$	<i>Day</i>	<i>Time</i>	<i>Origin</i>	<i>Destination</i>	<i>Distance (miles)</i>
$y_{11,9}$	Monday	4 to 5 pm	Home address	Fairmount Coffee Company	1.33
$y_{23,13}$	Tuesday	6 to 7 pm	School	Fairmount Coffee Company	0.42
$y_{28,13}$	Wednesday	11 to 12 pm	Home address	Fairmount Coffee Company	1.33
$y_{49,13}$	Friday	8 to 9 am	Home address	Fairmount Coffee Company	1.33

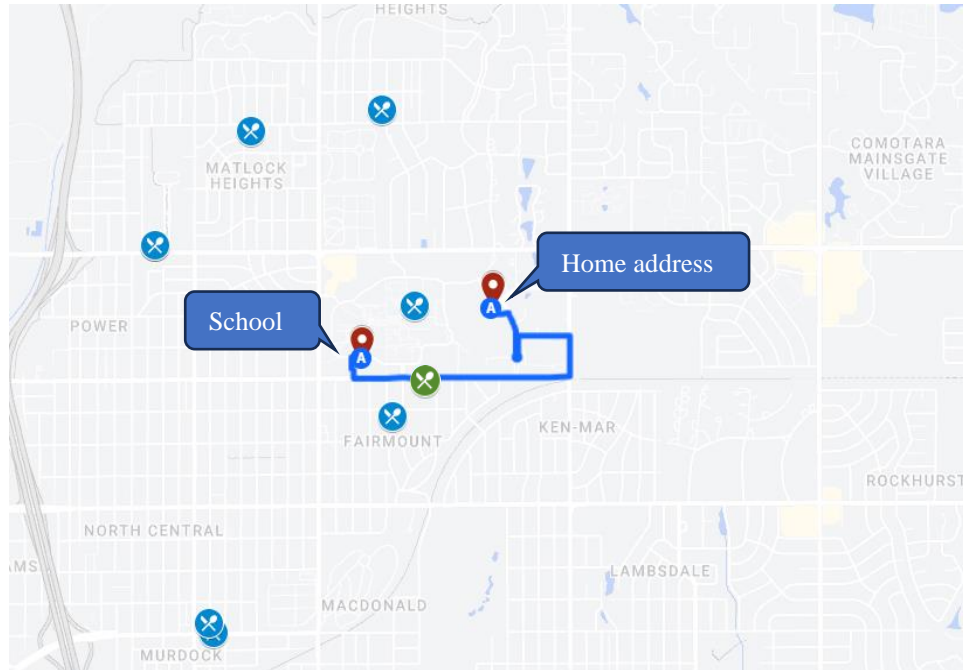


Figure 6. Map of trip's routes for the example individual.

### 3.6 Conclusion

Research has focused on measuring and improving food access, but not on supporting the navigation of the individual through the food system considering their needs and limitations. A methodology to obtain an individual schedule of food acquisition with the minimum distance was developed. The focus of this research was to investigate data collection needed to obtain the parameters for the proposed binary integer programming formulation considering spatiotemporal constraints. The method was illustrated with an example for an individual in Sedgwick County, Kansas and it resulted in a minimum distance of 4.41 miles to obtain the food required in the predefined time horizon.

Commonly used accessibility measures resulted in a shorter minimum distance than the optimal life-constrained; however, having a closer food outlet does not guarantee a fit to the individual's needs and constraints. The schedule provided a set of times and locations to obtain

the food needed for the time horizon for their household within a minimum driving distance. It selected the food opportunities that best fit the individual's locations, time availability, and suitability to the food opportunities' eligibility criteria.

Food assistance organizations that were consulted such as 211 Kansas United Way, The Kansas Food Bank and Sedgwick County only provide a list of food assistance opportunities by zip code, city, or county. The individual based approach used in this research allows a more refined and accurate representation of food access<sup>13,24,34,35,40,48,59-68</sup>. It considered multiple geographic locations, and individual characteristics and constraints, which better represents social context<sup>13</sup>. The model can be reproduced in other settings by following the data collection methodology and using a combination of Microsoft Excel and Python. The model can be extended to consider different modes of transportation.

Nevertheless, there were some limitations to the proposed approach. Data inputted to the model has to be collected, interpreted, and manually added into Excel tables. It assumes an individual only needs 3 meals per day and a maximum of 7 consecutive days, which limits the usefulness of the schedule for individuals needing assistance for more than one week and not getting full with the servings considered. The model can be improved to run faster and with less Random-Access Memory (RAM) by simplifying the code to make less iterations.

Future research includes developing methods to update the static parameters, given that food opportunities may change over time. These methods may include automating internet search and web scraping for parameters and using crowdsourcing techniques to maintain up-to-date lists and characteristics of the food assistance system in a community. In addition, the use of the proposed method to study life-constrained accessibility measure can be investigated in terms of

data collection and aggregation methods that provide a more comprehensive picture of how individuals interact with their food systems.

It was proposed to define the individual's food access as the minimum distance to access the food needed by a household in a period of interest. Future research should include these characteristics of an individual's life as it will better represent the reality of their food access. Understanding the perspective of consumers will allow policymakers to have a more realistic perspective of the food environment to make guided decisions for policy design and implementation.

## CHAPTER 4

### ILLUSTRATING THE USE OF THE LIFE-CONSTRAINED ACCESSIBILITY BASED ON THE FOOD ASSISTANCE OPPORTUNITY SYSTEM IN SEDGWICK COUNTY

#### 4.1 Introduction

The United States Department of Agriculture defines the term “food system” as “place-specific clusters of agricultural producers of all kinds—farmers, ranchers, fishers—along with consumers and institutions engaged in producing, processing, distributing, and selling foods”<sup>1</sup>. Food pantries are a component of food systems providing free or reduced-cost food to individuals, typically coming from donations. Individuals use food pantries when they are food insecure, whether for a temporary period or with a more regular frequency. About 36.5% of food insecure households reported using food pantries in the United States in 2020<sup>17</sup>. Their use appears to be rapidly increasing among all households. About 4.4% of American households used food pantries in 2019, and 6.7% in 2020<sup>17</sup>.

The objective of this study was to provide a shared understanding of the accessibility to the food assistance opportunity system in Sedgwick County. The system’s accessibility was characterized from two perspectives: the centralized, conventional perspective (i.e., based on geographical information) and the potential individual perspective (i.e., based on people in the community with specific characteristics). The centralized perspective measures accessibility using conventional methods and the individual perspective assesses a life-constrained accessibility measure per individual in the community and aggregates the results to the desired level of analysis. Details on how to calculate this measure per individual are provided in Chapter 3 of this thesis. In what follows, the academic and grey literature providing visual representations or conceptual

models of food systems was reviewed to identify the most appropriate approach to represent Sedgwick County's food opportunity system.

#### **4.2 Literature Review: Studies Understanding Food Systems**

The articles were searched using the keywords: "food systems", "food system characterization", "food system modeling", and "food system model" in the databases of Scopus, PubMed, Springer Link and Google Scholar. The objective was to investigate the hypothesis that most articles studying food system modeling use conceptual models. Therefore, papers with a focus on food systems modeling and their characterization were included. Six articles that characterized complex food systems using some or all the elements were identified and outlined in Table 8. All six articles included categories such as environmental, farming and production, economic, social and demographics, government and politics, access, and distribution<sup>82-88</sup>. Four of the articles included the individual's health in the system with the category of nutrition and diet<sup>83-86</sup>. Other four articles acknowledged the influence of technological advances on the development of the food system<sup>85-88</sup>. Only one article included ethics<sup>83</sup>, an area of opportunity for future research as global warming, animal rights, and land use, among other ethical considerations have an impact on the sustainability and development of the food systems. These conceptual models were general and cannot be used to understand the state of a given food system at various times or to assess accessibility or other measures of interest.

To identify methods to visualize actual food systems, websites corresponding to the food systems of a sample of cities and states in the U.S. were searched. The hypothesis was that organizations creating websites or reports characterizing food systems use mapping techniques to visualize food accessibility and other characteristics of their systems.

TABLE 11

FOOD SYSTEM CHARACTERIZATION

<i>Citation</i>	<i>Clancy</i> <sup>3</sup>	<i>Macdonald et al.</i> <sup>5</sup>	<i>Lindgren et al.</i> <sup>6</sup>	<i>Van Berkum et al.</i> <sup>10</sup>	<i>Ingram</i> <sup>7</sup>	<i>Kanter</i> <sup>8</sup>	<i>Ericksen</i> <sup>9</sup>
<i>Environmental</i>	x	x	x	x	x	x	x
<i>Farming and production</i>	x	x	x	x	x	x	x
<i>Economic</i>	x	x	x	x	x	x	x
<i>Access and distribution</i>	x	x	x	x	x	x	x
<i>Social and Demographics</i>	x	x	x	x	x		x
<i>Government and politics</i>	x	x	x	x	x		x
<i>Nutrition and diet</i>		x	x		x	x	
<i>Innovation and technology</i>				x	x	x	x
<i>Ethics</i>		x					

Six reports assessing food systems were found for the cities of Chicago<sup>89</sup>, Philadelphia<sup>90</sup>, Washington, D.C.<sup>91</sup>, and San Francisco<sup>92</sup> and the states of New York<sup>93</sup> and Massachusetts<sup>94</sup>. All of them used bar charts and maps for data visualization.

Bar charts showed different elements, including farms (number of farms, farms harvesting for human consumption, farm size, farmland by type of food, farm sales, farm employment demographics, farm subsidies, farmland protection funding), demographics (income, population, race, ethnicity, age, poverty, food expenditures by geography), some survey results (survey respondents, food system stakeholders, food system advantages, challenges, food system changes, food system recommendations, food system research gaps), food economics (U.S. Prices, market value of food by type, food sales methods, food manufacturing revenue, food distribution sales and revenue by retail type, aquaculture revenue by species), food supply chain (food transport by

type, food origins and destinations, food production by type, farmer markets), food employment (food employment by industry, food employment by demographics, food employment wages by industry type), health (nutrition by income, obesity by demographic, obesity by geography), and food assistance programs (food programs participation, food programs).

Maps in the reports show topics such as demographics (income, population, poverty obesity, diabetes, survey respondents), agricultural production (farms, community gardens, aquaculture), processing (food manufacturers, food supply chain), distribution (distribution centers, farmers markets, food retail by type), consumption (food deserts, food access by store type, food assistance programs, retailers accepting food assistance programs, food insecurity) and environment (waste, water system).

From the literature analysis, it is concluded that while there were many types of visualization to represent a food system, these were commonly represented with bar charts and maps showing the components that a food system is comprised of. In what follows, these mapping techniques were used, along with methods identified or proposed in previous chapters of this thesis, to represent the Sedgwick County food opportunity system.

### **4.3 Methods**

This stage of the research was guided by the hypothesis that conventional food access measurements overestimate the ability of people to access the food they need when they can obtain it given their routines. This hypothesis was tested based on the Sedgwick County food opportunity system characterized in Chapter 3 and a set of hypothetical individuals (Appendix D) with diverse characteristics needing the services of food opportunities for a period of 1 week.

### 4.3.1 Hypothetical Individuals

Hypothetical individuals from Sedgwick County were simulated based on characteristics such as: coordinates of the address of their top 3 frequented places (including a home address), school district, household size, poverty level, age, Wichita State University student status, need of Spanish translation, having an identity document, having an ID of all persons listed, proof of income, proof of address, social security card, presence of all household members when picking up food, and time availability to pick up food. These characteristics were generated using Montecarlo sampling techniques based on Sedgwick County census data from the year 2022<sup>95</sup>, and the results of a recent survey by the Sedgwick County Food System Master Plan<sup>96</sup>.

All the individual's frequent location address coordinates were generated as follows. Sedgwick County was divided into two areas A and B, as illustrated in Figure 7. The equations (4.1) and (4.2) were then used based on the latitude and longitude boundaries of each one of these areas. Given that the area of B was 10% of area A, 90 households were simulated inside area A and 10 households inside area B.

$$\textit{Simulated Latitude} = \textit{Min latitude} + (\textit{Random number} * (\textit{Max latitude} - \textit{Min latitude})) \quad (4.1)$$

$$\textit{Simulated Longitude} = \textit{Min longitude} + (\textit{Random number} * (\textit{Max longitude} - \textit{Min longitude})) \quad (4.2)$$

The generated coordinates were converted into their corresponding zip code and city using functions from the software ArcGIS Pro. The coordinates were overlapped with the feature layer “United States ZIP Code Boundaries 2020” and the “Spatial Join” geoprocessing tool was used to download a table with the matching data. The school districts of the generated household address coordinates were obtained in a similar manner using the layer “Kansas State Department of Education (KSDE) School District Lookup”.

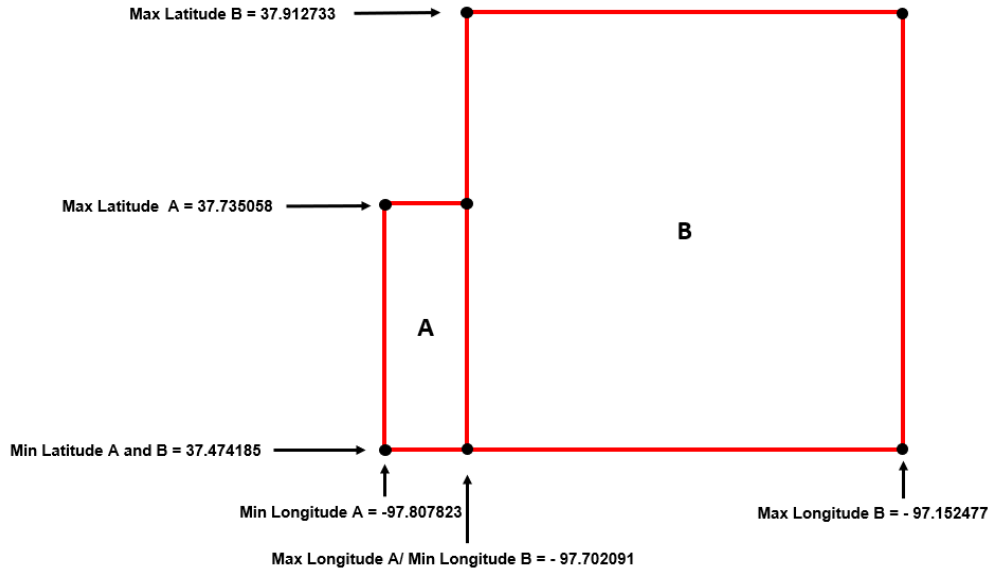


Figure 7. Boundary coordinates of Sedgwick County.

Household sizes were simulated as Poisson-distributed random variables with a mean household size of 2.51, which was obtained from U.S. census tract data. The hypothetical individuals' poverty level was generated based on a Bernoulli distribution with probability of being below the poverty level equal to the U.S. national percentage of poverty level of 11.5%<sup>97</sup>. The age of the hypothetical individuals was generated as an empirical random variable following the U.S. age distribution derived from census data<sup>98</sup> (Table 9).

TABLE 12

AGE DISTRIBUTION ACCORDING TO CENSUS DATA

<i>Age categories (years)</i>	<i>Cumulative Distribution Function</i>
0 – 18	0.231
19– 25	0.318
26 – 34	0.441
35 – 54	0.698
55 – 64	0.827

TABLE 13 (continued)

<i>Age categories (years)</i>	<i>Cumulative Distribution Function</i>
65 and more	1.000

Hypothetical individuals were assigned the “WSU student” status in a random manner following a Bernoulli distribution. To estimate the corresponding probability parameter, it was assumed that only undergraduate students seek food assistance. Given that undergraduate students at Wichita State University have an average age of 23 and a median of 21<sup>99</sup>, only hypothetical individuals who were assigned an age between 20 and 24 were considered. The number of students at Wichita State University and WSU Tech (19,000 students) were divided by the Sedgwick County population between the ages of 20 to 24 (36,962 individuals) to obtain the probability parameter of 51.4% of being a student for that age range.

Bernoulli distributions were also used to generate the need of Spanish translation for the individuals (with  $p= 4.6\%$  of people not fluent in English). Having an ID, having an ID of all persons listed, proof of income, proof of address, social security card, presence of all household members when picking up food were generated per individual with an assumed probability of 50% of having the documents and the presence of individuals. The availability to pick up food was generated per time slot of the week for each hypothetical individual. A 50% probability of being available was assumed. All random variables were generated using Excel formulas.

#### **4.3.2 Accessibility Measures**

The accessibility to the Sedgwick County food opportunity system of each hypothetical individual was measured based on the three most used measures identified in Chapter 2: nearest outlet, density and dichotomous. These measures were calculated based on both the individual’s census tract centroid and household locations using road network travel distances. The distances

were calculated using Google Maps API (coded in Microsoft Visual Studio). The nearest outlet measure was calculated as the distance between the selected individual’s location and the closest food opportunity. Density was calculated as the number of food opportunities in a buffer, and dichotomous was calculated as 1 if there was at least one food opportunity in the buffer and “0” otherwise. Buffers of 1 mile<sup>5</sup> and 10 miles were considered from the individual’s selected location. The life-constrained accessibility measure proposed in Chapter 3 was calculated for each hypothetical individual.

Figure 8 helps visualize the relationship between the nearest distance from the hypothetical individual’s census tract centroid and from their household location. The Figure shows an increase in variability in the distance from the household address when the distance from the centroid increases. Individuals with a centroid distance of 15.17 miles can have a household distance between 9.81 and 19.95 miles. There was a high positive relationship between both food access measures with a Person correlation of 0.87, showing an expected similarity between the measures.

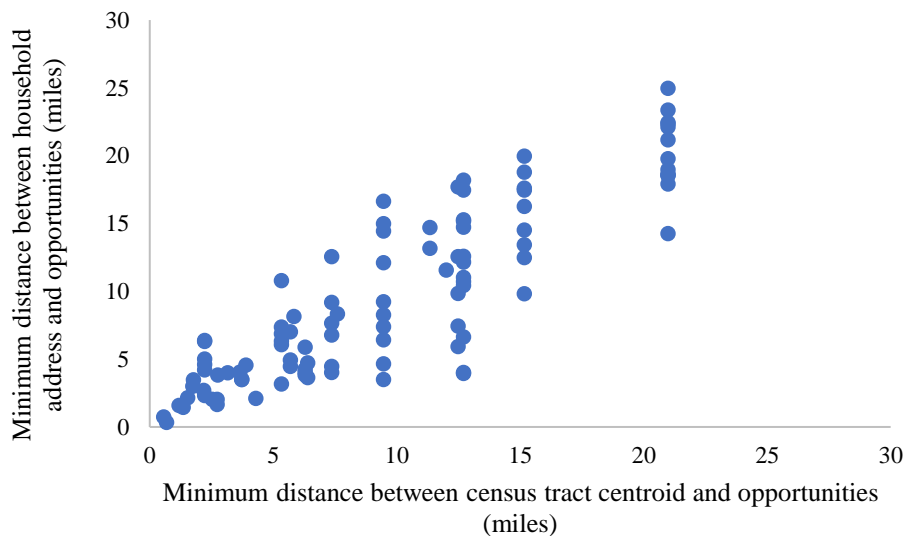


Figure 8. Minimum distance based on census tract centroid and opportunities with respect to Minimum distance between household address and opportunities.

### 4.3.3 Comparative Analysis of Accessibility Measures

Left-tailed independent t-tests<sup>100</sup> were performed assuming unequal variances to test the hypothesis, with a 95% confidence interval, using a significance level of  $\alpha = 0.05$ , as follows:

$$H_0: \mu_{conventional} \geq \mu_{life-constrained}$$

$$H_1: \mu_{conventional} < \mu_{life-constrained}$$

Where  $\mu_{conventional}$  refers to the mean of conventional accessibility measures and  $\mu_{life-constrained}$  refers to the mean of the life-constrained accessibility measures. This refers to conventional measurements suggesting smaller distances than what was practically possible given the individual's life constraints. Two of these independent t-tests were done; one comparing the minimum distance based on census tract centroid with the life-constrained accessibility and the other one comparing the minimum distance based on household addresses with the life-constrained accessibility.

## 4.4 Results

### 4.4.1 Hypothetical Individuals

The household addresses of the simulated individuals are shown in Figure 9. The average household size was 2.65 with a standard deviation of 1.49, a maximum of 6, minimum of 1 and a range of 5. This was consistent with the average of 2.51 from the census data with a difference of 5.2%. The unified school district with the most hypothetical individuals (19 individuals) was “USD 259” belonging to Wichita, only one individual was simulated for “USD 260” in Derby, “USD 394” in Rose Hill, “USD 375” in Circle and “USD 385” in Andover. This was consistent with the geographical data as Wichita was the city with the most territory in Sedgwick County. The average age was 43.81 with a standard deviation of 23.99, a maximum of 99, minimum of 19 and a range

of 80. This was consistent with the average 35–54-year category in the census. Nine individuals were assigned as being below federal poverty level, like the average of 11.5 from the census data with a difference of 21.7%. In total, 24 individuals were in the age category of 20 to 24, eleven were assigned student status which was 45.8%, this was consistent with the average of 51.4% considered for student status. Five individuals were assigned as needing Spanish translation, very similar to the 4.6% probability of needing Spanish translation.

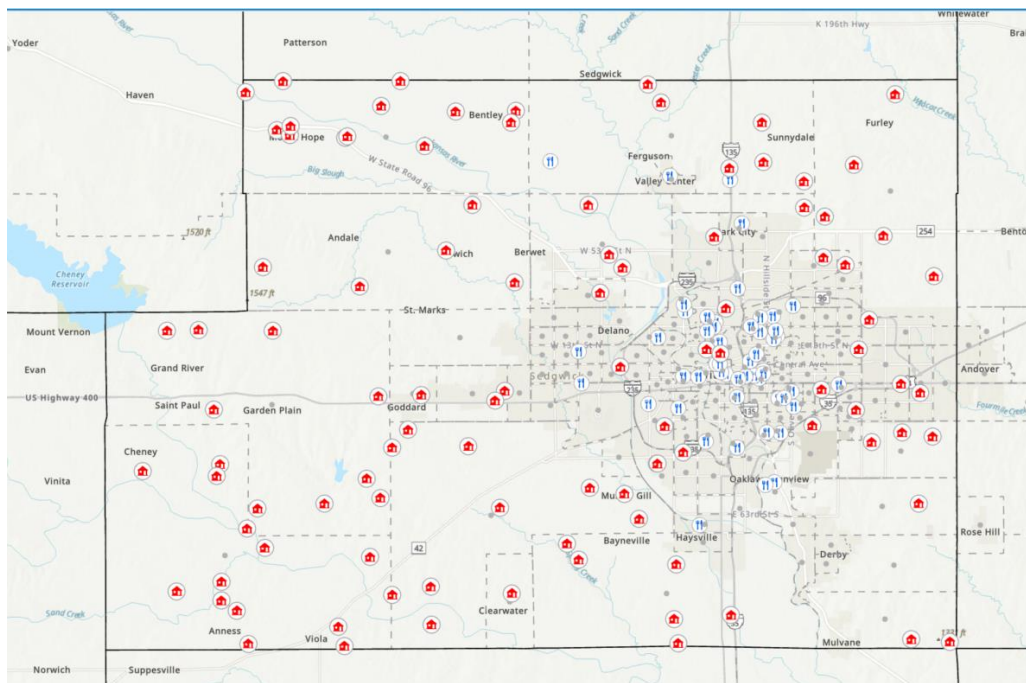


Figure 9. Map of simulated individuals' household locations.

#### 4.4.2 Accessibility to Food Opportunities

The calculations of the nearest outlet, density, and dichotomous accessibility to food opportunities for the simulated individuals can be found in Appendix E and the summary statistics in Table 10.

Based on the census tract centroids, the “Minimum distance” ranged between 0.56 and 20.98 miles with an average of 9.68 and a standard deviation of 6.09 miles. The average percentage of servings that can be obtained by going to the closest food opportunity was 21.45%. The one-mile radius “Density” measure had an average of 0.05 food opportunities inside the radius with a standard deviation of 0.41 and the one-mile radius “Dichotomous” indicated that 2% of individuals had at least one food opportunity within one mile. The 10-mile radius “Density” had an average of 8.59 food opportunities within the radius and a standard deviation of 14.47 and the 10-mile “Dichotomous” indicated that about 57% of hypothetical individuals had at least one food opportunity within 10 miles.

Based on the household locations the “Minimum distance” ranged between 0.32 and 24.95 miles with an average of 9.66 and a standard deviation of 6.4 miles. The average percentage of servings that can be obtained by going to the closest food opportunity was 20.56%. The one-mile radius “Density” measure had an average of 0.05 food opportunities inside the radius with a standard deviation of 0.41 and the one-mile radius “Dichotomous” indicated that 2% of individuals had at least one food opportunity within one mile. The 10-mile radius “Density” had an average of 9.38 food opportunities within the radius and a standard deviation of 14.45 and the 10-mile “Dichotomous” indicated that about 58% of hypothetical individuals had at least one food opportunity within 10 miles.

The life-constrained accessibility, i.e., the distance that each individual would need to travel to obtain the amount of food needed in one week, was obtained for 95 out of the 100 individuals as the optimization model for the other 5 resulted in infeasible as seen on Appendix F.

TABLE 14

MEASURE RESULTS

<i>Measure</i>	<i>Based on census tract centroid</i>	<i>Based on household address</i>
<i>Minimum distance mean in miles (standard deviation)</i>	9.68 (6.09)	9.66 (6.4)
<i>% Average servings obtained (standard deviation)</i>	21.45% (13.63%)	20.56% (13.49%)
<i>Density: average number of food opportunities per individual, (standard deviation)</i>		
<i>1-mile buffer</i>	0.05 (0.41)	0.05 (0.41)
<i>10-mile buffer</i>	8.59 (14.47)	9.38 (14.45)
<i>Dichotomous: % with food opportunities in the radius</i>		
<i>1-mile buffer</i>	2%	2%
<i>10-mile buffer</i>	57%	58%
<i>1-week Life-constrained overall mean in miles (standard deviation)</i>	53.65 (40.95)	
<i>% Average servings obtained</i>	100%	
<i>1-week Life-constrained overall mean with consecutiveness in miles (standard deviation)</i>	52.5 (39.7)	
<i>% Average servings obtained</i>	100%	
<i>1-week Life-constrained per trip in miles (standard deviation)</i>	7.75 (4.55)	
<i>% Average servings obtained</i>	18.66% (9.55%)	

This infeasibility was due to the need of Spanish translation. Only 17.2% (10/58) of the food opportunities reported to offer Spanish translation services and thus the optimization became infeasible. The obtained total distances traveled to obtain the food needed ranged between 1.56 and 187.21 miles with an average of 53.65 and a standard deviation of 40.95 miles. The life-constrained accessibility per trip ranged between 0.39 and 22.08 miles with an average of 7.75 and a standard deviation of 4.55 miles.

The life-constrained accessibility's distance results don't consider a scenario where the schedule recommends visiting several food opportunities in consecutive time slots. It considers the individual always makes each trip from one of their top 3 frequented locations, which is not the case when visiting one food opportunity after another. Therefore, the resulting schedules were adjusted by subtracting the distance from individual location to food opportunity as many times as the schedule suggested trips between food opportunities instead. The distance between the corresponding food opportunities was added. The modified total distances ranged between 1.6 and 183.2 miles with an average of 52.5 and a standard deviation of 39.7 miles.

#### **4.4.3 Comparative Analysis of Conventional Nearest Distance and Proposed Accessibility Measures**

A comparison was made for the life-constrained accessibility overall and the conventional measures of nearest distance as the fulfillment of 100% of the servings needed by the individuals was aimed to be included in the proposed measure. Figure 10 helps visualize the relationship between the nearest distance and proposed accessibility measures for the hypothetical individuals. The Figure shows distances tend to be higher for the life-constrained accessibility measure than the nearest outlet measures. There was a low positive relationship between both food access measures (Pearson correlation coefficients  $r < 0.3$ , as shown in Table 11).

The results of the t-tests considering a T-critical of 1.66 (shown in Table 12) suggest that there was enough evidence to reject the null hypothesis and confirm that the life-constrained accessibility measure values tend to be higher than that the nearest distance measurements (regardless of reference point) at a 5% significance level. Therefore, nearest distance measures overestimate the ability of individuals to access food. This result was expected given that the life-constrained accessibility measure includes an amount of food to satisfy in a time horizon, which may involve more than one trip. In contrast, the nearest distance metric considers exactly one trip

regardless of the needs of individuals. Note that visiting the nearest food opportunity covered, on average, about 21% of the food needs of the hypothetical individuals.

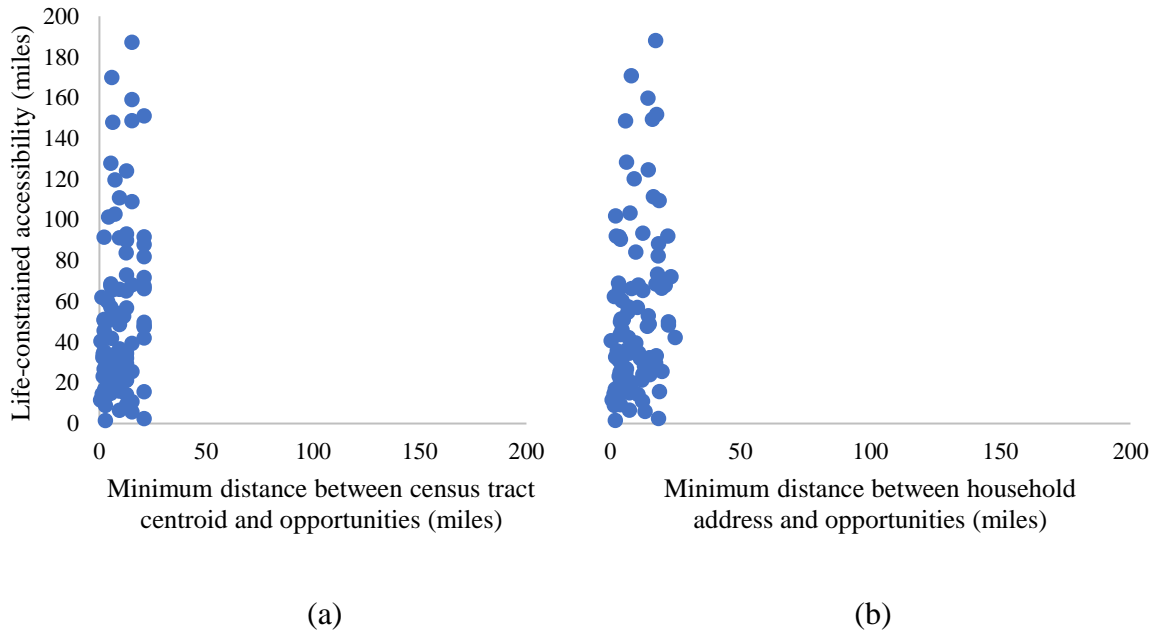


Figure 10. Life-constrained accessibility overall with respect to: (a) minimum distance based on census tract centroid and (Pearson correlation coefficient:  $r=0.209$ ) and (b) with respect to household address (Pearson correlation coefficient:  $r=0.264$ ).

TABLE 15

PEARSON AND SPEARMAN RANK CORRELATIONS BETWEEN NEAREST DISTANCES AND LIFE-CONSTRAINED ACCESSIBILITY

<i>Accessibility measure</i>	<i>Pearson correlation</i>	<i>Spearman Rank correlation</i>
<i>Minimum distance address census tract centroid to opportunities</i>	0.209	0.209
<i>Minimum distance to opportunities</i>	0.264	0.286

TABLE 16

T-TEST RESULTS FOR OVERALL LIFE-CONSTRAINED ACCESSIBILITY

	<i>T Test Score</i>	<i>P-value</i>
<i>Based on census tract centroid</i>	-10.35	1.01E-17
<i>Based on household address</i>	-10.35	1.03E-17

Another way to approach the comparison was to focus on the life-constrained accessibility per trip, which covers, on average, about 18.66% of the required food servings. Figure 11 helps visualize the relationship between the nearest distance and proposed accessibility measure per trip for the hypothetical individuals. The Figure shows an increase in variability in the life-constrained accessibility per trip when the nearest outlet distance increases. Individuals with a minimum distance of 20.98 miles from their census tract can have a life-constrained accessibility per trip between 0.64 and 16.4 miles, and from their address a minimum distance of 18.5 miles, they can have a life-constrained accessibility per trip in the range of 0.64 to 16.4 miles. There was a low positive relationship between both food access measures (Pearson correlation coefficients  $r < 0.4$ , as shown in Table 13).

The results of the t-tests considering a T-critical of 1.65 (shown in Table 14) suggest that there was enough evidence to reject the null hypothesis and confirm that the life-constrained accessibility per trip measure values tend to be higher than that the nearest distance measurements (regardless of reference point) at a 5% significance level. Therefore, nearest distance measures overestimate the ability of individuals to access food.

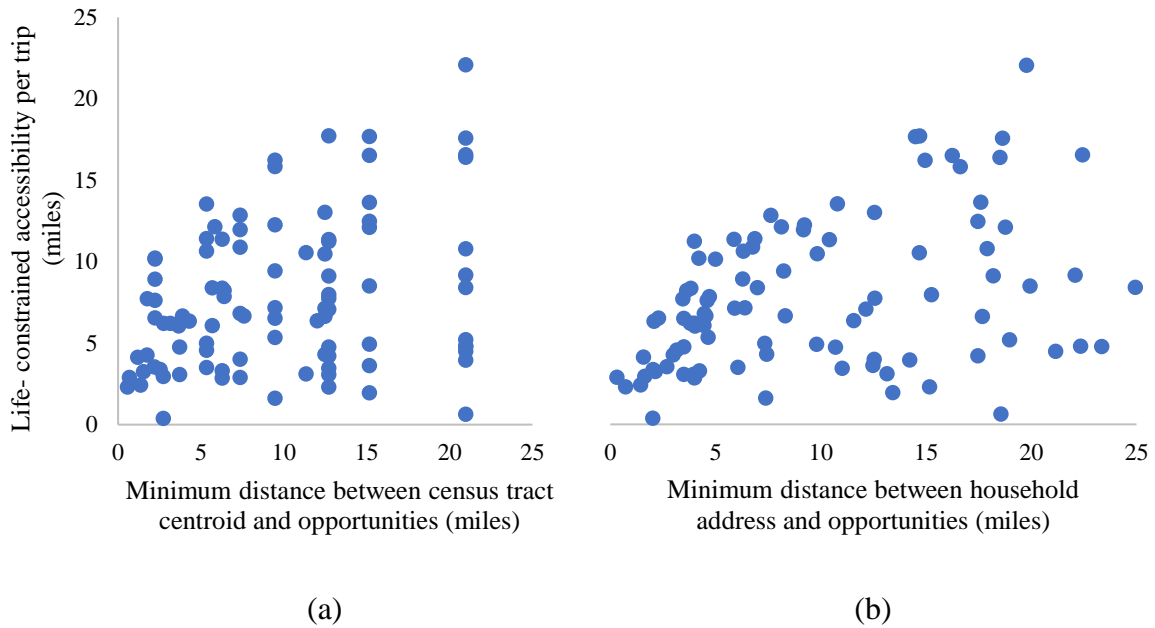


Figure 11. Life-constrained accessibility per trip with respect to: (a) minimum distance based on census tract centroid and (Pearson correlation coefficient:  $r=0.279$ ) and (b) with respect to household address (Pearson correlation coefficient:  $r=0.381$ ).

TABLE 17

PEARSON AND SPEARMAN RANK CORRELATIONS BETWEEN NEAREST DISTANCE MINIMUM DISTANCES AND LIFE-CONSTRAINED ACCESSIBILITY PER TRIP

<i>Accessibility measure</i>	<i>Pearson correlation</i>	<i>Spearman Rank correlation</i>
<i>Minimum distance address census tract centroid to opportunities</i>	0.279	0.232
<i>Minimum distance to opportunities</i>	0.381	0.356

TABLE 18

T-TEST RESULTS FOR LIFE-CONSTRAINED ACCESSIBILITY PER TRIP

	<i>T Test Score</i>	<i>P-value</i>
<i>Based on census tract centroid</i>	2.52	0.0063
<i>Based on household address</i>	2.41	0.0085

An additional comparison was made for the life-constrained accessibility overall considering schedules with consecutiveness. Figure 12 helps visualize the relationship between the nearest distance and proposed accessibility measure with consecutiveness for the hypothetical individuals. The Figure shows distances tend to be higher for the life-constrained accessibility with the consecutiveness measure than with the nearest outlet measures. There was a low positive relationship between both food access measures (Pearson correlation coefficients  $r < 0.21$ , as shown in Table 15).

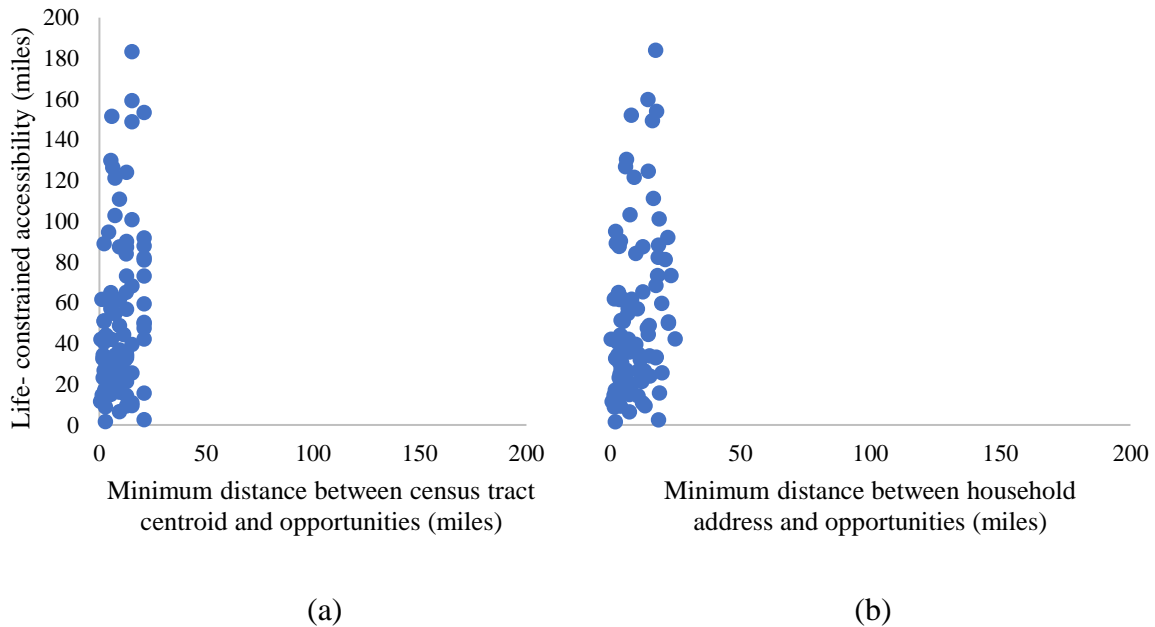


Figure 12. Life-constrained accessibility with consecutiveness with respect to: (a) minimum distance based on census tract centroid and (Pearson correlation coefficient:  $r=0.202$ ) and (b) with respect to household address (Pearson correlation coefficient:  $r=0.146$ ).

TABLE 19

PEARSON AND SPEARMAN RANK CORRELATIONS BETWEEN NEAREST DISTANCE MINIMUM DISTANCES AND LIFE-CONSTRAINED ACCESSIBILITY WITH CONSECUTIVENESS

<i>Accessibility measure</i>	<i>Pearson correlation</i>	<i>Spearman Rank correlation</i>
<i>Minimum distance address census tract centroid to opportunities</i>	0.202	0.146

TABLE 20 (continued)

<i>Accessibility measure</i>	<i>Pearson correlation</i>	<i>Spearman Rank correlation</i>
<i>Minimum distance to opportunities</i>	0.146	0.207

The results of the t-tests considering a T-critical of 1.66 (shown in Table 16) suggest that there was enough evidence to reject the null hypothesis and confirm that the life-constrained accessibility with consecutiveness measure values tend to be higher than that the nearest distance measurements (regardless of reference point) at a 5% significance level. Therefore, nearest distance measures overestimate the ability of individuals to access food.

TABLE 21

T-TEST RESULTS FOR LIFE-CONSTRAINED ACCESSIBILITY WITH  
CONSECUTIVENESS

	<i>T Test Score</i>	<i>P-value</i>
<i>Based on census tract centroid</i>	-10.4	8.12E-18
<i>Based on household address</i>	-10.4	7.46E-18

**4.5 Discussion and Conclusion**

The objective of this study was to provide a shared understanding of the accessibility to the food assistance opportunity system in Sedgwick County. The system’s accessibility was characterized from a centralized and conventional perspective based on the measures identified in Chapter 2 of this thesis, and the potential individual life-constrained accessibility based on the measure proposed in Chapter 3. The food opportunity system was visualized by using mapping techniques, which were found to be commonly used visualization techniques by various cities and states across the U.S.

Conventional food access measurement of nearest distance were found to overestimate the ability of people to access the food they need given their routines, using a set of hypothetical

individuals generated based on census data. The proposed measure covers 100% of the food servings while the nearest outlet does not meet the needs and constraints of individuals. This was consistent with what other researchers have discussed in the published food accessibility literature. For example, Mulrooney et al. stated that planimetric distance measurements do not truly represent the empirical costs of traveling, which is a barrier to individuals<sup>43</sup>. The strength of the study was that the proposed measure considers different barriers of individuals and food opportunities for food access in the categories of geographical distance, time availability, eligibility to receive food, and meals required. Similarly, Miller, H mentioned that spatiotemporal methods are more sensitive measures to access as they recognize constraints imposed by the demographic, economic and cultural contexts<sup>75</sup>. The low positive relationship between the nearest distances and life-constrained accessibility shows a minimal relationship between the measures. This implies that an individual with a short nearest distance could have either a small or big value of life-constrained accessibility as they were not dependent on each other.

An important consideration of this study was the inclusion of an individual and aggregated assessment instead of just aggregated which has been the most used in food access research. Miller, H states that place-based methods do not consider the conditions of individual's human existence, the aggregated perspective is no longer viable in an era of abundant data and theory and policy questions requires extension to a people-based perspective<sup>75</sup>. In addition, the measure uses the top 3 most frequented places of the individual, and could be expanded to include more, while conventional measures regularly reference the household location or census tract centroid. Kwan, M states that a difficulty of the conventional measures for individuals is proximity with respect to a single location as recent studies have shown that assuming one location deviates from travel behavior research<sup>60</sup>.

The study considers food opportunities as an important part of the food system, especially for people with low food access and with food insecurity. Most studies of the literature review in Chapter 1 measure access to commercial food outlets like supermarkets, grocery stores, fast-food places, and convenience stores.

One limitation of this study was the simulation of hypothetical individuals and their characteristics generated from independent probability data. There could be a more accurate representation of the population if data was collected from Sedgwick County individuals in a survey. This study acts as a proof of concept to justify a survey among residents of Sedgwick County to perform a similar study.

The life-constrained accessibility's formulation did not consider the distances between food opportunities in the case of consecutiveness in time slots. This consideration was included by individually checking and modifying the resulting schedules, therefore the formulation was limited as it will not automatically include consecutiveness. A new formulation that considers the possibility of visiting several food opportunities consecutively can be developed.

Another limitation in the study is the conventional food access measures thresholds of density and dichotomous were not divided by urban or rural area type as this is the approach used by the USDA's food access measure. This division could generalize the results for better comparison with the USDA's measurements.

Future research of food access measurement should consider individual needs and constraints, include more than one origin location, and consider food opportunities as part of the food system.

## CHAPTER 5

### CONCLUSION

The systematic review was done to investigate existing and potential models for food access measurements used to support system decisions for food access improvement. There was a lack of research to support actionable decisions for improvement in food access, as there were a few decision-oriented studies. The opportunity to improve measures of food access was identified as there was a need to develop evidence-based measures to effect a change. The aspiration was that more comprehensive measures of accessibility will improve the health and life quality of the communities.

Therefore, the maximum accessibility level achievable by individuals within their life and environment constraints was investigated using optimization techniques. The methodology to support navigation of individuals through their food system was developed. The data collection needed to obtain the parameters of a binary integer programming formulation was described. The output was a schedule of times and locations for an individual to acquire the food needed in a time frame with minimal distance considering their needs and limitations. This formulation was used to provide a shared understanding of the food assistance opportunity system in Sedgwick County from two perspectives: the centralized (conventional) and the individual (proposed) perspectives. The food opportunity system was visualized using mapping techniques. A set of hypothetical individuals with diverse characteristics was generated based on census data. Different barriers were considered such as geographical distance, time availability, eligibility to receive food, and meals required. The results were compared, and it was confirmed that the nearest distance food access measure overestimates the ability of people to access the food they need given their routines.

The outcome was consistent with most recent literature, which suggests that only considering geographical distance was not an accurate representation of the food access limitations of people.

The proposed measure can be implemented in other geographical contexts, to different transportation types, larger time frames, and more frequented places of individuals, among others. The methodology could be improved by automating data collection and data update over time. This study motivates a survey-based study with the residents of Sedgwick County.

Future food access research should include a focus on system decision support for access improvement. Food access measurements could benefit by including an individual perspective along with their needs and constraints, diversifying origins other than household address and including food opportunities in the food system.

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## APPENDICES

APPENDIX A

SEARCH TERMS AND RESULTS

<i>Search</i>	<i>Search Term Construction</i>	<i>Articles Located</i>
1. PubMed (MEDLINE)	("models, statistical"[MeSH] OR "logistic models"[MeSH] OR "models, theoretical"[MeSH] OR "linear models"[MeSH] OR "simulation modeling") AND ("food access*" OR "food proximity" OR "food desert*" OR "food insufficiency" OR "food insecurity" [MeSH] OR "food security" [MeSH] OR supermarkets [MeSH]) AND (transportation [MeSH] OR "spatial navigation"[MeSH] OR "geographic information system*" [MeSH])	11
2. CINAHL	model* AND ("health food" OR "food security" OR "grocery stores"[CINAHL Subject Headings]) AND (transportation OR travel OR "geographic information system*" [CINAHL Subject Headings])	10
<i>**Variant search</i>	model* AND ("food desert*" OR "food access*" OR "food proximity" OR "food purchases" OR "shopping patterns" OR "shopping frequency") AND (transportation OR travel OR "geographic information system*" [CINAHL Subject Headings])	5
3. ProQuest Nursing & Allied Health Source	("models, statistical" OR "logistic models" OR "models, theoretical" OR "linear models"[MeSH terms]) AND ("food insecurity" OR "food security" OR supermarkets [MeSH terms]) AND (transportation [MeSH] OR "spatial navigation" [MeSH] OR "geographic information system*" [MeSH])	0
<i>**Variant search</i>	("models, statistical" OR "logistic models" OR "models, theoretical" OR "linear models"[MeSH terms]) AND ("food access*" OR "food proximity" OR "food desert*" OR "food insufficiency") AND (transportation [MeSH] OR "spatial navigation" [MeSH] OR "geographic information system*" [MeSH])	4

APPENDIX A (continued)

<i>Search</i>	<i>Search Term Construction</i>	<i>Articles Located</i>
4.Consumer Health Complete	model* AND ("food security" OR "grocery shopping" OR "grocery industry" OR supermarkets [Consumer Health Complete Subjects]) AND ("local transit access" OR transportation OR "geographic information systems" OR travel OR commuters OR commuting [Consumer Health Complete Subjects])	3
**Variant search	model* AND ("food desert*" OR "food access*") AND ("local transit access" OR transportation OR "geographic information systems" OR travel OR commuters OR commuting [Consumer Health Complete Subjects])	0
5. Scopus	(model* OR measure* OR metric* OR quantitative OR "data mining") AND ("food access*" OR "food desert*" OR "shopping distance" OR "shopping frequency")	49

APPENDIX B

FOOD ASSISTANCE QUESTIONNAIRE

1. Date for the schedule in DD-Month-YYYY
2. For how many days will you be needing food assistance?
3. How many people need food assistance?
4. For the food assistance horizon time slots, mark with an **X** the available times of the person driving to the food opportunities:

<i>Hour/Day</i>	<i>08:00-09:00 am</i>	<i>09:00-10:00 am</i>	<i>10:00-11:00 am</i>	<i>11:00-12:00 am</i>	<i>12:00-01:00 pm</i>	<i>01:00-02:00 pm</i>	<i>02:00-03:00 pm</i>	<i>03:00-04:00 pm</i>	<i>04:00-05:00 pm</i>	<i>05:00-06:00 pm</i>	<i>06:00-07:00 pm</i>	<i>07:00-08:00 pm</i>
<i>Monday</i>												
<i>Tuesday</i>												
<i>Wednesday</i>												
<i>Thursday</i>												
<i>Friday</i>												
<i>Saturday</i>												
<i>Sunday</i>												

5. For the food assistance horizon time slots, write the places you will be at (home, work, school, etc.):

<i>Hour/Day</i>	<i>08:00-09:00 am</i>	<i>09:00-10:00 am</i>	<i>10:00-11:00 am</i>	<i>11:00-12:00 am</i>	<i>12:00-01:00 pm</i>	<i>01:00-02:00 pm</i>	<i>02:00-03:00 pm</i>	<i>03:00-04:00 pm</i>	<i>04:00-05:00 pm</i>	<i>05:00-06:00 pm</i>	<i>06:00-07:00 pm</i>	<i>07:00-08:00 pm</i>
<i>Monday</i>												
<i>Tuesday</i>												
<i>Wednesday</i>												
<i>Thursday</i>												
<i>Friday</i>												
<i>Saturday</i>												
<i>Sunday</i>												

APPENDIX B (continued)

6. Write the address of every location of question 5:

<i>Place</i>	<i>Address (Street, City, State, Zip code)</i>

7. Home state

8. Home county

9. Home city

10. Home zip code

11. Home school district

12. Are you in federal poverty level?

13. Age

14. Are you a student at WSU?

15. Do you need Spanish translation?

16. Do you have a photo ID?

17. Do you have ID of all persons listed?

18. Do you have proof of income?

19. Do you have proof of address?

20. Do you have social security card?

21. Do you have presence of all household members needing food?

APPENDIX C

FOOD ASSISTANCE OPPORTUNITIES AS OF SEPTEMBER 7TH OF 2022

<i>J</i>	<i>Name</i>	<i>Type of food opportunity</i>	<i>Address</i>	<i>Zip code</i>	<i>Hours of operation</i>	<i>Phone number</i>	<i>Requirements</i>	<i>E-mail</i>	<i>Webpage</i>	<i>Average food servings</i>
1	Antioch Giving Center	Food pantry	255 S Estelle, Wichita	67211-2008	Sundays from 11:30AM - 12:30PM	316-425-5654		info@antiochwichita.org	<a href="https://antiochwichita.org/food-bank">https://antiochwichita.org/food-bank</a>	8
2	Bread of life	Food pantry	1301 E Galena	67216	Tuesday 10:00 AM – 1:45 PM. Additional Produce Giveaway the third (3rd) Saturday of the month 1:00 pm.	316-689-6866	Photo ID, mail with current address, social. Security cards for each member of the household, proof of income, each person must be present to sign the form.		<a href="https://www.breadoflifewichita.com/">https://www.breadoflifewichita.com/</a>	8
3	CC ICT – Our Daily Bread Food Pantry	The emergency food assistance program TEFAP Distribution Site	2825 S Hillside St, Wichita	67214	Tues. – Wed. – Thurs 8:30 a.m. – Noon. 4th Saturday of the Month 9a.m. – Noon. Commodities (TEFAP) available 1st and 3rd Tuesdays of each month.	316-264-8344 x1504	Application on file with the pantry. ID of head of household and for all persons listed on file , proof of address within the past 60 days.		<a href="https://www.catholiccharitieswichita.org/our-daily-bread-food-pantry/">https://www.catholiccharitieswichita.org/our-daily-bread-food-pantry/</a>	10
4	CHD Boxing club	ICT Community Fridge	2505 E 9th St N	67214	Monday, Wednesday, Thursday: 5:00 pm - 8:00 pm ,Saturday: 12:30-2 pm	(702) 742-5017		ictfreefood@gmail.com. masontraceysr@gmail.com	<a href="https://www.facebook.com/CHDNC3/about">https://www.facebook.com/CHDNC3/about</a>	6

APPENDIX C (continued)

<i>J</i>	<i>Name</i>	<i>Type of food opportunity</i>	<i>Address</i>	<i>Zip code</i>	<i>Hours of operation</i>	<i>Phone number</i>	<i>Requirements</i>	<i>E-mail</i>	<i>Webpage</i>	<i>Average food servings</i>
5	College Crest Church of Christ	Soup kitchen	2615 N Wellesley St, Wichita	67220-2441	Monday 11:30 AM – 1:00 PM Lunch	316-686-1981	photo ID		<a href="https://www.facebook.com/CollegeCrestChurchofChrist/about/?ref=page_internal">https://www.facebook.com/CollegeCrestChurchofChrist/about/?ref=page_internal</a>	2
6	College Hill United Methodist (CHUM)	Food pantry	2930 E 1st St.	67214	First Tuesday of the month from 9:00 a.m. to 12:00 p.m. and the third Saturday of the month from 9:00 a.m. to 11:00 a.m.	316-683-4643		Food pantry: <a href="mailto:annegibson725@gmail.com">annegibson725@gmail.com</a> . Center lunches: <a href="mailto:debbie.snell@collegehillumc.org">debbie.snell@collegehillumc.org</a>	<a href="http://collegehillumc.org/">http://collegehillumc.org/</a>	8
7	Covenant Presbyterian Church Pantry	Food pantry	1750 N. Tyler Road, Wichita	67212	3:00 p.m. to 5:00 p.m. on the 2nd and 4th Wednesdays of each month.	316-722-7613	One person per household who is at least 18 years of age and ID.	<a href="mailto:office@covenantwichita.org">office@covenantwichita.org</a>	<a href="http://www.covenantwichta.org/">http://www.covenantwichta.org/</a>	8
8	Dead Center Vintage	ICT Community Fridge	626 E Douglas Ave	67202	1 - 6 pm Tues - Thurs & Sun; 12 - 7 pm Fri, Sat.	N/A	Anyone, no questions asked. Take what you need and leave what you can	<a href="mailto:ictfreefood@gmail.com">ictfreefood@gmail.com</a>	<a href="https://www.facebook.com/ICTfridgefood/">https://www.facebook.com/ICTfridgefood/</a>	6
9	Derby Food Pantry	Food pantry	4900 S. Clifton	67216	Tuesday mornings by appointment 3rd Saturday of the month from 10am-12pm	316-519-5867	Must live within Derby school district boundaries	<a href="mailto:derbyfoodpantry@gmail.com">derbyfoodpantry@gmail.com</a>	<a href="https://www.derbyfoodpantry.com/">https://www.derbyfoodpantry.com/</a>	8
10	East High school	ICT Community Fridge	2301 E Douglas Ave	67211	24/7 Outdoor Access	(316) 973-7200	Anyone, no questions asked. Take what you need and leave what you can	<a href="mailto:ictfreefood@gmail.com">ictfreefood@gmail.com</a>	<a href="https://www.facebook.com/pg/ICTfridgefood/posts/">https://www.facebook.com/pg/ICTfridgefood/posts/</a>	6

APPENDIX C (continued)

<i>J</i>	<i>Name</i>	<i>Type of food opportunity</i>	<i>Address</i>	<i>Zip code</i>	<i>Hours of operation</i>	<i>Phone number</i>	<i>Requirements</i>	<i>E-mail</i>	<i>Webpage</i>	<i>Average food servings</i>
11	ESS Venture House	Soup kitchen	1010 N Main St, Wichita	67203	Mon- Fri between 11:00 a.m. and Noon	316-269-4160		barbara.andres@esswichita.org	<a href="https://www.episcopassetmap.org/dioceses/diocese-kansas/list/episcopal-social-services-venture-house">https://www.episcopassetmap.org/dioceses/diocese-kansas/list/episcopal-social-services-venture-house</a>	2
12	Evergreen Community Mobile Food Pantry	Mobile food pantry	2700 N. Woodland, Wichita	67204	1st Friday of each month starting at 1 p.m.	316-265-3663	Number of people in their household along with the number of seniors and kids.	info@kansasfoodbank.org	<a href="https://kansasfoodbank.org/mobile-food-pantries-in-wichita/">https://kansasfoodbank.org/mobile-food-pantries-in-wichita/</a>	8
13	Fairmount Coffee Company	Food pantry	3815 E 17th St N	67208	Mon-Friday 7AM–10PM, Saturday 8AM–8PM	(316) 207-4063		info@fairmountministries.org	<a href="https://www.fairmountministries.org/">https://www.fairmountministries.org/</a>	8
14	Feng Cha	ICT Community Fridge	8007 E Kellog Dr	67207	Friday 11AM–9:30PM, Saturday 11AM–9:30PM, Sunday 11AM–9PM	(316) 977-9994	Anyone, no questions asked. Take what you need and leave what you can	ictfreefood@gmail.com	<a href="https://www.facebook.com/pg/ICTFridgefood/posts/">https://www.facebook.com/pg/ICTFridgefood/posts/</a>	6
15	First Metropolitan Church	Food pantry	156 S Kansas St, Wichita	67211-1922	By appointment: 9:00 am to Noon and 1:00 to 2:00 pm. All food must be picked up before 2:30PM.	316-267-1852	Photo ID, ID for all in household, Proof of Address	info@mccwichita.com	<a href="http://www.tableofhopeict.org/">http://www.tableofhopeict.org/</a>	8
16	Goddard UMC Food Pantry	Food pantry	300 N. Cedar Street, Goddard	67052	Wednesday and Thursday, 9:00 - 11:30 a.m.	316-794-2207	ID required for food assistance. Must have proof of Goddard address	secretary@goddardumc.org	<a href="https://www.goddardumc.org/missions.html">https://www.goddardumc.org/missions.html</a>	8

APPENDIX C (continued)

<i>J</i>	<i>Name</i>	<i>Type of food opportunity</i>	<i>Address</i>	<i>Zip code</i>	<i>Hours of operation</i>	<i>Phone number</i>	<i>Requirements</i>	<i>E-mail</i>	<i>Webpage</i>	<i>Average food servings</i>
17	Haysville Senior Center-Commodities program	The emergency food assistance program TEFAP Distribution Site	160 E. Karla, Haysville	67060	Third Wednesday of the month beginning at 1:00 pm.	316-529-5903	Kansas driver's License or State ID with zip codes: 67060, 67216, or 67037. Sign a form stating that their total household income meets the income guidelines determined by the State of Kansas.	kmcdaniel@haysville-ks.com	<a href="https://www.haysville-ks.com/food-bank-commodities">https://www.haysville-ks.com/food-bank-commodities</a>	10
18	Haysville Senior Center-Food bank	Food pantry	160 E. Karla, Haysville	67060	Monday-Friday 8:00 a.m. – 5:00 p.m. Schedule a pick-up time.	316-529-5903	Haysville address or in the USD 261 school district. Utility bill showing your name and address.	kmcdaniel@haysville-ks.com	<a href="https://www.haysville-ks.com/food-bank-commodities">https://www.haysville-ks.com/food-bank-commodities</a>	8
19	His Helping Hands, Inc.	Food pantry	1441 E 37th St N, Wichita	67219	1st Tuesday 4:30 PM – 6:00 PM Pantry Distro, 1st Sunday 9:00 AM – 11:30 AM Produce Distro, 3rd Tuesday 4:30 PM – 6:00 PM Pantry & Mobile Distro Neighborhood Specific	316-838-8528	Photo ID	hhh@ccc.org	<a href="https://www.ccc.org/hishelpinghands">https://www.ccc.org/hishelpinghands</a>	8
20	ICT books	ICT Community Fridge	1740 S Colorado St	67209	10 am-6pm Wednesday-Sundays	3169257157	Anyone, no questions asked. Take what you need and leave what you can	ijtlcks@gmail.com	<a href="https://www.facebook.com/ICTBooks/videos/?ref=page_internal">https://www.facebook.com/ICTBooks/videos/?ref=page_internal</a>	6

APPENDIX C (continued)

<i>J</i>	<i>Name</i>	<i>Type of food opportunity</i>	<i>Address</i>	<i>Zip code</i>	<i>Hours of operation</i>	<i>Phone number</i>	<i>Requirements</i>	<i>E-mail</i>	<i>Webpage</i>	<i>Average food servings</i>
21	Iglesia La Resurreccion	Food pantry	2345 N Park Place, Wichita	67204	2nd and 3rd Saturday of each month from 7-8:30am	316-558-1230		laresurreccion316@gmail.com	<a href="https://www.facebook.com/IglesiaLaResurreccion/">https://www.facebook.com/IglesiaLaResurreccion/</a>	8
22	Jehovah Jireh Food & Clothing Center	The emergency food assistance program TEFAP Distribution Site	627 Ash, Wichita	67214	Thursday and Friday 1-2:30 pm and Saturday 9:00-10:30	316-262-2192	ID and income restriction	jehovahjirehccministry@gmail.com	<a href="https://www.facebook.com/jehovahjirehfoodandclothingcenter/">https://www.facebook.com/jehovahjirehfoodandclothingcenter/</a>	10
23	Knox center	ICT Community Fridge	2924 E Douglas Ave	67214	24/7 Outdoor Access	3162658511	Anyone, no questions asked.	ictfreefood@gmail.com	<a href="https://www.facebook.com/ICTfridgefood/">https://www.facebook.com/ICTfridgefood/</a>	6
24	Leslie Coffee Co	ICT Community Fridge	930 W. Douglas Ave Suite A	67203	Everyday 6:30 am- 4:30 pm	3165006868		ictfreefood@gmail.com	<a href="https://www.facebook.com/ICTfridgefood/">https://www.facebook.com/ICTfridgefood/</a>	6
25	Living Water Ministry	Food pantry	1400 E Kellogg Dr, Wichita	67211	Wednesday 1:00 PM – 3:00 PM	316-858-1406	Address verification	livingwater@firstnaz.org	<a href="https://firstnaz.org/living-waters/">https://firstnaz.org/living-waters/</a>	8
26	Neighborhood Love Pantry	Food pantry	812 S Oliver St, Wichita	67218	2nd Monday 5:30 PM – 6:30 PM, 4th Monday 5:30 PM – 6:30 PM	316-990-5819				8
27	New Beginnings SDA	The emergency food assistance program TEFAP Distribution Site	209 W. 21st Street, Wichita	67203	Every Wednesday 1:00 PM – 3:00 PM	316-267-6504	ID for each family member, proof of address, proof of income		<a href="https://www.facebook.com/cprfoks/">https://www.facebook.com/cprfoks/</a>	10
28	New Hope Church	The emergency food assistance program TEFAP Distribution Site	3401 Park Place, Wichita	67220	10:05 am on Saturday.	316-409-6260	Fill out online form by Thursday at 5:00 pm for Saturday pickup: <a href="https://newhopechurchayer.breezechms.com/form/57ba13">https://newhopechurchayer.breezechms.com/form/57ba13</a>	INFO@newhopechurchweb.com	<a href="https://newhopechurchweb.com/food-pantry/">https://newhopechurchweb.com/food-pantry/</a>	10

APPENDIX C (continued)

<i>J</i>	<i>Name</i>	<i>Type of food opportunity</i>	<i>Address</i>	<i>Zip code</i>	<i>Hours of operation</i>	<i>Phone number</i>	<i>Requirements</i>	<i>E-mail</i>	<i>Webpage</i>	<i>Average food servings</i>
29	New Life Church of Wichita Produce Pantry	Food pantry	1156 N Oliver, Wichita	67208	4th Friday of each month from 4:45-5:45pm	(316) 558-3003			<a href="https://www.facebook.com/newlifeoliver/">https://www.facebook.com/newlifeoliver/</a>	8
30	Northwest High school	ICT Community Fridge	1220 Tyler Rd	67212	Mon-Fri 8:00-3:00	3169736000	Anyone, no questions asked. Take what you need and leave what you can	ictfreefood@gmail.com	<a href="https://www.facebook.com/ICTfridgefood/">https://www.facebook.com/ICTfridgefood/</a>	6
31	Oaklawn Improvement District	The emergency food assistance program TEFAP Distribution Site	2927 Oaklawn Drive, Wichita	67216	Office Hours: M-F, 8:00 a.m. - 5:00 p.m.	316-524-0281		oaklawn1@juno.com	<a href="http://www.oaklawnndistrict.com/about">http://www.oaklawnndistrict.com/about</a>	10
32	Park City Pride, Inc.	Food pantry	6512 N East Park View, Park City	67219	3rd Saturday 9:30 AM – 11:00 AM	316-744-8685	Must be a Park City resident and provide proof of income.	PCKSPride@gmail.com	<a href="https://www.facebook.com/ParkCityPRIDE501c3/">https://www.facebook.com/ParkCityPRIDE501c3/</a>	8
33	Pleasant Valley Food Share	Food pantry	1600 W 27th St N, Wichita	67204-5000	2nd and 4th Fridays of each month, from 3:00pm – 5:00pm.	316-838-1600		carrieheiman@icloud.com.	<a href="https://pvumc.com/?page_id=426">https://pvumc.com/?page_id=426</a>	8
34	Positive directions	ICT Community Fridge	154 N Topeka St	67202	Monday- Friday 9 am- 4 pm	3162632214	Anyone, no questions asked. Take what you need and leave what you can	ictfreefood@gmail.com	<a href="https://www.facebook.com/ICTfridgefood/">https://www.facebook.com/ICTfridgefood/</a>	6
35	Progressive Missionary Baptist Church Mobile food pantry	Mobile food pantry	2725 E 25th St	67219	The last Friday of every month	316-265-3663	First time visitors: photo ID and proof of address. Number of people in their household along with the number of seniors and kids.	info@kansasfoodbank.org. p_sec1@yahoo.com	<a href="https://kansasfoodbank.org/mobile-food-pantries-in-wichita/">https://kansasfoodbank.org/mobile-food-pantries-in-wichita/</a> . <a href="https://www.pmbaptist.net/">https://www.pmbaptist.net/</a>	8

APPENDIX C (continued)

<i>J</i>	<i>Name</i>	<i>Type of food opportunity</i>	<i>Address</i>	<i>Zip code</i>	<i>Hours of operation</i>	<i>Phone number</i>	<i>Requirements</i>	<i>E-mail</i>	<i>Webpage</i>	<i>Average food servings</i>
36	Salvation Army – West Orchard	The emergency food assistance program TEFAP Distribution Site	1910 S Everett St, Wichita	67213-3215	Tuesday 10:00 AM – 2:00 PM, Thursday 10:00 AM – 2:00 PM.	316-943-9893	For zip codes: 67001-016-025-026-030-050-052-060-101-108-120-149-205-209-212-213-215-217-223-227-231-235	wichitawo.ea@usc.salvationarmy.org	<a href="https://www.facebook.com/SalArmyWichitaWestOrchard/">https://www.facebook.com/SalArmyWichitaWestOrchard/</a>	10
37	Salvation Army ICT – Citadel	The emergency food assistance program TEFAP Distribution Site	1739 S Elpyco St, Wichita	67218-4307	Tuesday 10:00 AM – 2:00 PM, Thursday 10:00 AM – 2:00 PM.	316-685-8699 x 102	ZIP codes: 67037-060-110-133-202-206-207-210-216-218-221-230-233-236	wichitacitadel@gmail.com	<a href="https://www.facebook.com/WichitaCitadel/">https://www.facebook.com/WichitaCitadel/</a>	10
38	Salvation Army ICT- Downtown Wichita Koch Center location	The emergency food assistance program TEFAP Distribution Site	350 N Market St, Wichita	67202-2010	8:30 am - 4:30 pm (Monday - Friday)	316-425-6120	ZIP codes: 67017-067-135-147-201-203-204-208-211-214-219-220-226-228-278	brenda.awtrey@usc.salvationarmy.org	<a href="https://centralusa.salvationarmy.org/wichita/koch-center/">https://centralusa.salvationarmy.org/wichita/koch-center/</a>	10
39	Salvation Army Mobile Pantry- Pattie	The emergency food assistance program TEFAP Distribution Site	Goldenrod Park Community Facility 1340 S. Pattie St., Wichita	67211	Monday from 2-4:30pm	316-263-2769			<a href="https://centralusa.salvationarmy.org/wichita/news/new-food-pantry/">https://centralusa.salvationarmy.org/wichita/news/new-food-pantry/</a>	10
40	Salvation Army Mobile Pantry- Colvin	The emergency food assistance program TEFAP Distribution Site	Colvin Community Center. 2820 S. Roosevelt St., Wichita	67210	Tuesday and Thursday from 2-4:30pm	316-263-2769			<a href="https://centralusa.salvationarmy.org/wichita/news/new-food-pantry/">https://centralusa.salvationarmy.org/wichita/news/new-food-pantry/</a>	10
41	Salvation Army Mobile Pantry- Fairmount	The emergency food assistance program TEFAP Distribution Site	Fairmount Community Center. 1647 N. Yale Blvd., Wichita	67218	Wednesday from 2-4:30pm	316-263-2769			<a href="https://centralusa.salvationarmy.org/wichita/news/new-food-pantry/">https://centralusa.salvationarmy.org/wichita/news/new-food-pantry/</a>	10

APPENDIX C (continued)

<i>J</i>	<i>Name</i>	<i>Type of food opportunity</i>	<i>Address</i>	<i>Zip code</i>	<i>Hours of operation</i>	<i>Phone number</i>	<i>Requirements</i>	<i>E-mail</i>	<i>Webpage</i>	<i>Average food servings</i>
42	Shepherd's Heart Food Pantry	The emergency food assistance program TEFAP Distribution Site	8605 W Maple St, Wichita	67209-1413	5:30 pm and 7:00 pm on the 2nd & 4th Monday of each month	316-722-1251		rollinghillschurchwichita@gmail.com	<a href="https://www.rhc.c.church/shepherds-hearti">https://www.rhc.c.church/shepherds-hearti</a>	10
43	Shocker Support Locker	Food pantry	1967 Research Pl, Wichita	67208	Monday through Friday 12:00 PM to 3:00 PM	316-978-3480	Shocker ID	sga@wichita.edu	<a href="https://www.wichita.edu/student_life/sga/Shocker_Food_Locker.php">https://www.wichita.edu/student_life/sga/Shocker_Food_Locker.php</a>	8
44	Simple House	Food pantry	1910 W Douglas Ave, Wichita	67202-1189	Every Monday 11:00 AM – 1:15 PM. Every Tuesday 9:30 AM – 12:15 PM	316-265-9653	Photo ID		<a href="http://www.westlinkchurch.org/simple_house/">http://www.westlinkchurch.org/simple_house/</a>	8
45	Sisters of Joseph Dear Neighbor Center	Food pantry	1329 S Bluffview Dr, Wichita	67218-3031	Monday through Friday between 8:00 a.m. - noon, or 1:00 p.m. - 4:30 p.m.	316-684-5120	Must be a Wichita resident.	info@dearneighbor.org	<a href="https://dearneighbor.org/services-dn/community-food-pantry">https://dearneighbor.org/services-dn/community-food-pantry</a>	8
46	South High school	ICT Community Fridge	701 W. 33rd S, Wichita	67217	Mon-Fri 8:00-3:00	3169735450	Anyone, no questions asked. Take what you need and leave what you can	ictfreefood@gmail.com	<a href="https://www.facebook.com/ICTfridgefood/">https://www.facebook.com/ICTfridgefood/</a>	6
47	St. Jude Catholic Church	Food pantry	3130 N Amidon, Wichita	67204	Monday 9:00 AM – 10:00 AM	316-838-1963			<a href="https://stjudewichita.org/service/lorde-pantry">https://stjudewichita.org/service/lorde-pantry</a>	8

APPENDIX C (continued)

<i>J</i>	<i>Name</i>	<i>Type of food opportunity</i>	<i>Address</i>	<i>Zip code</i>	<i>Hours of operation</i>	<i>Phone number</i>	<i>Requirements</i>	<i>E-mail</i>	<i>Webpage</i>	<i>Average food servings</i>
48	St. Patrick's Lord's Pantry	Food pantry	2007 N Arkansas, Wichita	67203-1550	Tuesday 8:30 AM – 10:00 AM	316-262-4683	ID's for each member of household, current address and proof of income (if any). Must live within these boundaries: West of Broadway, East of West Street, South of 37th St. North, and North of Central Ave. Proof of address is required.	stpatrikchurch@stpatswichita.org	<a href="https://stpatswichita.org/Website/HTML/church.html">https://stpatswichita.org/Website/HTML/church.html</a>	8
49	The Lord's Diner of Wichita-Hillside	Soup kitchen	2825 S. Hillside, Wichita	67216	Mon - Sat 5:30–7:30PM	316-266-4966		info@thelordsdiner.org	<a href="https://thelordsdiner.org/">https://thelordsdiner.org/</a>	2
50	The Lord's Diner of Wichita-Terrace	Food truck	1329 South Terrace in Wichita	67218	Monday-Friday 4-6 p.m.	316-266-4969		info@thelordsdiner.org	<a href="https://thelordsdiner.org/">https://thelordsdiner.org/</a>	2
51	The Lord's Diner of Wichita-Broadway	Soup kitchen	520 North Broadway Wichita	67214	Mon - Sat 5:30–7:30PM	316-266-4966		info@thelordsdiner.org	<a href="https://thelordsdiner.org/">https://thelordsdiner.org/</a>	2
52	The Lord's Diner of Wichita-19th	Food truck	2755 E 19th St. N.	67214	Monday-Friday 4-6 p.m.	316-266-4970		info@thelordsdiner.org	<a href="https://thelordsdiner.org/">https://thelordsdiner.org/</a>	2
53	The Lord's Diner of Wichita-25th	Food truck	NW of 25th St. N. and Arkansas St.	67204	Monday-Friday 4-6 p.m.	316-266-4968		info@thelordsdiner.org	<a href="https://thelordsdiner.org/">https://thelordsdiner.org/</a>	2

APPENDIX C (continued)

<i>J</i>	<i>Name</i>	<i>Type of food opportunity</i>	<i>Address</i>	<i>Zip code</i>	<i>Hours of operation</i>	<i>Phone number</i>	<i>Requirements</i>	<i>E-mail</i>	<i>Webpage</i>	<i>Average food servings</i>
54	United Methodist Open Door-Commodity Supplemental Food Program	The emergency food assistance program TEFAP Distribution Site	2130 E 21st St N, Wichita	67214	Hours: Monday –Friday 9:00 a.m. -11:45 lunch 1:00-4:00 p.m.	316.267.0511.	People age 60 and older qualify at 130% of the federal poverty level. Proof of identity and age, proof of residency and poof of gross monthly income. Social Security if available. Once a month box.	administration@umopendoor.org	<a href="https://umopendoor.org/how-we-help/food-ministry/">https://umopendoor.org/how-we-help/food-ministry/</a>	10
55	United Methodist Open Door-Community Food Ministry	Food pantry	2130 E 21st St N, Wichita	67214	Monday –Friday 9:00 a.m. -11:45 LUNCH 1:00-4:00 p.m.	316-265-9371	ID for each household member, proof of address, and proof of income must be at 130%. Photo ID, 21 years or older, Sedgwick Co. residents only.	administration@umopendoor.org	<a href="https://umopendoor.org/how-we-help/food-ministry/">https://umopendoor.org/how-we-help/food-ministry/</a>	8
56	Urban League Mobile food pantry	Mobile food pantry	2418 E 9th St N	67214	Third Thursday of every month, starting at 2:00 p.m.	316-265-3663	Number of people in their household along with the number of seniors and kids.	info@kansasfoodbank.org	<a href="https://kansasfoodbank.org/mobile-food-pantries-in-wichita/">https://kansasfoodbank.org/mobile-food-pantries-in-wichita/</a>	8

APPENDIX C (continued)

<i>J</i>	<i>Name</i>	<i>Type of food opportunity</i>	<i>Address</i>	<i>Zip code</i>	<i>Hours of operation</i>	<i>Phone number</i>	<i>Requirements</i>	<i>E-mail</i>	<i>Webpage</i>	<i>Average food servings</i>
57	West Side GNC	Food pantry	3500 W 13th St N, Wichita	67203-4560	Wednesday 8:30 AM – 11:30 AM. 2nd Saturday 8:30 AM – 11:30 AM	316-942-7349	Photo ID, SS Card for each, proof address, Maize, Goddard, Park City, Valley Center, Haysville, ICT	info@westsideg nc.org	<a href="https://westsidegnc.org/contact">https://westsidegnc.org/contact</a>	8
58	Wichita birth justice society	ICT Community Fridge	1540 N Broadway Suite 203, Wichita	67214	weekdays between 11 am and 2 pm	N/A	Anyone, no questions asked. Take what you need and leave what you can	ictfreefood@gm ail.com	<a href="https://www.facebook.com/ICTfridgefood/">https://www.facebook.com/ICTfridgefood/</a>	6

## APPENDIX D

### HYPOTHETICAL INDIVIDUAL'S DATA

<i>ID</i>	<i>Individuals' number per household</i>	<i>Address Latitude</i>	<i>Address Longitude</i>	<i>Place 2 Latitude</i>	<i>Place 2 Longitude</i>	<i>Place 3 Latitude</i>	<i>Place 3 Longitude</i>	<i>Address city</i>	<i>Address zip code</i>	<i>Address school district</i>	<i>Individual in poverty</i>	<i>Age</i>	<i>Student at WSU</i>	<i>Spanish translation needed</i>	<i>Photo ID</i>	<i>ID of all persons listed</i>	<i>Proof of income</i>	<i>Proof of address</i>	<i>Social Security Card</i>	<i>Presence of all household members</i>
1	3	37.691908	-97.411737	37.495126	-97.728958	37.878407	-97.357315	Wichita	67212	USD 259	No	25	No	No	Yes	Yes	No	No	No	Yes
2	2	37.501139	-97.326569	37.869866	-97.214076	37.848277	-97.538948	Peck	67120	USD 263	No	83	No	No	Yes	No	No	No	No	Yes
3	1	37.86822	-97.623316	37.515397	-97.535765	37.540062	-97.339736	Mount Hope	67108	USD 312	No	53	No	No	No	Yes	No	Yes	No	No
4	3	37.482479	-97.187902	37.70388	-97.617735	37.688997	-97.250098	Mulvane	67232	USD 263	No	24	Yes	No	Yes	No	Yes	No	Yes	Yes
5	2	37.480694	-97.158297	37.875168	-97.59053	37.754806	-97.181265	Mulvane	67110	USD 263	No	29	No	No	No	No	Yes	Yes	Yes	No
6	5	37.646288	-97.377627	37.814015	-97.617449	37.79167	-97.441992	Wichita	67217	USD 259	No	22	No	No	No	Yes	No	No	Yes	Yes
7	1	37.874147	-97.676069	37.802651	-97.341728	37.718422	-97.768684	Mount Hope	67108	USD 312	No	33	No	No	Yes	Yes	Yes	No	No	Yes
8	3	37.756739	-97.493015	37.879231	-97.571386	37.591929	-97.356978	Maize	67067	USD 267	No	82	No	No	Yes	Yes	Yes	Yes	Yes	Yes
9	2	37.598843	-97.435248	37.585697	-97.214224	37.908684	-97.564727	Clearwater	67215	USD 261	No	64	No	No	Yes	No	No	Yes	No	No
10	2	37.543682	-97.443863	37.638504	-97.766219	37.8023	-97.158934	Clearwater	67026	USD 264	No	25	No	No	No	Yes	Yes	No	No	Yes

APPENDIX D (continued)

ID	Individuals' number per household	Address Latitude	Address Longitude	Place 2 Latitude	Place 2 Longitude	Place 3 Latitude	Place 3 Longitude	Address city	Address zip code	Address school district	Individual in poverty	Age	Student at WSU	Spanish translation needed	Photo ID	ID of all persons listed	Proof of income	Proof of address	Social Security Card	Presence of all household members
11	6	37.540172	-97.368668	37.71572	-97.245109	37.762742	-97.355322	Haysville	67120	USD 261	No	20	Yes	No	Yes	No	Yes	No	Yes	No
12	2	37.770321	-97.238717	37.568062	-97.697749	37.689117	-97.65249	Wichita	67226	USD 259	No	89	No	No	Yes	Yes	Yes	No	No	Yes
13	1	37.888713	-97.492281	37.661418	-97.232034	37.807895	-97.513652	Sedgwick	67135	USD 440	No	43	No	No	Yes	Yes	Yes	No	No	No
14	3	37.719686	-97.679	37.740664	-97.66633	37.499828	-97.715491	Garden Plain	67223	USD 267	No	43	No	No	Yes	No	Yes	No	No	No
15	3	37.775831	-97.255582	37.838476	-97.292939	37.757296	-97.215874	Wichita	67220	USD 259	No	24	Yes	No	Yes	Yes	Yes	No	No	Yes
16	2	37.834516	-97.27065	37.548486	-97.702238	37.593871	-97.584033	Valley Center	67147	USD 262	No	54	No	No	Yes	Yes	No	Yes	Yes	Yes
17	2	37.807385	-97.254438	37.662333	-97.444695	37.534617	-97.464589	Kechi	67147	USD 259	No	27	No	No	No	No	No	No	No	Yes
18	2	37.638312	-97.171593	37.788689	-97.515011	37.899837	-97.422221	Wichita	67232	USD 259	No	97	No	No	Yes	Yes	No	No	No	Yes
19	1	37.791807	-97.339634	37.687508	-97.29658	37.828439	-97.572423	Wichita	67204	USD 259	No	23	Yes	No	No	No	No	No	No	Yes
20	1	37.567515	-97.698983	37.733483	-97.415281	37.4823	-97.617267	Cheney	67149	USD 268	No	24	No	No	Yes	Yes	No	Yes	No	Yes
21	3	37.911373	-97.671231	37.60569	-97.317867	37.837478	-97.540237	Mount Hope	67020	USD 369	No	87	No	No	Yes	No	No	Yes	Yes	Yes

APPENDIX D (continued)

<i>ID</i>	<i>Individuals' number per household</i>	<i>Address Latitude</i>	<i>Address Longitude</i>	<i>Place 2 Latitude</i>	<i>Place 2 Longitude</i>	<i>Place 3 Latitude</i>	<i>Place 3 Longitude</i>	<i>Address city</i>	<i>Address zip code</i>	<i>Address school district</i>	<i>Individual in poverty</i>	<i>Age</i>	<i>Student at WSU</i>	<i>Spanish translation needed</i>	<i>Photo ID</i>	<i>ID of all persons listed</i>	<i>Proof of income</i>	<i>Proof of address</i>	<i>Social Security Card</i>	<i>Presence of all household members</i>
22	2	37.888202	-97.538582	37.897207	-97.643989	37.554005	-97.52372	Sedgwick	67016	USD 440	No	47	No	Yes	Yes	No	Yes	No	Yes	No
23	3	37.678826	-97.19592	37.553241	-97.342892	37.724642	-97.794291	Wichita	67207	USD 259	No	59	No	No	Yes	Yes	Yes	Yes	Yes	No
24	4	37.869932	-97.665981	37.666593	-97.286651	37.61119	-97.220864	Mount Hope	67108	USD 312	No	60	No	No	No	Yes	No	Yes	Yes	No
25	3	37.781525	-97.545825	37.506286	-97.428203	37.805275	-97.370734	Colwich	67030	USD 267	No	43	No	No	No	No	Yes	No	No	Yes
26	1	37.552834	-97.685319	37.51375	-97.255345	37.716307	-97.306868	Cheney	67050	USD 267	No	19	No	No	No	Yes	No	No	No	Yes
27	5	37.492094	-97.628727	37.550135	-97.748147	37.777064	-97.420068	Viola	67149	USD 356	No	44	No	No	Yes	Yes	Yes	No	No	No
28	4	37.658729	-97.230464	37.613661	-97.699252	37.628475	-97.327332	Wichita	67207	USD 259	No	24	Yes	No	Yes	Yes	Yes	No	No	Yes
29	2	37.89516	-97.380531	37.70713	-97.516142	37.717388	-97.553897	Valley Center	67147	USD 439	No	85	No	No	No	No	Yes	No	No	No
30	1	37.879926	-97.302875	37.699204	-97.582745	37.813356	-97.342985	Valley Center	67147	USD 262	Yes	22	No	No	Yes	Yes	No	No	Yes	No
31	2	37.674597	-97.256974	37.485753	-97.159749	37.569651	-97.425479	Wichita	67207	USD 259	No	53	No	No	No	Yes	Yes	No	Yes	No
32	3	37.673456	-97.500756	37.482057	-97.319561	37.563682	-97.670057	Wichita	67235	USD 265	No	41	No	No	Yes	Yes	Yes	No	Yes	Yes

APPENDIX D (continued)

ID	Individuals' number per household	Address Latitude	Address Longitude	Place 2 Latitude	Place 2 Longitude	Place 3 Latitude	Place 3 Longitude	Address city	Address zip code	Address school district	Individual in poverty	Age	Student at WSU	Spanish translation needed	Photo ID	ID of all persons listed	Proof of income	Proof of address	Social Security Card	Presence of all household members
33	5	37.869091	-97.621717	37.599537	-97.327337	37.624473	-97.635119	Mount Hope	67108	USD 312	No	79	No	No	Yes	No	Yes	No	Yes	No
34	1	37.665987	-97.50828	37.81378	-97.203439	37.820164	-97.633315	Wichita	67235	USD 265	No	60	No	No	Yes	Yes	No	No	Yes	Yes
35	3	37.498188	-97.370479	37.736387	-97.537148	37.580015	-97.284335	Peck	67120	USD 264	No	79	No	No	No	No	Yes	No	No	Yes
36	1	37.816561	-97.525536	37.804795	-97.275923	37.63989	-97.703387	Colwich	67030	USD 267	No	55	No	No	No	No	Yes	Yes	No	No
37	1	37.606101	-97.606885	37.620293	-97.343371	37.84081	-97.380889	Goddard	67052	USD 265	No	99	No	No	Yes	No	No	Yes	No	No
38	6	37.646882	-97.264151	37.647442	-97.767895	37.514274	-97.226776	Wichita	67221	USD 259	No	21	No	No	Yes	No	No	No	No	Yes
39	3	37.892485	-97.595744	37.825247	-97.472944	37.663699	-97.421985	Sedgwick	67135	USD 369	No	19	No	No	Yes	Yes	No	No	No	Yes
40	3	37.847263	-97.232081	37.584104	-97.593309	37.583739	-97.662042	Valley Center	67147	USD 206	No	22	No	No	No	Yes	Yes	No	No	Yes
41	3	37.522965	-97.557707	37.763865	-97.617919	37.695703	-97.192941	Clearwater	67149	USD 264	No	56	No	Yes	Yes	Yes	No	Yes	Yes	Yes
42	2	37.705372	-97.345362	37.84342	-97.424575	37.591835	-97.30957	Wichita	67203	USD 259	Yes	41	No	No	Yes	Yes	No	No	No	Yes
43	3	37.70536	-97.228375	37.574158	-97.383805	37.504133	-97.200067	Wichita	67206	USD 259	No	79	No	No	No	Yes	Yes	No	Yes	No

APPENDIX D (continued)

ID	Individuals' number per household	Address Latitude	Address Longitude	Place 2 Latitude	Place 2 Longitude	Place 3 Latitude	Place 3 Longitude	Address city	Address zip code	Address school district	Individual in poverty	Age	Student at WSU	Spanish translation needed	Photo ID	ID of all persons listed	Proof of income	Proof of address	Social Security Card	Presence of all household members
44	1	37.911583	-97.58093	37.578506	-97.356989	37.771654	-97.168722	Sedgwick	67135	USD 440	No	29	No	No	No	Yes	Yes	No	No	Yes
45	3	37.768041	-97.410019	37.489286	-97.219939	37.712998	-97.447189	Wichita	67101	USD 266	No	30	No	No	Yes	Yes	No	No	No	No
46	4	37.761473	-97.17073	37.888665	-97.191748	37.798763	-97.611721	Wichita	67228	USD 385	No	22	No	No	No	Yes	No	No	Yes	Yes
47	5	37.702446	-97.334802	37.628827	-97.576765	37.877381	-97.3591	Wichita	67214	USD 259	No	43	No	No	No	No	No	No	Yes	Yes
48	1	37.672055	-97.181136	37.828985	-97.651425	37.736455	-97.190664	Wichita	67230	USD 259	No	67	No	No	No	Yes	Yes	No	Yes	No
49	6	37.574985	-97.397276	37.562326	-97.238117	37.730844	-97.765475	Haysville	67217	USD 261	Yes	25	No	No	Yes	Yes	Yes	Yes	No	Yes
50	2	37.477429	-97.624102	37.869817	-97.537783	37.668889	-97.636844	Viola	67149	USD 356	No	25	No	No	Yes	No	No	No	No	No
51	2	37.909177	-97.390627	37.693456	-97.675591	37.636464	-97.322498	Sedgwick	67135	USD 439	Yes	31	No	Yes	No	Yes	Yes	No	No	Yes
52	1	37.670471	-97.564818	37.674288	-97.230528	37.864503	-97.344046	Goddard	67052	USD 265	No	93	No	No	Yes	No	Yes	No	No	No
53	2	37.586779	-97.639441	37.564667	-97.663366	37.621055	-97.554292	Viola	67149	USD 267	No	24	No	No	Yes	Yes	Yes	No	No	Yes
54	2	37.768708	-97.686732	37.670728	-97.760719	37.672315	-97.23928	Mount Hope	67001	USD 267	No	25	No	No	No	Yes	No	Yes	Yes	Yes

APPENDIX D (continued)

ID	Individuals' number per household	Address Latitude	Address Longitude	Place 2 Latitude	Place 2 Longitude	Place 3 Latitude	Place 3 Longitude	Address city	Address zip code	Address school district	Individual in poverty	Age	Student at WSU	Spanish translation needed	Photo ID	ID of all persons listed	Proof of income	Proof of address	Social Security Card	Presence of all household members
55	1	37.617578	-97.383709	37.869003	-97.455915	37.883944	-97.469706	Wichita	67217	USD 261	No	23	No	No	Yes	Yes	No	No	Yes	No
56	2	37.861722	-97.562393	37.772455	-97.195079	37.846178	-97.538394	Colwich	67030	USD 267	Yes	86	No	No	No	No	No	No	No	No
57	5	37.556058	-97.452862	37.676378	-97.505308	37.905217	-97.361271	Clearwater	67026	USD 264	No	19	No	No	No	No	No	Yes	No	No
58	3	37.879816	-97.495933	37.837698	-97.282981	37.825637	-97.580664	Sedgwick	67016	USD 440	No	44	No	No	Yes	No	No	No	No	No
59	4	37.545686	-97.604284	37.686404	-97.413729	37.679983	-97.209169	Viola	67026	USD 264	No	25	No	No	Yes	No	Yes	No	No	No
60	2	37.792755	-97.209469	37.582911	-97.625375	37.580208	-97.582168	Wichita	67147	USD 375	No	19	No	No	No	Yes	Yes	Yes	No	Yes
61	1	37.594483	-97.408718	37.560372	-97.685409	37.839249	-97.666264	Wichita	67215	USD 261	No	31	No	No	No	No	Yes	No	No	Yes
62	3	37.669394	-97.597999	37.719293	-97.180703	37.643826	-97.313302	Goddard	67052	USD 265	No	35	No	No	No	No	Yes	Yes	Yes	No
63	1	37.582908	-97.690837	37.820672	-97.3269	37.794949	-97.196763	Cheney	67050	USD 267	No	78	No	No	Yes	No	No	Yes	No	Yes
64	3	37.876932	-97.665501	37.885108	-97.396889	37.488361	-97.735202	Mount Hope	67108	USD 312	No	19	No	No	No	Yes	Yes	No	Yes	No
65	3	37.748705	-97.427334	37.801416	-97.237159	37.716471	-97.628357	Wichita	67205	USD 266	No	21	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes

APPENDIX D (continued)

ID	Individuals' number per household	Address Latitude	Address Longitude	Place 2 Latitude	Place 2 Longitude	Place 3 Latitude	Place 3 Longitude	Address city	Address zip code	Address school district	Individual in poverty	Age	Student at WSU	Spanish translation needed	Photo ID	ID of all persons listed	Proof of income	Proof of address	Social Security Card	Presence of all household members
66	1	37.643508	-97.575054	37.556747	-97.797223	37.518893	-97.487093	Goddard	67052	USD 265	No	28	No	No	Yes	Yes	No	Yes	No	No
67	1	37.631046	-97.528523	37.683849	-97.247564	37.571491	-97.397953	Goddard	67227	USD 265	No	78	No	No	No	Yes	Yes	Yes	No	No
68	4	37.617509	-97.383362	37.63998	-97.274011	37.855158	-97.353071	Wichita	67217	USD 261	No	35	No	No	Yes	No	No	Yes	No	Yes
69	1	37.479542	-97.367412	37.715739	-97.667622	37.661025	-97.495378	Peck	67120	USD 263	No	92	No	No	No	Yes	Yes	Yes	No	No
70	1	37.736857	-97.330543	37.901879	-97.357124	37.606405	-97.359401	Wichita	67219	USD 259	No	23	Yes	No	Yes	Yes	No	No	No	No
71	4	37.479191	-97.69797	37.82761	-97.26181	37.57218	-97.507438	Milton	67031	USD 268	No	20	Yes	No	Yes	No	No	Yes	No	No
72	6	37.586999	-97.182331	37.538686	-97.626512	37.524596	-97.643059	Derby	67037	USD 394	No	33	No	No	No	Yes	Yes	Yes	No	No
73	2	37.728028	-97.220257	37.711141	-97.46894	37.795377	-97.168756	Wichita	67226	USD 259	Yes	23	No	No	Yes	No	No	No	No	Yes
74	2	37.849284	-97.301696	37.567542	-97.475021	37.868127	-97.368955	Valley Center	67147	USD 262	Yes	25	No	No	Yes	Yes	No	No	No	Yes
75	6	37.844655	-97.327961	37.505938	-97.385207	37.739983	-97.248454	Valley Center	67147	USD 262	No	93	No	No	No	No	No	Yes	Yes	No
76	1	37.591333	-97.596423	37.747653	-97.305313	37.641839	-97.666893	Viola	67149	USD 265	No	79	No	No	No	No	Yes	Yes	No	No

APPENDIX D (continued)

ID	Individuals' number per household	Address Latitude	Address Longitude	Place 2 Latitude	Place 2 Longitude	Place 3 Latitude	Place 3 Longitude	Address city	Address zip code	Address school district	Individual in poverty	Age	Student at WSU	Spanish translation needed	Photo ID	ID of all persons listed	Proof of income	Proof of address	Social Security Card	Presence of all household members
77	3	37.641488	-97.195134	37.640053	-97.611174	37.727571	-97.733234	Wichita	67232	USD 259	No	25	No	Yes	Yes	Yes	Yes	No	Yes	Yes
78	3	37.90286	-97.699985	37.761309	-97.199753	37.729482	-97.67289	Mount Hope	67543	USD 312	No	21	Yes	No	No	Yes	No	Yes	No	No
79	1	37.814422	-97.270199	37.585442	-97.467278	37.529081	-97.611822	Valley Center	67147	USD 262	No	33	No	No	No	No	Yes	Yes	No	Yes
80	3	37.583881	-97.504464	37.518601	-97.37617	37.528558	-97.363046	Clearwater	67227	USD 264	No	20	Yes	No	Yes	No	Yes	No	Yes	Yes
81	2	37.626321	-97.363411	37.806433	-97.16048	37.639283	-97.157613	Wichita	67217	USD 259	No	21	No	No	Yes	No	No	Yes	No	Yes
82	5	37.778231	-97.420435	37.772959	-97.461927	37.566293	-97.652358	Wichita	67101	USD 266	No	20	Yes	No	Yes	Yes	No	Yes	No	Yes
83	2	37.90136	-97.20051	37.49754	-97.325654	37.659858	-97.225945	Valley Center	67147	USD 206	No	52	No	No	No	Yes	Yes	No	No	No
84	3	37.493864	-97.557088	37.710077	-97.696982	37.5446	-97.524823	Clearwater	67149	USD 264	Yes	42	No	No	Yes	Yes	No	Yes	No	Yes
85	3	37.62991	-97.58739	37.732595	-97.652382	37.751892	-97.252046	Goddard	67052	USD 265	No	23	No	Yes	Yes	No	Yes	Yes	No	No
86	2	37.753741	-97.612102	37.594408	-97.534069	37.834705	-97.67527	Andale	67067	USD 267	No	37	No	No	Yes	No	No	No	Yes	Yes
87	1	37.816297	-97.436499	37.533655	-97.722975	37.722806	-97.702569	Valley Center	67147	USD 262	Yes	23	No	No	Yes	No	Yes	No	No	Yes

APPENDIX D (continued)

ID	Individuals' number per household	Address Latitude	Address Longitude	Place 2 Latitude	Place 2 Longitude	Place 3 Latitude	Place 3 Longitude	Address city	Address zip code	Address school district	Individual in poverty	Age	Student at WSU	Spanish translation needed	Photo ID	ID of all persons listed	Proof of income	Proof of address	Social Security Card	Presence of all household members
88	2	37.634055	-97.218541	37.873594	-97.494684	37.893113	-97.243989	Wichita	67210	USD 260	No	38	No	No	No	No	No	No	Yes	No
89	2	37.517987	-97.495124	37.651391	-97.401984	37.512762	-97.568484	Clearwater	67026	USD 264	No	60	No	No	No	Yes	No	No	No	No
90	1	37.516725	-97.58714	37.839976	-97.655893	37.477364	-97.764422	Clearwater	67026	USD 264	No	73	No	No	Yes	Yes	No	Yes	Yes	Yes
91	4	37.719736	-97.760383	37.519972	-97.481528	37.545603	-97.29551	Cheney	67025	USD 267	No	53	No	No	Yes	Yes	Yes	No	No	Yes
92	4	37.526802	-97.718574	37.537829	-97.407164	37.60123	-97.364794	Milton	67106	USD 268	No	61	No	No	Yes	Yes	No	Yes	Yes	No
93	6	37.504627	-97.706658	37.70909	-97.342442	37.911719	-97.211677	Milton	67106	USD 268	No	35	No	No	Yes	No	No	Yes	No	No
94	2	37.617119	-97.719793	37.600198	-97.707827	37.489215	-97.495477	Cheney	67025	USD 268	No	31	No	No	No	No	No	No	No	No
95	6	37.720528	-97.73633	37.519299	-97.298867	37.825322	-97.415784	Cheney	67025	USD 267	No	20	No	No	Yes	Yes	Yes	No	Yes	Yes
96	5	37.5122	-97.718709	37.732391	-97.695479	37.711657	-97.399925	Milton	67106	USD 268	No	96	No	No	No	No	No	Yes	No	Yes
97	4	37.659109	-97.724498	37.904715	-97.435017	37.483446	-97.165887	Garden Plain	67050	USD 268	No	40	No	No	No	No	No	Yes	Yes	No
98	1	37.607943	-97.722292	37.792504	-97.695751	37.526454	-97.78802	Cheney	67025	USD 268	No	52	No	No	Yes	No	No	No	Yes	Yes

APPENDIX D (continued)

<i>ID</i>	<i>Individuals' number per household</i>	<i>Address Latitude</i>	<i>Address Longitude</i>	<i>Place 2 Latitude</i>	<i>Place 2 Longitude</i>	<i>Place 3 Latitude</i>	<i>Place 3 Longitude</i>	<i>Address city</i>	<i>Address zip code</i>	<i>Address school district</i>	<i>Individual in poverty</i>	<i>Age</i>	<i>Student at WSU</i>	<i>Spanish translation needed</i>	<i>Photo ID</i>	<i>ID of all persons listed</i>	<i>Proof of income</i>	<i>Proof of address</i>	<i>Social Security Card</i>	<i>Presence of all household members</i>
99	2	37.519489	-97.752917	37.759176	-97.386279	37.708022	-97.594016	Milton	67106	USD 268	No	43	No	No	Yes	Yes	No	No	No	No
100	1	37.611811	-97.779136	37.667712	-97.776243	37.62667	-97.655513	Cheney	67025	USD 268	No	41	No	No	Yes	Yes	Yes	Yes	Yes	Yes

APPENDIX E

CONVENTIONAL FOOD ACCESS MEASUREMENTS FOR HYPOTHETICAL INDIVIDUALS

ID	Address centroid to opportunities					Address to opportunities				
	Minimum distance (miles)	Density (1 mile radius)	Dichotomous (1 mile radius)	Density (10 miles radius)	Dichotomous (10 miles radius)	Minimum distance (miles)	Density (1 mile radius)	Dichotomous (1 mile radius)	Density (10 miles radius)	Dichotomous (10 miles radius)
1	2.18	0	0	43	1	2.69	0	0	38	1
2	5.33	0	0	2	1	10.79	0	0	0	0
3	12.71	0	0	0	0	12.15	0	0	0	0
4	11.34	0	0	0	0	13.16	0	0	0	0
5	11.34	0	0	0	0	14.69	0	0	0	0
6	1.18	0	0	45	1	1.59	0	0	48	1
7	12.71	0	0	0	0	15.26	0	0	0	0
8	12.48	0	0	0	0	7.44	0	0	3	1
9	9.46	0	0	1	1	6.41	0	0	11	1
10	5.33	0	0	2	1	6.87	0	0	2	1
11	5.33	0	0	2	1	3.17	0	0	8	1
12	7.37	0	0	2	1	4.47	0	0	23	1
13	12.71	0	0	0	0	3.95	0	0	2	1
14	15.17	0	0	0	0	14.50	0	0	0	0
15	3.15	0	0	37	1	3.99	0	0	27	1
16	2.22	0	0	6	1	5.01	0	0	8	1
17	7.37	0	0	2	1	4.02	0	0	16	1
18	5.69	0	0	15	1	7.00	0	0	10	1
19	2.73	0	0	37	1	2.03	0	0	35	1
20	20.98	0	0	0	0	18.97	0	0	0	0
21	12.71	0	0	0	0	17.47	0	0	0	0
22	12.71	0	0	0	0	6.63	0	0	1	1
23	2.75	0	0	35	1	3.81	0	0	28	1
24	12.71	0	0	0	0	15.17	0	0	0	0
25	12.48	0	0	0	0	9.84	0	0	1	1
26	20.98	0	0	0	0	18.56	0	0	0	0
27	20.98	0	0	0	0	17.91	0	0	0	0
28	1.53	0	0	43	1	2.15	0	0	34	1

APPENDIX E (continued)

ID	Address centroid to opportunities					Address to opportunities				
	Minimum distance (miles)	Density (1 mile radius)	Dichotomous (1 mile radius)	Density (10 miles radius)	Dichotomous (10 miles radius)	Minimum distance (miles)	Density (1 mile radius)	Dichotomous (1 mile radius)	Density (10 miles radius)	Dichotomous (10 miles radius)
29	2.22	0	0	6	1	4.61	0	0	3	1
30	2.22	0	0	6	1	6.29	0	0	3	1
31	1.35	0	0	47	1	1.44	0	0	46	1
32	6.40	0	0	4	1	3.64	0	0	7	1
33	12.71	0	0	0	0	12.57	0	0	0	0
34	6.40	0	0	4	1	4.71	0	0	7	1
35	5.33	0	0	2	1	6.07	0	0	2	1
36	12.48	0	0	0	0	5.91	0	0	1	1
37	15.17	0	0	0	0	13.42	0	0	0	0
38	4.30	0	0	27	1	2.09	0	0	45	1
39	12.71	0	0	0	0	11.02	0	0	0	0
40	7.37	0	0	2	1	7.64	0	0	3	1
41	9.46	0	0	1	1	14.44	0	0	0	0
42	0.56	4	1	53	1	0.73	1	1	53	1
43	1.74	0	0	45	1	3.00	0	0	41	1
44	12.71	0	0	0	0	10.70	0	0	0	0
45	6.29	0	0	15	1	4.24	0	0	24	1
46	7.37	0	0	2	1	9.18	0	0	1	1
47	0.68	1	1	52	1	0.32	4	1	53	1
48	3.65	0	0	27	1	4.03	0	0	22	1
49	9.46	0	0	1	1	3.50	0	0	10	1
50	20.98	0	0	0	0	18.52	0	0	0	0
51	2.22	0	0	6	1	6.37	0	0	2	1
52	7.60	0	0	2	1	8.32	0	0	2	1
53	15.17	0	0	0	0	17.61	0	0	0	0
54	12.48	0	0	0	0	17.69	0	0	0	0
55	3.72	0	0	25	1	3.50	0	0	24	1
56	12.71	0	0	0	0	10.42	0	0	0	0
57	5.33	0	0	2	1	6.33	0	0	3	1
58	12.71	0	0	0	0	4.00	0	0	1	1
59	20.98	0	0	0	0	14.24	0	0	0	0

APPENDIX E (continued)

ID	Address centroid to opportunities					Address to opportunities				
	Minimum distance (miles)	Density (1 mile radius)	Dichotomous (1 mile radius)	Density (10 miles radius)	Dichotomous (10 miles radius)	Minimum distance (miles)	Density (1 mile radius)	Dichotomous (1 mile radius)	Density (10 miles radius)	Dichotomous (10 miles radius)
60	7.37	0	0	2	1	6.77	0	0	5	1
61	9.46	0	0	1	1	4.65	0	0	12	1
62	15.17	0	0	0	0	9.81	0	0	1	1
63	15.17	0	0	0	0	19.95	0	0	0	0
64	12.71	0	0	0	0	14.71	0	0	0	0
65	3.89	0	0	14	1	4.55	0	0	22	1
66	9.46	0	0	1	1	9.23	0	0	1	1
67	9.46	0	0	1	1	7.39	0	0	2	1
68	3.72	0	0	25	1	3.50	0	0	24	1
69	5.33	0	0	2	1	7.35	0	0	2	1
70	2.73	0	0	37	1	1.65	0	0	48	1
71	20.98	0	0	0	0	22.10	0	0	0	0
72	5.84	0	0	10	1	8.14	0	0	3	1
73	6.29	0	0	20	1	4.00	0	0	31	1
74	2.22	0	0	6	1	4.21	0	0	4	1
75	2.22	0	0	6	1	2.30	0	0	15	1
76	15.17	0	0	0	0	12.48	0	0	0	0
77	5.69	0	0	15	1	4.92	0	0	18	1
78	12.71	0	0	0	0	18.20	0	0	0	0
79	1.77	0	0	34	1	3.46	0	0	18	1
80	9.46	0	0	1	1	8.25	0	0	6	1
81	2.53	0	0	33	1	2.04	0	0	33	1
82	6.29	0	0	15	1	5.88	0	0	17	1
83	7.37	0	0	2	1	12.54	0	0	0	0
84	9.46	0	0	1	1	16.64	0	0	0	0
85	9.46	0	0	1	1	12.10	0	0	0	0
86	12.48	0	0	0	0	12.56	0	0	0	0
87	6.29	0	0	15	1	3.83	0	0	6	1
88	5.69	0	0	15	1	4.45	0	0	22	1
89	12.01	0	0	0	0	11.57	0	0	0	0
90	9.46	0	0	1	1	14.97	0	0	0	0

APPENDIX E (continued)

<i>ID</i>	<i>Address centroid to opportunities</i>					<i>Address to opportunities</i>				
	<i>Minimum distance (miles)</i>	<i>Density (1 mile radius)</i>	<i>Dichotomous (1 mile radius)</i>	<i>Density (10 miles radius)</i>	<i>Dichotomous (10 miles radius)</i>	<i>Minimum distance (miles)</i>	<i>Density (1 mile radius)</i>	<i>Dichotomous (1 mile radius)</i>	<i>Density (10 miles radius)</i>	<i>Dichotomous (10 miles radius)</i>
91	15.17	0	0	0	0	18.78	0	0	0	0
92	20.98	0	0	0	0	22.35	0	0	0	0
93	20.98	0	0	0	0	21.17	0	0	0	0
94	20.98	0	0	0	0	18.64	0	0	0	0
95	15.17	0	0	0	0	17.47	0	0	0	0
96	20.98	0	0	0	0	23.36	0	0	0	0
97	15.17	0	0	0	0	16.25	0	0	0	0
98	20.98	0	0	0	0	19.78	0	0	0	0
99	20.98	0	0	0	0	24.95	0	0	0	0
100	20.98	0	0	0	0	22.44	0	0	0	0

APPENDIX F

LIFE-CONSTRAINED ACCESSIBILITY DISTANCES FOR HYPOTHETICAL INDIVIDUALS

<i>ID</i>	<i>Accumulated distance (miles)</i>	<i>Number of trips</i>	<i>Distance per trip (miles)</i>
1	35.43	10	3.54
2	67.75	5	13.55
3	21.27	3	7.09
4	28.07	9	3.12
5	52.78	5	10.56
6	62.03	15	4.14
7	23.94	3	7.98
8	34.47	8	4.31
9	35.89	5	7.18
10	57.12	5	11.42
11	68.61	15	4.57
12	34.09	5	6.82
13	9.24	3	3.08
14	159.14	9	17.68
15	49.78	8	6.22
16	50.79	5	10.16
17	17.42	6	2.90
18	42	5	8.40
19	1.56	4	0.39
20	15.62	3	5.21
21	29.5	7	4.21
22	Infeasible	Infeasible	Infeasible
23	43.53	7	6.22
24	32.26	14	2.30
25	83.89	8	10.49
26	2.55	4	0.64
27	151.18	14	10.80
28	32.51	10	3.25
29	45.77	6	7.63
30	26.79	3	8.93
31	14.58	6	2.43

APPENDIX F (continued)

<i>ID</i>	<i>Accumulated distance (miles)</i>	<i>Number of trips</i>	<i>Distance per trip (miles)</i>
32	65.88	8	8.24
33	93.08	12	7.76
34	23.6	3	7.87
35	24.57	7	3.51
36	21.42	3	7.14
37	5.86	3	1.95
38	101.54	16	6.35
39	34.6	10	3.46
40	102.86	8	12.86
41	Infeasible	Infeasible	Infeasible
42	11.53	5	2.31
43	34.23	8	4.28
44	14.28	3	4.76
45	29.71	9	3.30
46	119.65	10	11.97
47	40.57	14	2.90
48	18.16	3	6.05
49	91.34	14	6.52
50	82.01	5	16.40
51	Infeasible	Infeasible	Infeasible
52	20.02	3	6.67
53	68.24	5	13.65
54	33.2	5	6.64
55	14.31	3	4.77
56	56.8	5	11.36
57	127.85	12	10.65
58	90.03	8	11.25
59	47.48	12	3.96
60	54.5	5	10.90
61	16.08	3	5.36
62	39.45	8	4.93
63	25.52	3	8.51
64	124.04	7	17.72

APPENDIX F (continued)

<i>ID</i>	<i>Accumulated distance (miles)</i>	<i>Number of trips</i>	<i>Distance per trip (miles)</i>
65	60.04	9	6.67
66	36.8	3	12.27
67	6.51	4	1.63
68	30.82	10	3.08
69	14.98	3	4.99
70	8.88	3	2.96
71	91.73	10	9.17
72	169.98	14	12.14
73	20.07	7	2.87
74	51.13	5	10.23
75	91.62	14	6.54
76	10.89	3	3.63
77	Infeasible	Infeasible	Infeasible
78	73.04	8	9.13
79	23.16	3	7.72
80	66.02	7	9.43
81	16.9	5	3.38
82	147.95	13	11.38
83	24.06	6	4.01
84	110.86	7	15.84
85	Infeasible	Infeasible	Infeasible
86	65.12	5	13.02
87	25.13	3	8.38
88	30.43	5	6.09
89	31.89	5	6.38
90	48.71	3	16.24
91	109.03	9	12.11
92	48.12	10	4.81
93	67.55	15	4.50
94	87.9	5	17.58
95	187.21	15	12.48
96	71.8	15	4.79
97	148.79	9	16.53

APPENDIX F (continued)

<i>ID</i>	<i>Accumulated distance (miles)</i>	<i>Number of trips</i>	<i>Distance per trip (miles)</i>
98	66.24	3	22.08
99	42.12	5	8.42
100	49.72	3	16.57