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EXPLORING THE POTENTIAL FOR GEOGRAPHIC TRANSPORTATION MODELING TO IMPROVE FOOD ASSISTANCE: A CASE STUDY OF THE MISSOULA FOOD BANK

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By

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Exploring the Potential for Geographic Transportation Modeling to Improve Food Assistance: A Case Study of the Missoula Food Bank

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Abstract:

Over the last ten years, the Missoula Food Bank has seen a greater need for its services leading to funding shortfalls. To meet the needs of an increasing number of clients with a limited budget, the Missoula Food Bank must look for ways to modify its operations while increasing efficiency of its services. As the Food Bank budget is used to acquire food and currently also transport it from warehouse locations to the food pantry in a crowded space, reducing distances and transport cost of hauling food would in turn free up funds to obtain more food. At the same time, the Food Bank needs to operate from a central location that can be readily accessed by its clients. The primary objective of this thesis is to explore whether the current or an alternative location would be better for operating the food bank in order to provide the greatest level of access to food bank clients. To accomplish this, GIS-based facility location modeling is employed using the p-median approach and incorporating a variety of scenarios. Geographically, scenarios include the entire county as well as a smaller area centered on the Missoula urban area. Socio-demographically, location models are run without taking populations into account (unweighted), by using population weight, and by weighting for poor and very poor households. Separate sets of models include and exclude the current food bank location as a candidate site. Whether for the entire Missoula county or the smaller urban areas, whether with or without socio-demographic weights, the facility location models identify the same sites as most accessible based on minimal average costs of access to clients. The findings of this thesis help to inform the discussion about ways to improve services designed to eradicate community food insecurity, and contribute to broadening the use of GIS to advance the efficiency of social services.

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CHAPTER I: INTRODUCTION

In the State of Montana as well as throughout the United States, food insecurity has been on the rise (Burhop and Bradford Devino, 2013) and has reached historic highs (Resnikoff, 2014). The United States Department of Agriculture defines food insecurity as, "a household-level economic and social condition of limited or uncertain access to adequate food" (Coleman-Jensen, Gregory, and Rabbitt, 2015, page 1). Food insecurity is also a significant problem in Missoula, where the Missoula Food Bank struggles with a growing demand for its services while also facing increasing overhead costs. Alongside needing more food supplies to assist a growing clientele, the Missoula Food Bank, located near the center of town at 219 South Third Street, is also in need of more space as it is oftentimes overcrowded as families wait for pantry services. Food bank volunteers describe the facility as "bursting at the seams," requiring them to spend some of their time making this crowded space an effective working environment. Furthermore, the current location for the food pantry is too small to stock the large quantities of food acquired—mostly purchased pallets of bulk commodities—therefore creating the need for an additional warehouse space. This space is located several miles from the pantry, requiring added monthly rental costs, and multiple daily trips between each location in order to maintain inventory of food pantry goods. In fact, because of space constraints, the Missoula Food Bank is currently operating from four different buildings: the store on Third Street, a leased administrative building next door, and two off-site warehouses located at the Wye area for food storage. The cost of renting space and transporting foods from warehouse to pantry adds to the overhead costs for the Missoula Food Bank requiring funds that could be used to acquire more foods for the growing number of clients.

As a consequence of increasing demands and in light of the overhead costs for renting space and transporting foods, the Missoula Food Bank has been re-examining its current location for some time. Relocation is seen as an opportunity to better serve the needs of their clientele. It has been suggested that the facility move from its current, centrally located but small facility, to a larger and possibly more removed location. This move would cut costs for the organization and could perhaps better serve populations living on the fringe of Missoula's downtown region. These circumstances provide good rationale for seeking a more suitable location that could function as both storage warehouse and pantry.

This research was sparked through discussion about the actual ongoing relocation initiative in which the Missoula Food Bank is currently involved. While serving as a volunteer for the Missoula Food Bank, I personally experienced the organization's need for a larger and more appropriate space from which to serve their clients.

While the Missoula Food Bank is looking to address space constraints and reduce operating costs, this social service institution must also assess the needs of citizens and meet them to the highest ability. Identifying areas and populations that are in need of emergency food services and providing those resources to people in need is a complex task that must take into account both socio-economic and geographic factors.

The spatial element in addressing both household and community food insecurity cannot be ignored. Geographic perspective by nature is universal and is at the very foundation of social and cultural issues. Therefore, introducing a spatial context to efforts focused on food security is not additional, but imperative. Communities in which individuals take care of each other and provide for themselves as a whole are becoming the model for the recent trend in prioritizing local sustainability. Laying a foundation of spatial connection between people and food, from which to build all other social efforts, is an obvious means to improved understanding of how all people can acquire necessary commodities, and ultimately work toward enhanced community sustainability.

For my thesis, I set out to draw on the knowledge base and the analytical capabilities and skill sets used in the discipline of Geography to make a contribution to addressing the Food Bank's location problem. The purpose of this thesis is to employ the capabilities of a transportation-based Geographic Information System (GIS-T) as a mechanism by which to improve the location of food assistance to meet clients' needs for access.

Significance

Transportation modeling and facility location analysis—tools used by geographers, large for-profit companies, and some public service planners—may be useful in finding ways to lower costs and strengthen food emergency services by taking into account clients' access to service locations. This thesis seeks to utilize such modeling to answer the question of where the best fit for a social service location is, in this case the Missoula Food Bank. A different location and more spacious facilities could certainly save funds now used for transporting foods from warehouses to the pantry and free up resources to boost food supplies. Additionally, and that is considered in this study, it could also offer equal or better access to the food banks clientele. The current location and other 'candidate sites' are being considered in this project in order to explore whether or not geographic access to this particular support service can be improved.

This work makes a case for using spatial analysis to create a more cost efficient service model. In this research, GIS-T is used to identify a location for the Food Bank that is the most accessible to clients who travel by foot, bike and car to reach the food bank. Additionally, this analysis can assist the organization in gaining insight on the location of potential clientele, as obtained from public income data. Importantly, it will provide a geographic tool for the evaluation and implementation of food allocation programs. As an added benefit, this information can also be used to enhance or even shape future policy efforts to address community food insecurity by evaluating where the greatest needs may be.

There are two elements to this study: 1) Using transportation GIS modeling to evaluate the overall access to both the current food bank location and alternative locations for a food bank relocation. And 2) Using generally available socio-demographic data to weight these analyses using income criteria to provide best access to this service, specifically access for lower income populations. Utilizing GIS-T as an analytical tool to make informed decisions has the goal of improving access to social services at a time when the need for government assistance is here to stay.

This thesis is divided into five chapters. Following this introductory chapter, the second chapter provides a review of relevant literature and offers the conceptual background for this research. The aim of the chapter is to establish the conceptual context on which this research is built, and the concepts of food security and insecurity, spatial inequity, and access are explained. Chapter three introduces the research methodology, including the Missoula as the study area, a comprehensive report on the procedure used and how the geographic and socio-demographic data were obtained, compiled and analyzed. Chapter four shows those analysis results and provides results from additional modeling. Chapter five provides an overview of the thesis, including limitations, and the contribution of this study.

CHAPTER II: CONCEPTUAL FRAMEWORK

At the core of this study stands access to social services, namely food assistance. Issues of food insecurity, equal access to food, and distance to food assistance are relevant for understanding the importance of food assistance access and concern for improving access to food assistance. The purpose of this chapter is to review the scientific and scholarly literature in geography and allied disciplines on food insecurity and on distance, transportation and access to food, which provides the theoretical context for this thesis.

Measuring Food Security and Insecurity

There is a tremendous amount of literature addressing food security in the discipline of geography and allied fields. Food security as defined by the World Health Organization during the World Food Summit of 1996 exists "when all people at all times have enough food for an active and productive healthy life, which is necessary for all people to be healthy and well nourished" (World Health Organization, 1996). In 2008, the United States Department of Agriculture used survey data collected from the Current Population Survey (CPS), which included national and state level statistics on food security. Data from 44,000 households were examined to obtain a descriptive picture of state and national levels of food security and insecurity. These statistics were collected from questions asking about the difficulty of meeting basic food needs (U.S. Department of Agriculture. Economic Research Service, 2008), and they show that a total of 14.6% or 17 million households were food insecure. In addition, the study revealed that 42.2% of households residing near or below the federal poverty line had substantially higher incidence of food insecurity. It was emphasized that households with children living in them, and headed by single mothers or fathers, had the highest prevalence of food insecurity. It also revealed that the majority of the food insecurity was seen in rural areas and in large urban areas (Andrews, Carlson, Nord, and Coleman-Jensen, 2010). This report concluded that a devastating number of Americans are food insecure. Much of this food insecurity comes down to a basic notion that equality is fundamentally about people having equal access to resources that promote and facilitate human functioning; food being a main contributor (Laraque-Manty, 2001). With my thesis research, I aim to address this issue by looking for a more financially efficient delivery of resources to those experiencing food insecurity.

One contributing aspect of food insecurity is limited access to nutritional food in many parts of this country, leaving families little or no choice about where their food comes from or the types of food they purchase. In fact, much research has been done to locate food deserts, which are defined as areas in which local residents have limited access to affordable food (Furey, Farley, and Strugnell, 2002). Food deserts often occur when a population is too small to support a supermarket. Morton and Blanchard (2007) approached this definition spatially in saying that food deserts are areas in which all residents have low access to large food retailers, specifically, each person in a food desert lives more than ten miles away from a supermarket. This distance is particularly critical in that poorer populations often have fewer choices for transportation and therefore less mobility to access such retailers. With this in mind, it is possible to measure populations living in food deserts simply by locating food retailers and determining how many people live beyond a certain distance of them.

Blanchard and Lyson (2005) take a more demographic approach to defining food deserts as urban centers with relatively low incomes, high rates of food insecurity and chronic diseases, and poor access to healthy foods. These communities are often characterized by having few full service grocery stores but relatively high concentrations of fast food and convenience stores.

However, research suggests that even affluent exurban and suburban communities have unique problems in accessing healthy food and coping with food insecurity, which have been largely ignored by public health research (Donkin, Dowler, Stevenson, and Turner, 1999). Only recently have researchers begun developing methods using geographic information systems (GIS) for identifying *rural* food deserts. In 2005 Wrigley coined the phrase ‘unsupportive local food environments’ and this provided a more inclusive term that could be used to describe any area, encompassing both rural and urban environments. McEntee and Agyeman (2010) used this concept to support their development of a method for identifying rural food deserts in Vermont. They did so by calculating a mean distance to food retailer for census tracts. One of the key purposes of their study was to refine food desert research by developing a method that could be applied to any rural locations. In essence these same approaches could be used to evaluate access to free food services, such as food assistance offices or food pantries. Jim Herries, a product engineer for the Environmental Systems Research Institute (ESRI) stresses the importance of the contribution made by GIS in discussions about how people access food, recreation, and other human needs (Herries, 2011). He goes on to emphasize how useful it would be to draw a map of where people are and the types of food available around them. In fact there are multiple social service organizations around the country that provide free food assistance aiming to do just that.

Community Food Security

Community food security is a relatively new concept that attempts to address the localized issue of hunger and its causes. It stems from a variety of disciplines, including socio-political, socio-economic, socio-environmental and socio-cultural environments. A widely accepted definition of community food security is: “A situation in which all community residents obtain a safe, culturally acceptable, nutritionally adequate diet through a sustainable food system that maximizes self-reliance and social justice" (Hamm and Bellows, 2003, page 37). Hunger on any level, whether it is discussed by national or state standards, could be understood as a community inequality. If resources such as food are systematically accessible to some and not others, then it is likely a disparity that stems from community inequalities, and efforts to reduce this could be addressed within that population. Baker and Friel (2009) note that the unequal distribution of resources is a fundamental flaw within our deeper social structures and processes. Over time, there has been an apparent shift from national policy to statewide, and even civic policy, in regards to the management of these types of social issues.

Rather than focusing on an individual's food security, the community-based perspective focuses on civic-wide prevention and management of food attainment, not short-term intervention (Gottlieb and Fisher, 2006). In a community food assessment, carried out in the mid-nineties by economists and food environmentalists Robert Gottlieb and Andrew Fisher it was noted that community food security is a framework that can bring together local economies, food production, food accessibility and community development. The emphasis is placed on the fundamental social and economic frameworks that can affect the quality and affordability of food in a community. Community food security encompasses a variety of concepts, including, but not limited to income, transportation, food prices, nutritious and culturally appropriate food choices; and existence of and access to adequate, local, non-emergency food sources (Gottlieb and Fisher, 2006). This community-based prevention framework is one that aims to identify food resources that accommodate both community and individuals in a sustainable way. Therefore, a solution to *in*security can be achieved by understanding the complex relationships among communities, resources, and social and physical environments. Understanding the relationships involves the assessment of issues affecting food availability, affordability, accessibility, and quality (Castello, Desjardins, Kraak, Ladipo, and McCullum, 2005).

Measuring community food insecurity is not as simple as identifying food deserts as poor access to grocery stores. There are communities where individuals have sufficient geographic access to nutritional food and yet there are still significant portions of their populations who cannot afford to purchase food and must rely on food assistance due to low income and high rates of poverty (Maxwell and Smith, 1992). It is therefore crucial to also understand how individuals who do rely on food assistance programs obtain their food. GIS can be an instrumental tool in doing so, and ultimately provide knowledge on how to improve access to these food assistance programs. There is a methodological gap in the literature regarding improved access to food assistance programs, and ultimately in decreasing distance between food resources and the food-insecure. However, geospatial technologies have been helpful in finding ways to decrease distance barriers: there are, for instance, some organizations beginning to explore online mapping databases that provide links between food retailers (including restaurants, school cafeterias, and universities) and non-profits in need of food in order to connect these resources for 'recycled' food programs.

As stated above, food access research has been primarily consumer-based, measuring access to stores. As an example of capturing access to stores Algert, Agrawal, and Lewis (2006) were able to measure access to food retailers from individual addresses, producing analysis of how far each food store client lives from the nearest food retailer. What appears to be missing from abundant food desert—and food access—research is a spatial understanding of the solutions to such deficits. In 2008, 49 million Americans were reported to use food assistance programs, including 17 million children. As a result, food banks across the country are constantly being challenged to improve overall operation and access to their services. At the same time, there is little work on access to food assistance facilities. An integral part of access studies and geospatial innovation is not only to grasp where the people in need are, but also to recognize where the available food resources are in relation to the population.

Spatial Equity

Many studies of spatial equity revolve around the evaluation of geographic access (Talen and Anselin, 1998). However, there is also a social dimension of geographic access, as social groups with limited resources have fewer means to travel to gain resources. Wekerle (1985) highlighted the critical need for discussion of how ‘locally oriented populations’ – residents who rely on modes of transport other than automobiles (e.g. the elderly, the disabled and the poor) access services because distance is not elastic, or changeable. Most research has measured food access through attributes of locations or individuals. An example of this is research using individuals’ consumption of a certain type of food, indicating that they are obtaining nutritious food, and therefore have greater access to healthful foods. From a mapping perspective, this type of research uses point data that contains attribute data, such as daily consumption of a certain type of food—typically fruits and vegetables, and grain calories—while placing a distance buffer around food retailers to determine its service zone (McEntee and Agyeman, 2010). The advantages of food assistance programs obtaining spatial information could be similarly practical: connecting food and people, but from a needs-based perspective rather than from a market-based perspective. Such information could be used, for instance, to reduce food miles for non-profit agencies when supplementing donated resources for food pantries. Reducing food miles would, consequently, reduce spending as well as be supportive of local food producers or manufacturers.

Access to social services has been studied on another level, using GIS to link low-income families to government assistance for which they may be eligible. Led by epidemiologists Stopka, Gradziel, and Krawczyk (2011) researchers at the California Department of Public Health have created a GIS program that identifies geographic locations of people who are entitled for but not receiving WIC services (Women, Infants and Children). WIC funds can be used at grocery outlets, farmers markets and oftentimes at schools to ensure that children and low-income mothers get the food they need. Most commonly, as shown by a number of investigators including Handy and Niemeier (1997), Kwan (1999), and Hewko, Smoyer-Tomic, and Hodgson (2002), indicators of socioeconomic status are mapped relative to access (high or low) as a way of determining possible indicators of unbalanced, or biased, distribution. One of the earliest studies that mapped accessibility patterns was done by Knox (1978), and was used to assess the equity of resource distribution. Using gravity-based measurements of proximity to medical services in urban settings, Knox demonstrated that they could be used as indicators of social well being in cities. The map he produced showed the relative levels of access to a specific urban service, medical care in this case.

There is a trend in recent social service research examining the shift from cash assistance to support services (Allard, 2007). It has been reported that currently over one-half of all Temporary Assistance for Needy Families (TANF) dollars go the provision of support services, in contrast to the TANF system that was replaced in 1996 where over 80 percent of all welfare dollars went to cash assistance (Allard, 2007). Such findings suggest that there is currently a greater need for identifying and improving access to social support services and identifying where those services are located in relation to where the population served resides. A service-based system places greater importance on making sure eligible individuals have access to the social support they need. Due to over half a century of suburbanization in America, the gap between the location of support services and clients who use those services may have been widening, as central urban populations have moved to suburban areas. Considering these shifts, and the need to identify deficiencies in access to social services, it is crucial that greater attention be paid to the location of support services, based on the current distribution of the population.

Location Analysis and Access to Services

For understanding access to social services such as emergency food assistance programs, concepts and methods are needed to identify service areas as well as potential service gaps. The economist and poverty specialist Scott Allard (2004, page 2) notes that, "Struggling to make programmatic choices amidst budget deficits and declining federal support for social services, state and local policy-makers should consider the spatial distribution of social service providers when setting program funding levels or deciding which programs to eliminate altogether." Incorporating a spatial dimension to establishing such services could oftentimes reduce disparities in access to social services and goods. Improved technology and greater affordability of mapping software and smart devices provides the opportunity for better understanding of geographical language and relationships, therefore strengthening economic processes.

Location theory and location analysis focus on the impacts of location and distance on people's lives, and therefore has relevance for this thesis. How people acquire goods and services is commonly centered on where they live and how far they need to travel to a service facility. Christaller (1972) proposed the concept of *central places* as a core concept in urban geography to explain the distribution patterns and urban hierarchy of cities and towns. Central Place Theory is also useful for understanding the arrangement of retail and service facilities as distribution centers within an urban area. Service facilities function as *central places* that provide goods and services to the populations in surrounding areas or *hinterlands*. Service facilities and their clients are in a relationship of interdependence. Christaller suggested there is a maximum distance or *range* over which people will travel to obtain goods or services (Christaller, 1972). He further proposed that the *range* varies by type of good. Frequently needed, or *low-order* goods, such a basic groceries have a short range. While infrequently needed, or *high-order* goods, such as specialized medical care have a long range. Given the context of this thesis, people in need of food assistance, presumably a *low-order* service, should find a service facility, or food bank, within a relatively low range or short distance. Food banks should therefore be located within easy reach of the population in need. The decision for locating or relocating a food bank calls for a deliberate and systematic process that pays attention to the access needs of clients. As food bank clients typically have lower incomes and often limited transportation options they may ill-afford high transportation costs for obtaining food. A highly accessible, central location is therefore crucial when placing or relocating a food bank.

Highly relevant and useful for this process are facility location models (Drezner, Drezner, and Said, 2002). Facility location modeling, which is at the nexus of operations research and economic geography, are used to identifying the most suitable (*optimal*) locations or sites for establishing businesses or services, based on the location of clients. Solving location problems typically involve determining the best location for one or more facilities from a set of possible locations (*candidates*). Facility location modeling is useful for both private and public private sectors, and can be of great value in locating critical public services such as hospitals, emergency shelters, public transportation transfer stations, healthcare clinics, public libraries, police stations, and the like (Eiselt and Marianov, 2015). For many applications, the goal is to minimize the average distance or transport cost between the facility and its clients. This is referred to as the *p-median problem*. Alternatively, facility locations may be sought to minimize the highest cost of service, or the *p-centers or Minimax problem*, often used for emergency services (Drezner et al., 2002). There are several other applications for location models including those for siting 'noxious' or undesirable facilities, such as landfills, or nuclear power plants. For undesirable facilities, the goal is to maximize the distance between a facility and the population (*Maximin problem*) (Suzuki and Drezner, 1996). The p-median problem is widely used as a facility location model, and also the model used here. It has the goal of identifying the location that minimizes the average distance or transportation cost for clients to access a facility.

The relationship between a facility and the clients it serves involves understanding a measure known as *cost of service*, a key concept and criterion in the location decision (Daskin, Snyder, and Berger, 2003). In business applications used in the private, for-profit sector, *cost of service* may include fixed costs, such as overhead cost for operating a facility, and variable cost which vary with the volume of goods or services produced. *Cost of service* importantly includes a measure of transportation and access: either the cost of delivering goods or services from the facility to the clients, or the cost for the clients to access goods or services at the facility. For public service or non-profit application, the *cost of service* is first and foremost the cost of accessing a facility by the clients it serves. The *cost of service* concept becomes essentially a concept and measure of access.

This access measure may be based on distance between clients and facility, on travel time, or on the monetary cost of travel. It may further be derived without or with using *weights* associated with the clients. When using cost of service without weights, distance, travel time or monetary costs of travel between facility and client locations are the main inputs. Scenarios with *weights* consider either the number of clients, such as entire population, or clients by type, such as populations or households with certain characteristic, for instance income or age.

The specifics of implementing the facility location model used in this study are discussed in greater detail in the following methodology chapter.

CHAPTER III: METHODOLOGY

This chapter will introduce the research site and will provide a background for the issue regarding food insecurity and emergency food assistance within the community. It will then provide a description of the research methods for conducting the facility location modeling.

Research Site

This study centers on Missoula, Montana, a community of roughly 70,000 people. The town was founded in 1860 as trading post still part of Washington Territory. The arrival of the Northern Pacific Railway in 1883 brought rapid growth and the development of the local lumber industry. In 1893 the Montana Legislature chose Missoula as the site for the state's first university. Lumber and the university would remain the primary sources for the local economy for the next hundred years. By the 1990's, Missoula's lumber industry had slowly disappeared and the city's largest employers were the University of Montana, Missoula County Public Schools and two hospitals in Missoula. Over the years it had become primarily a service economy that also garnered significant influence from tourism with two national parks nearby and a reputation for summer recreation, outdoor activities, and cultural events.

Missoula has a poverty rate of 16.7% with a per capita income just over $25,548 (U.S. Census Bureau, 2014), which is higher than the poverty rate of Montana of 14.8% (Burhop and Bradford Devino, 2013). In Missoula as elsewhere, many poor households are food insecure and need to turn to food banks for assistance. In the year 2014, Missoula Food Bank provided more than 98,000 food services to Missoula residents who might otherwise have gone hungry; this is an increase of 9.8 percent over food services provided in 2013 (Hutton and Brock, The

Missoulian Daily Newspaper, 2015). According to Aaron Brock, the Executive Director of the Missoula Food Bank, "In 2005 we were providing 35,000 services each year, nearly one-third of today's need" (Hutton and Brock, 2015, page 1).

The current Montana Food Bank system relies on a Missoula-based distribution center and a network of 125 local food pantries to get food into the hands of the food insecure. As the hub, the Montana Food Bank Network distributes thousands of pounds of food across the state at a significant transportation cost. The Missoula Food Bank, being just one of the local food pantries receiving food supplies, has an annual budget of $130,000. Food supplies purchased by the Food Bank are intermittently supplemented by food donations.

To make foods available to clients in need of food assistance, the Food Bank not only needs foods available for distribution but the clients also need to be able to reach the Food Bank. In other words, the Food Bank needs to operate from an accessible location. Identifying the most accessible location, with or without relocation is at the core of this work.

TransCad Modeling: An Overview

The approach taken in this study is quantitative in nature. I am using established GIS software, namely TransCad, to comprehend the geospatial relationships between a service site and its users. Specifically, this project will utilize these relationships in order to solve a location problem regarding access to food emergency services.

TransCad is a unique modeling platform that integrates geographic systems with modeling capabilities focusing on streets and transportation. Geographic data, including distances, street network size and shape, and highway/road features are necessary for accurate transportation modeling. The measurements contained in the geographic data are derived directly from GIS instruments and provide the model with information that enables efficient and reliable planning decisions. The streets layer is connected to demographic and socio-economic data so that the spatial analyses can consider the spatial distribution of the population and their characteristics. The street layer is also connected to potential facility locations. A cost matrix defining the lowest travel burden (in distance) to all possible Food Bank locations is built and this matrix is used for the location modeling. The next step of analysis is to use facility location modeling, a robust tool housed within TransCad mapping and analysis software, to identify where facilities should be located to ensure an optimal level of access based on travel distance. The method used here is to minimize the average cost of travel from clients to a service center (p-median problem).

The model is used to perform a series of analyses with some using the entire Missoula County and others using a smaller urban area centered on the City of Missoula. Different model runs also allow taking into account socio-demographic attributes, namely variables related to poverty. To make for realistic results, this project utilizes current Missoula County streets data, which are identical to those used by Missoula transportation planners. It also uses spatially detailed population data from the U.S. Bureau of the Census, described in the next section.

This application demonstrates how TransCad modeling can be incorporated into establishing social service location decisions that provide the greatest level of access to as many people as possible. It has the capabilities to be a tool used by organizations, such as the Missoula Food Bank, to improve aspects of their operation and enhance access of their services to their clients.

Working with Geographic Data

The population data chosen for this study are the 2010 American Community Survey (ACS) bock group data and the 2010 United States Census block data. These datasets, which were the most current at the time the analyses were conducted, were joined using tools in the GIS software in order to compile the most comprehensive data consisting of both geographic location and their socio-economic descriptors.

In the map of Missoula County (Figure 1), each census block, the smallest geographic unit used by the U.S. Census Bureau, is depicted as a black dot, showing a greater clustering of the population in the center of the county, which is the Missoula urban area. The map also shows the network of streets and highways of Missoula County.

Population data for blocks are used for analysis, based on counts from the 2010 Census of Population and Housing, which are then supplemented with survey data from a sampling of households. In cities, a census block typically corresponds to a city block whereas in rural areas where fewer roads exist blocks may be limited by other features, such as creeks or larger highways. The number of residents per block averages around 40, but varies significantly, depending on the type of housing within that block (multi-family housing versus low-density single family housing). The map in Figure 2 shows the borders of each block highlighted in green, with the centroid of each block shown as a black dot.

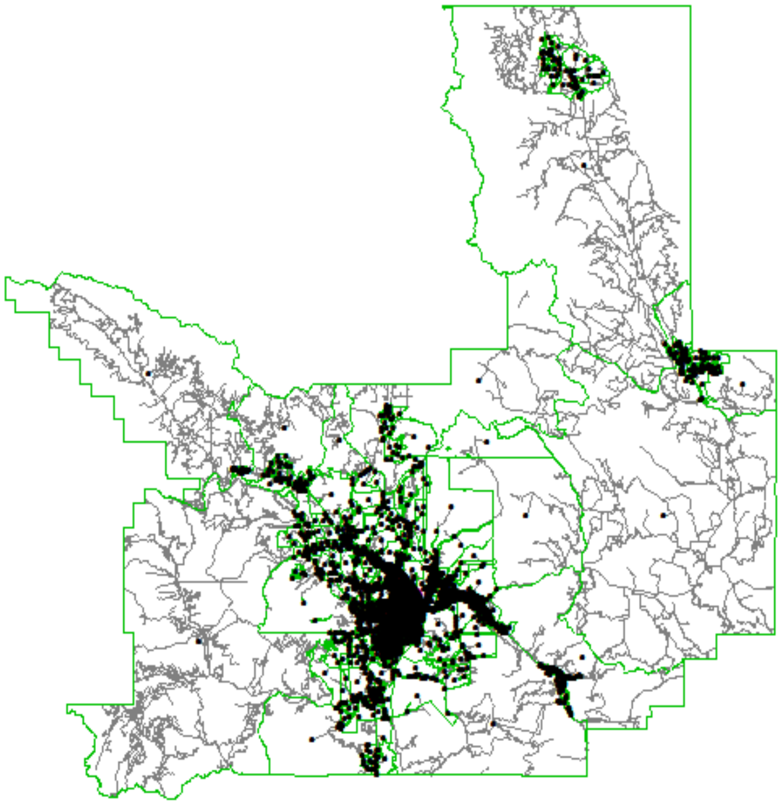


Figure 1. Missoula County with census blocks and highways. Source: American Community Survey.

Census blocks are grouped into block groups and then into census tracts. A block group is a grouping of blocks, on average consisting of 39 blocks with 1500 residents. However, population figures may range from 600 to roughly 3,000 per block group. There are 842 block groups within Missoula County and 3,495 blocks. All blocks were considered for the first of several sets of the location modeling for the entire county.

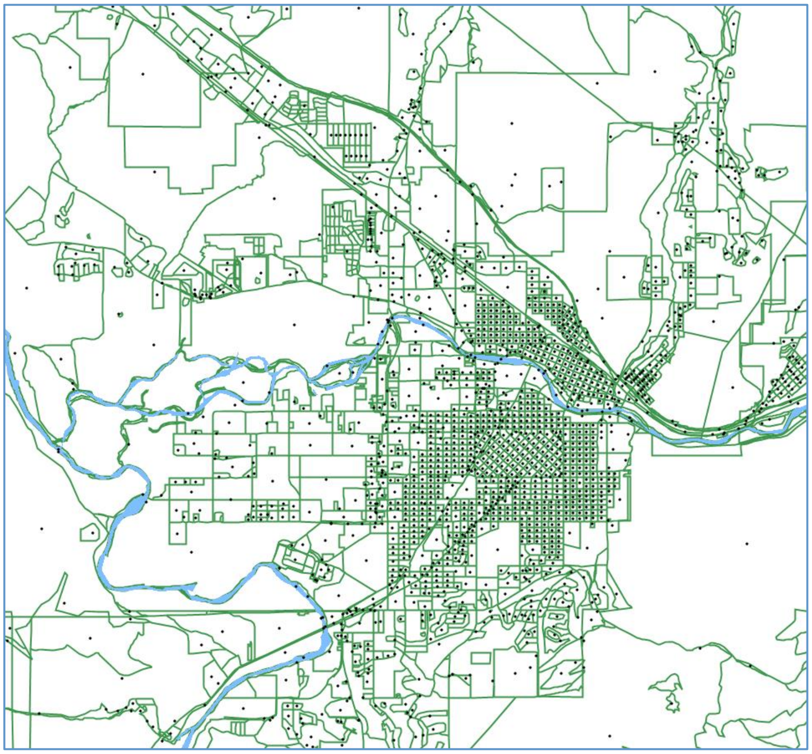


Figure 2. Missoula blocks, defined by green borders. Centroids shown by black dots. Source: American Community Survey.

Each block and block group have a unique identifier or code based on the FIPS (Federal Information Processing Standard). For each block, the code is established by concatenating or "adding" state, county, census tract, block group and block numbers together in order to get a complete geographic identifier. For example, the code for Montana is '30' and the county code for Missoula is '063'; and one particular census tract located in the University District neighborhood within Missoula County is designated with the number '0005.00', with a block group having a unique identifier as well, say number '1'. Combining these identifiers together for that specific block group, results in a 12-digit numeric code of '300630005001'. Each block has a unique 15-digit numeric code, providing greater detail to its specific geographic location and description. This system of unique codes has been established in order to "ensure that all federal government and agencies adhere to the same guidelines regarding security and communication" (U.S. Census Bureau, 2009). It is critical to understand the importance of such geographic links because it helps maintain the integrity of the model as it is manipulated or analyzed. The system is of crucial importance when joining socio-demographic data to geospatial data.

While blocks offered the greatest geographic detail, more detailed attribute data are available for block groups and their aggregates. The most relevant attributes for this analysis are income and poverty data from the American Community Survey.

Across Missoula, incomes are fairly heterogeneous between the different neighborhoods. This is caused by a variety of factors. One influence is the presence of a university within the city, allowing for college students, who typically have low incomes, to live scattered throughout the city, mostly in rentals and shared living situations. Another influence on the mixed income population is the level of employment diversity in Missoula. The employment diversity includes but is not limited to service industry positions, such as health and social services, retail trade, college employment, teaching and education services, legal and financial services, recreation and tourism as well as construction and some manufacturing (U.S. Bureau of Economic Analysis, 2006). Having such an assortment of mixed income throughout a small urban region provides, as seen in Figure 3, for a blended area of incomes that results in a fairly heterogeneous distribution across all Missoula neighborhoods.

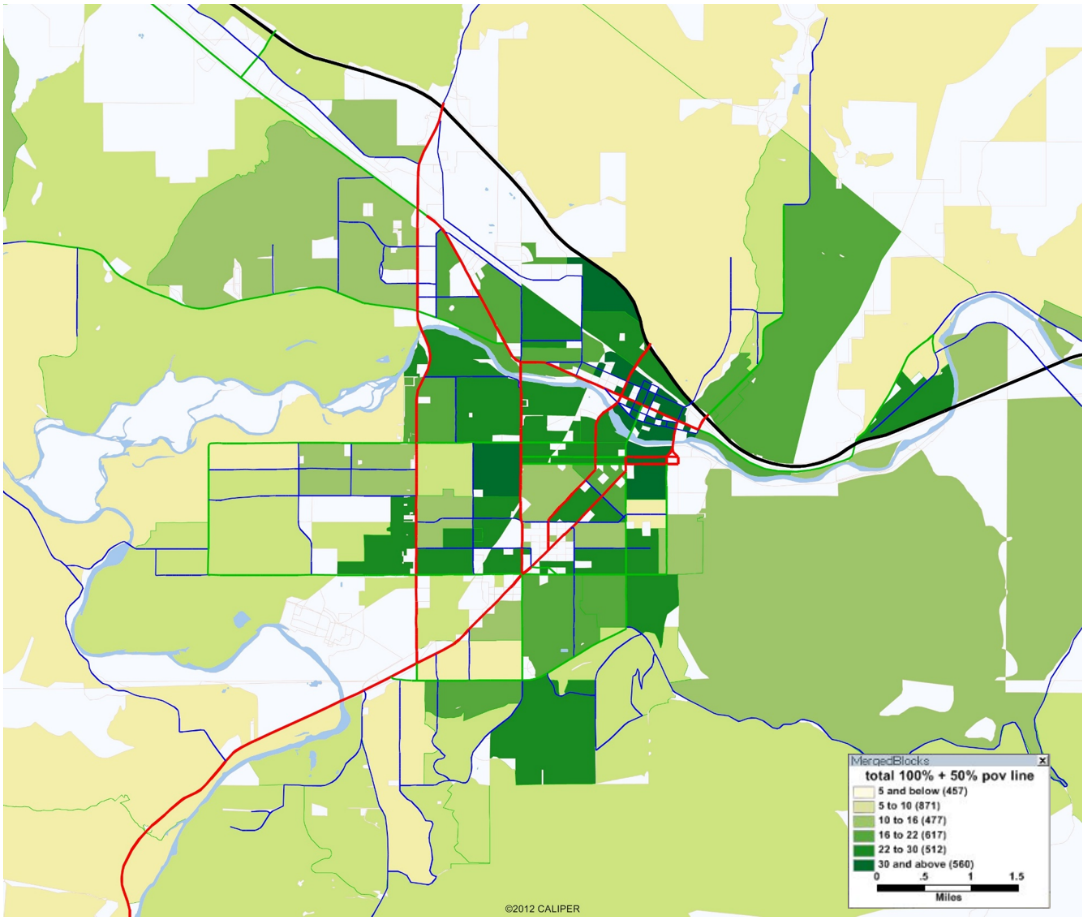


Figure 3. Poverty rates in greater Missoula area (derived from American Community Survey 2010).

Using Poverty Thresholds

This research has specifically focused on the population of Missoula County, and the greater Missoula urban area, who would likely utilize the Food Bank to supplement their household food supply. In order to identify the population that met these criteria, two national poverty thresholds were included for analysis: income threshold at 100% of the poverty level and incomes at 50% of the poverty levels. These income thresholds were used to determine the number of households living below the poverty line and the number of households living fifty percent below the poverty line. According to the U.S. Census Bureau, people and families are classified as being in poverty if their income is less than their poverty threshold. If their income is less than half their poverty threshold, they are below 50% of poverty, or severely poor.

Table 1. U.S. Poverty Guidelines. Source: Federal Register, 2014.

Household size	1	2	3	4	5
100%	$11,670	$15,730	$19,790	$23,850	$27,910
50%	$5,835	$7,865	$9,895	$11,925	$13,955

Table 1 shows the most current (2014) poverty guidelines for the United States Following these guidelines households of two people (a couple with no children, for example) are considered to be living in poverty if their annual household income is $15,730 or less. If they were living fifty percent below the poverty line their total annual household income would be $7,865. Figure 4 shows the number of people living below the poverty line over the last thirty years in Missoula County, illustrating the increasing trend. In 2010, the number of people in Missoula County living below the poverty line was 19,236, over twice as high as the number of Missoula residents living in poverty in 1980 (Missoula County, 2012.)

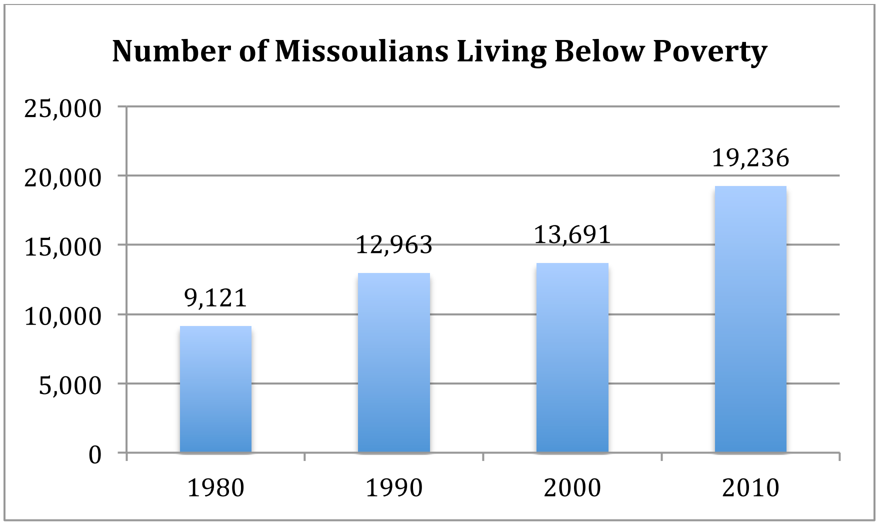


Figure 4. Missoula County residents living below the poverty line. (Missoula County 2012)

Defining the Urban Area

Missoula County covers just over 2,600 square miles with boundaries roughly defined by the communities of Seeley Lake to the north, Lolo to the south, Frenchtown to the west and Clinton to the east. Because food pantries do not exist or offer only limited services in these townships, residents of Missoula County's smaller towns may make the trip to the Missoula Food Bank if they need help providing food for their families. For this reason, this research has included all of the county population in the facility location modeling, as the assumption is that people dispersed across the entire county may need access to a food bank. However, a smaller urban center was also defined for modeling purposes to serve Food Bank clients who may not travel far to access food bank services. Clients with limited transportation options may need to, or others may choose to walk or bike in order to access the facility. For others, the cost of traveling by car may act as a barrier to traveling greater distances to a food bank. The population clustered around urban Missoula may in reality be the service area of the Missoula Food Bank.

Creating a selection set in TransCad using a distance radius around a central location delineates this sub-county urban area. For the analysis of a smaller urban area the Missoula County Courthouse was chosen for the central city location, and a radius of eight miles was deemed to be a reasonable upper limit of distance (or *range*) for residents to travel to the Food Bank, either by motorized or non-motorized transportation.

Transportation and Facility Location Modeling

The foundation of transportation modeling is built by creating a network file from a geographic layer of streets. Utilizing a layer with the street data embedded, a network file allows the user to perform computations in TransCad involving shortest path, transport modeling and location modeling (TransCad, 2007). A network was created using the 2010 Missoula streets layer obtained from the Transportation Division of the Missoula Office of Planning and Grants (now Office of Development Services.) Once the database of streets is accessed, a network can be created. Anytime a change is made to the layer, such as moving a node or a link, it precipitates the creation of a new network file that incorporates the change to the network. This guarantees that each relationship between the network and any possible attached data is maintained. TransCad modeling procedures further require that areas of polygons or points must be connected to the features of a street layer.

Population data are based on blocks, which are polygons that need to be connected to the line data of the road network. This is accomplished by converting blocks to block centroids and developing a path through the *centroid connector* feature within TransCad. A centroid is a point at the center of the block polygon, shown by black dots on the map in Figure 2. The centroids are the points used in the centroid connection assignment, which is a critical step for maintaining the connectivity, and thus communication, between the various data. Socio-demographic data associated with blocks, such as the number of persons, households, or households with certain income characteristics, are essential in location models that take population size and population type into account. Location modeling including socio-demographic data uses socio-demographics as *weights* for a more refined and appropriate analysis and for developing different scenarios. Without connection the network to the socio-demographic block data, only analysis without weights – meaning without socio-demographics – could be employed.

A core concept in transportation and location modeling pertains to *cost of service*, a measure of accessing a service by traveling to a facility. Cost of service is operationalized in a cost matrix, which shows the cost of travel using a shortest path from a set of origins to a set of destinations. The metrics of cost matrices may be distance (length), travel time, or monetary cost of travel. The measure used here is distance in miles between potential food bank locations and the locations of clients. Distance is used for this study, as it is independent of mode of transportation (walking, biking, bus, car, etc.). In contrast, travel time varies by travel modes because of differences in speed. The monetary cost of travel is also-mode dependent, and relatively low for walking or biking and much higher for driving by motorized vehicle.

In order to determine the best-fit location using a facility location model, a set of candidate sites need to be provided. For finding the optimal food bank location, I identified five candidate sites: the current site and four potential new sites located in the city of Missoula (Figure 5).

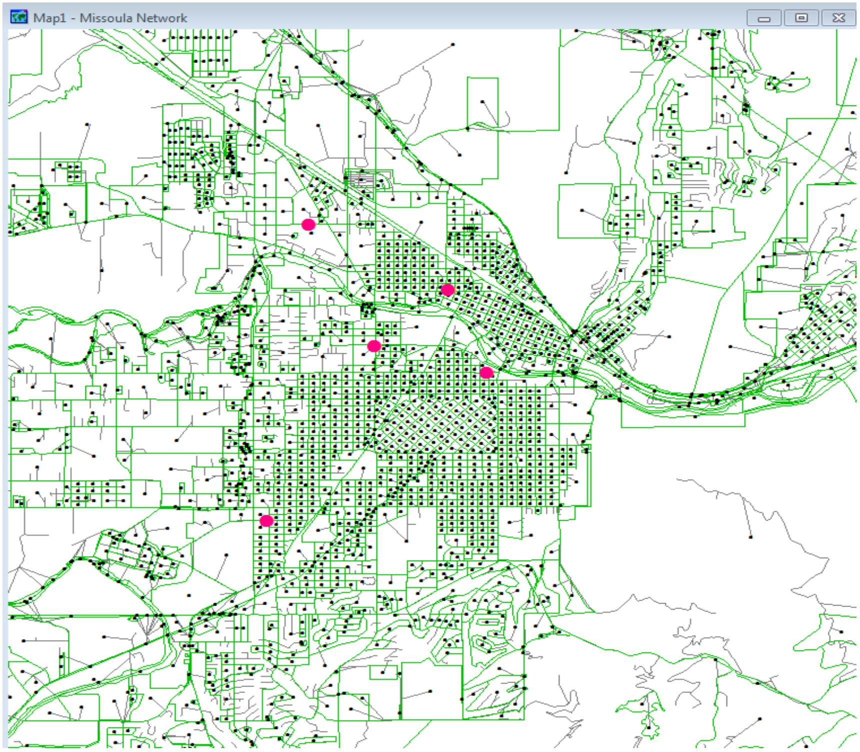


Figure 5. Potential sites for relocation.

The criteria for the potential new sites were: locations that were for sale for commercial use when this study was first started (June 2012). Furthermore, all potential sites are large commercial lots or pre-established warehouses located throughout the city - each location in a different region of the city. In all, they represent a broad area of service for the city population. The locations are described by their street names: Russell Street, Dearborn Street, Palmer Street, Toole Street, Third Street (existing facility). These sites meet the conditions and provide a sufficient grouping for alternative locations for the Missoula Food Bank. In the map in Figure 5, the potential locations are highlighted with pink dots. These suggested localities provide a varied distribution across the urban area, which could lead to the total population being better served by a different region of the city than the current location. The location on the far right is the current Food Bank facility on Third Street.

Potential (or *candidate*) facility locations that were used in the analysis, including both the existing Food Bank location and the four other potential sites, have three unique identifiers attached to them that allow the model to distinguish them from each other. The first identifier is the street address and they are as follows: 2409 Dearborn St., 109 Russell St., 2685 Palmer St., 1038 Toole St., and 219 South Third St. (the existing Food Bank location). Each location also has a Site ID that corresponds to the map layer of potential sites. These are, respectively, 4281, 4289, 4297, 4305, and 4313. The final identifier is the centroid IDs, which are the numbers assigned to each block centroid when the centroid data was linked to the block data. These are, in the same order as the previous lists: 1795, 1253, 240, 382, 1155. The table below shows each potential relocation site and the correlating geographic information used in the TransCad modeling software.

Table 2. Potential Food Bank Sites.

Site Name	Street Address	Site ID	Centroid ID
Third Street (existing Food Bank location)	219 S. 3rd St. West	433	1155
Dearborn Avenue	2409 Dearborn Ave.	4281	1795
Russell Street	109 S. Russell St.	4289	1253
Palmer Street	2685 Palmer St.	4297	240
Toole Street	1038 Toole St.	4305	382

The following chapter presents the results of the modeling analysis. By utilizing the aforementioned methods and data sources, the different modeling scenarios along with each set of results will be described in the next section.

CHAPTER IV: RESULTS

This study was designed to create a GIS model that could be used to evaluate and improve access to social services. The findings presented here are for a specific population based on various measurements, including low- and very low-income populations. The model was employed to identify the best, most accessible location for the Missoula Food Bank while incorporating basic and detailed population data. The intent, however, goes beyond this particular case and sets out to provide a transferable model, which illustrates how the facility location tool could be applied to different settings, both socio-economic and geographic.

Scenarios: Description of Models Used

The process of identifying the most accessible site for the Missoula Food Bank was carried out by preparing and employing facility location data. These data are: 1) a point layer containing 'candidate locations.' Candidates included both the existing and other potential food bank locations; 2) a point layer of 'client locations.' Client locations are the blocks in Missoula County, which were converted from an area layer to a point layer of block centroids; and 3) a cost matrix. The cost matrix represents travel distance between the clients served (block centroids) and each candidate facility (existing and potential). As seen in Figure 6, the matrix is a table that shows candidate facilities in rows and block centroids in columns. The number in each cell represents the cost-of-service, in travel miles, from each potential facility to each block centroid. In the interest of space, only 14 blocks are shown, but the actual matrix table shows 3494 columns, or the total number of blocks.

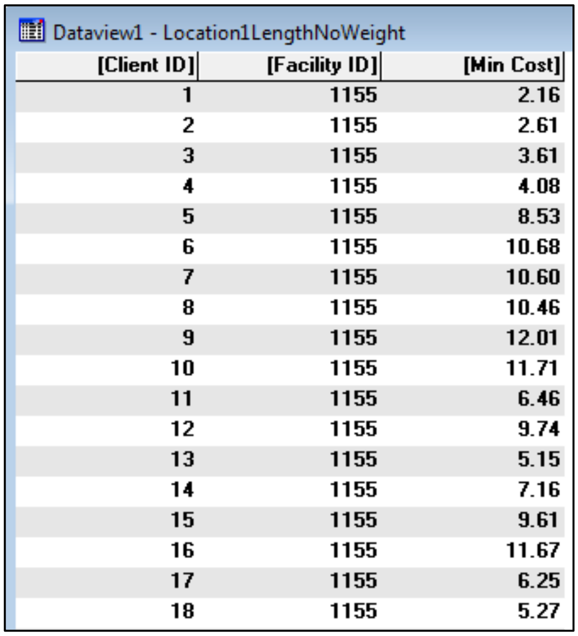
Matrix10 - Cost Matrix2 (Length)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
240	3.15	3.32	3.71	3.86	5.88	6.18	6.49	6.51	6.74	6.57	4.64	5.88	3.89	5.05
382	1.79	1.96	2.35	2.50	4.35	4.64	4.95	4.97	5.20	5.03	3.11	4.34	2.36	3.51
1155	0.89	1.06	1.42	1.57	4.16	4.45	4.77	4.79	5.02	4.85	2.92	4.16	2.17	3.33
1253	2.09	2.26	2.42	2.57	5.33	5.62	5.94	5.95	6.18	6.02	4.09	5.33	3.34	4.50
1795	3.16	3.33	3.08	3.22	6.83	7.12	7.44	7.45	7.68	7.51	5.59	6.83	4.84	6.00

Figure 6. Cost matrix used for facility location input.

The facility location problem is solved by using the cost matrix as input for the model, which then chooses from candidate sites the optimal or best-fit location based on the lowest travel burden for all combined clients. The computation produces a table that shows as an output the minimum cost, or shortest path, represented in travel miles, from each block centroid to the optimal facility, as shown in Figure 7. Summary statistics from this output table can help determine the overall *cost of service* or cost *burden* in each type of analysis performed. They allow, as shown in table 4 below, for each model to be compared to each other for further insight. As mentioned earlier, all models in this research measure travel cost based on road length.

Beyond the simplest case of using road miles, one can apply a population weight for a cost measure of *person miles* rather than road miles. Person miles are the amount of road miles multiplied by the number of people traveling them. For example, if two people were in car that drove ten miles round trip, the person miles would equal twenty.



Dataview1 - Location1LengthNoWeight

[Client ID]	[Facility ID]	[Min Cost]
1	1155	2.16
2	1155	2.61
3	1155	3.61
4	1155	4.08
5	1155	8.53
6	1155	10.68
7	1155	10.60
8	1155	10.46
9	1155	12.01
10	1155	11.71
11	1155	6.46
12	1155	9.74
13	1155	5.15
14	1155	7.16
15	1155	9.61
16	1155	11.67
17	1155	6.25
18	1155	5.27

Figure 7. Facility location output table.

The analysis was first run for the entire Missoula County taking into account distance only, in order to assess the most centrally located facility without using population to pull it in any direction. It then used total population as a weight without additional socio-demographic measures. Population weights essentially pull the facility to be chosen toward candidate sites based on where people live by giving more weight to blocks with higher populations. The population-weighted analysis multiplied the number of miles to the location by the number of people. Two additional models were run with two different income thresholds thereby taking into account measures of poverty. One of these models used as weights the number of households at or below 100% of the poverty level, and the other model used as weight the number of households at or below 50% of the poverty level. These same analyses were also performed for the Missoula urban area, the area previously defined as being within an eight-mile radius of the Missoula County Courthouse (please see Table 3).

Table 3. Models used for location analysis.

Study Area	Models Used
Missoula County	Distance only, no weights Distance weighted by total population Distance weighted by number of households at or below 100% of the poverty threshold (poor) Distance weighted by number of households at or below 50% of the poverty threshold (very poor)
Missoula Urban Area (8 mile radius from the Court House)	Distance only, no weights Distance weighted by total population Distance weighted by number of households at or below 100% of the poverty threshold (poor) Distance weighted by number of households at or below 50% of the poverty threshold (very poor)

Model Results Including the Current Location

When including the existing Food Bank location as a candidate site, all models indicated the best-fit location to be centroid ID 1155, the current Missoula Food Bank facility on Third Street. For all scenarios, including those that relied only on geographic distance and those that took into account socio-economic characteristics, the results were consistent whether examining the larger Missoula County study area or the smaller urban area. Although this finding was somewhat unexpected, it reveals that this location is in fact a highly centralized site within Missoula County and within the urban area.

Table 4 represents summary values from each facility location model that was performed. Table 4 is essentially the summary of eight facility location output tables, as shown in Figure 7. For each model, Table 4 contains the total count or the number of block centroids considered, the average cost, the maximum cost, the sum of the average cost, and the optimum location represented by the centroid ID. The aggregate values shown in Table 4 make it possible to compare total travel costs between models.

Table 4. Results of facility location models: scenarios including the current food bank location.

Type of analysis (area and weight)	Total count	Average cost of service	Maximum cost of service	Sum of cost of service	Optimum location (centroid ID)
Missoula County unweighted	3494	8.43	83.8	29450.66	1155
Missoula County population only	2002	418.95	53073.94	838745.79	1155
Missoula County HH* below poverty	1868	26.44	4838.56	49404.75	1155
Missoula County HH 50pc below poverty	1697	12.21	2963.99	20724	1155
Missoula urban area (8m radius) unweighted	2781	3.76	19.82	10467.42	1155
Missoula urban area (8m radius) population only	1646	174.69	4610.86	287542.19	1155
Missoula urban area (8m radius) HH below poverty	1585	11.44	685.71	18135.33	1155
Missoula urban area (8m radius) HH 50pc below poverty	1436	6.04	312.56	8684.97	1155

*HH = households

The County of Missoula has 3494 blocks and 2002 populated blocks. The majority of populated blocks, or 1868 of 2002 blocks, has persons at or below the poverty level. We find very poor people, at or below 50 percent of the poverty level, in 1697 blocks. This suggests that poverty is quite dispersed in Missoula County.

The Missoula urban area comprises 1646 of 2002, or 82 percent, of all populated blocks in the county. Nearly 85 percent (1585 of 1868) of the county's blocks with household incomes at or below the poverty level are in the urban area. The same is true for blocks with severely poor households with incomes at or below 50% of poverty thresholds (1436 of 1697). In the last instance, the difference between the County and the urban area is only 261 blocks indicating that most of these blocks are located in the Missoula urban area.

The results of the location models for the entire county of Missoula without population weights show an average cost of 8.43. This is the average round trip distance in miles from every block centroid of the county to the best location identified by the model. Using the Missoula urban area without population weights shows an average cost of 3.76 miles from all block centroids to the proposed facility location. This value is significantly less in miles than for the entire County, making it feasible for people to access the facility using transport modes other than motorized vehicles. While the average cost of the Missoula County model without population weights is 8.4 miles, the maximum travel cost for that model is 83.8 miles. This number is simply the length of a round trip from the farthest block of the county to the location identified as optimal, which is the Third Street location. The sum of the average cost of travel is roughly 29,450 miles, or the average miles multiplied with the number of blocks.

When including population as a weight, the statistics become more complex, as it involves both travel length in miles and the number of people living in the blocks of the county. For the Missoula County population-only model, the mean average cost is 418.95 *person* miles, and a count of 2002 blocks analyzed. This is further confirmation of the accuracy of the model because there are exactly 2002 blocks within Missoula County that are occupied by people, the other 1,492 are unpopulated or 'empty' blocks (3,494 total blocks – 2,002 populated blocks). The sum of the average cost of service or the sum of person miles traveled from centroids to the facility is 838,745.79. This means if hypothetically every person in the county would travel from the block centroid to the Third Street location of the Missoula Food Bank and back, it would amount to nearly 840,000 person miles.

As the model becomes continually selective, using poverty thresholds for households, the data shows proportionally smaller values overall. Referring to Table 4, all of the cost values for the households living fifty percent below the poverty line are roughly half of the cost values for the households living below the poverty line. This reveals that the number of households living fifty percent below the poverty line is roughly half the number of households living below the poverty line. In other words, nearly half of people in poverty are severely poor. The mean average cost of service for the smaller group – or the fifty percent below poverty group – is 12.21 person miles, whereas the mean average cost of service for the total households living below the poverty line is 26.44, or approximately double. Likewise, the maximum average costs of service for the two groups are 2,964 and 4,839, again roughly double.

Model Results Excluding the Current Food Bank Location

Of the five locations considered, the model selected the current facility on Third Street as the best-fit location. This facility is centrally located, accessible by many of the larger roadways and even benefits from the interstate I-90 feeding into town. Additionally, it is pedestrian- and transit-friendly. Although the model did not take some of these other factors into consideration, and was based solely on the geographic location of the selected grouping of populations, it maintains this location at the best fit for access.

The Missoula Food Bank is planning to relocate, based on the need for more space and on the fact that current overhead expenses are becoming cost-prohibitive. Due to space limitations and considerable costs to the Food Bank for renting additional space and for transporting food from a warehouse to the food bank outlet, the organization would find it challenging to remain in its current location. Given that, the organization sees the need to operate from a different site in the future. In the terminology used in facility location modeling, the Third Street facility is no longer a 'candidate site' for the Food Bank. Therefore, an additional set of models is used to identify the most accessible location without considering the Third Street location. This set of models is identical to those described above (and condensed in Table 4), but based on only four candidate locations: Dearborn Avenue, Russell Street, Palmer Street, and Toole Street. Table 5 shows the results of this additional analysis.

Results from the additional set of models suggest that the Russell Street location, on the west side of town, is the most-accessible, best-fit selection for every type of analysis conducted. It minimizes the cost of service—measured in length—for the Missoula County models or the Missoula urban area models, whether unweighted, with population weights, or with poverty weights. This location corresponds to the centroid ID 1253. The facility location model suggests that this should be the chosen facility for a relocated food bank.

Table 5. Results of facility location models: scenarios excluding the current food bank location.

Type of analysis (area and weight) Excluding 3rd St. location	Total count	Average cost of service	Maximum cost of service	Sum of cost of service	Optimum location (centroid ID)
Missoula County unweighted	3494	8.50	84.97	29699.56	1253
Missoula County population only	2002	419.02	51659.16	838877	1253
Missoula County HH below poverty	1868	26.63	4721.42	49749.45	1253
Missoula County HH 50pc below poverty	1697	12.28	2892.23	20842.98	1253
Missoula urban area (8m radius) unweighted	2781	3.85	19.74	10730.51	1253
Missoula urban area (8m radius) population only	1646	175.71	3998.12	289386.28	1253
Missoula urban area (8m radius) HH below poverty	1585	11.62	594.59	18426.10	1253
Missoula urban area (8m radius) HH 50pc below poverty	1436	6.19	295.68	8903.42	1253

This location is essentially identical to the proposed Food Bank location described in the Missoulian article from February 8, 2015. In addition to minimizing distance in length (as used by the model), this location also offers good access by public transportation and, very importantly, would provide a greater facility space.

It is worth noting that the summary statistics from Table 4, based on the Third Street location, and from Table 5, for the Russell Street location, show relatively small differences. This indicates that both locations are near equally accessibly to clients. Therefore a relocation of the Food Bank from Third Street to Russell Street for the benefits of having more space and lower operating costs for the organization would not come at the expense of serving clients. On the contrary, the reduced cost of operating from the Russell Street location would benefit clients as the savings could be used to purchase more foods and make them available to people in need of food bank services at a highly accessible location.

CHAPTER V: SUMMARY AND CONCLUSION

Hunger can be defined as a limitation in food resources, and is associated with inadequate food availability, affordability, and accessibility. These factors directly contribute to food insecurity. Many people who are food insecure turn to community services, such as food banks. This study focuses on accessibility to food bank services, specifically access to the Missoula Food Bank. The aim of this study was to apply a transportation GIS for potentially improving access to a social service facility by identifying the most accessible location. Social services are abundant and deserve the highest amount of attention given that the challenging economy has left hundreds of thousands of Americans without basic services and therefore dependent upon assistance programs. These services include homeless shelters, mental health facilities, free or low cost medical clinics, drug rehabilitation centers, utility assistance programs, food banks and food pantries, employment assistance centers, disability services, and many other offices or facilities that promote health and well being which people may not be able to provide for themselves. It is now common to see GIS software in use in municipalities, states, utilities, transportation companies, consulting firms and governmental agencies like the U.S. Forest Service. GIS applications are an important tool that can be used in addressing the location of people in need and the institutions or facilities that could serve them. Overall, the approach used in this thesis proved to be useful in connecting both of these critical pieces of information in improving the link between clients in need and social services.

The broader goal of this GIS location analysis – beyond its immediate use for food assistance – is to provide a model that can be transferable to different areas, or used for different applications. The idea is to establish relevant analysis criteria and that can be put to use in other applications including larger urban areas, demands for different types of social services, or to assess other socio-economic variables for the same kind of analysis. An example of this would be to use this type of analysis to identify where to locate a new early education facility such as Headstart. The model could be weighted so that it considered not only the area that had the most potential program participants, but could also take into account factors, such as the location of single-parent households if there was evidence that this particular group benefited more from an early education program. The model used in this research demonstrates that such analysis is readily doable once a road network is connected to socio-economic data, and a cost matrix has been established and is in place.

For this application, understanding the way in which poor populations are dispersed across the Missoula community is useful for the Missoula Food Bank in that it helps in identifying how broad, in a geographical context, their services need to reach. Siting a facility to improve proximity and ease of access to low-income populations leads to reduced cost of access to people in need of food bank services.

Discussion

I embarked on this analysis of identifying a social service location, in this case the Missoula Food Bank, which is the most accessible to clients using a very systematic approach. My findings proved the current location as the most central, and the second best-fit location being west of town on Russell Street. After I began my study, and potentially sparked by my discussions with Missoula Food Bank staff, the Montana Food Bank Network, the principal organization providing support for the Missoula Food Bank, conducted its own relocation project using a somewhat different method. That method encompassed convenience, transportation challenges, and dynamic relationships between the Food Bank and other local partner organizations such as the Missoula Salvation Army, the Western Montana Mental Health Center, and a number of local community farms that supplement the Food Bank inventory. Their results were presented in recent news media and the new site for relocation is also west of the city center on the corner of Wyoming and Caitlin Streets, very nearby Russell Street and essentially the same location as the Russell Street site considered in this thesis project. The findings of this thesis and the food bank study are not at odds but rather complement each other, given the overlap in intent. Given that the organization employed the use of GIS analysis, their facility location outcome further confirmed the utility of the TransCad model and of the analysis performed in this research. The data used for this project draw on the 2010 population. Since over the last five years the Russell Street corridor has increased in population the case is even stronger for choosing the Russell Street location for the Missoula Food Bank.

All in all, this study confirms that the Food Bank currently operates at the most accessible site on Third Street, which however has become too small to meet client needs. Importantly, when excluding the Third Street site from consideration, the analysis presented here identified a site near Russell Streets as highly accessible. These findings are in agreement with the Food Bank's independent search for a location that better meets facility needs while also providing good access to clients.

Limitations

'Cost of service' is a key concept in location modeling. The 'cost' chosen for this specific application was travel distance, in miles, to the facility from blocks, using an unweighted model, a model with population as weight, and models weighted for households experiencing poverty or severe poverty. A potential method that this project did not include is the complex approach of comparing different modes of travel. These modes could vary from motorized travel—car and public transportation—to non-motorized travel—pedestrian and bicycle transportation. When using mode-specific travel time instead of distance the model might generate different results. Using other elements such as proximity to bus routes and stops could be taken into account as well as the presence of pedestrian- and bike-friendly infrastructure like trails.

Another limitation of this project is that its focus was confined to publicly available income and poverty data. A more detailed decision-making process might include analyses for different household types and socio-demographic groups, by either extracting a broader set of variables from public data, by seeking access to internal records, or by investing time and money in survey data. The limitations mentioned here could be overcome in a more extensive study, which would fall beyond the scope of this thesis.

Contribution of this Study

Over the last decade there have been significant economic challenges both nationwide and in the State of Montana. As a result, public and social services, which have faced limited private and governmental support, have struggled to meet their increased demand. Montana social service and non-profit organizations have increased focus on serving these disadvantaged populations over recent years by attempting to increase private donations, public awareness and involvement and access to free resources that provide comfort to many people, such as food and shelter. The Missoula Food Bank was providing 35,000 services in 2005. In 2014, Missoula Food Bank supplied more than 98,000 services to people in Missoula who might otherwise have gone hungry (Hutton and Brock, 2015), nearly three times as much as the decade before. The Food Bank has done a remarkable job of meeting the drastic increase in food assistance needs.

The expansion of services in an increasingly crowded location was complicated by the Missoula Food Bank currently operating from four different buildings with more and more resources spent on transporting foods from warehouses to pantry location. I experienced the challenges first hand as a food bank volunteer, and that was the impetus for conducting the analysis presented in this thesis. I was looking for a way to make a contribution in seeking a solution to the food assistance problem by drawing on my knowledge and geospatial skill set as a geographer. Of the factors known to influence food insecurity – availability, affordability, and accessibility – this work consequently focuses on issues of accessibility.

This project demonstrated an effective application of GIS-T modeling to evaluate and improve access to a social service, such as emergency food assistance. The analysis of this thesis contributes to highlighting and understanding the geographic element when attempting to address social problems by drawing attention to the relevance of location when it comes to service center. Within GIS mapping and analysis is the ability to improve opportunity for underprivileged communities to better meet essential needs such as education, transportation, health care and emergency services. Using GIS models to connect these communities, or populations, to such services is highly beneficial, and will ultimately be a standard as municipalities strive harder to offer high levels of service to all people. The methodology established in this study can serve as an example of how geospatial and mapping tools are valuable in community and social processes. Ultimately it can serve as a guideline for future efforts in ensuring that for all populations basic needs are met, therefore establishing greater equity between people.

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