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Addressing Barriers to Food Access: A Comprehensive Study of Fresh Mobile Market Distribution in Low-Income Communities

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Abstract

The challenge of food insecurity in low-income communities warrants innovative solutions like Fresh Mobile Markets (FMMs) to improve access to fresh produce and address health disparities. This study analyzes demographic landscapes and travel patterns among Greensboro, NC, USA, FMM patrons and evaluates whether the FMMs effectively serve local communities or draw from distant areas. Additionally, the study highlights the potential impact of transportation barriers on patronage in the network. Analyses reveal disparities in FMM distribution, with some regions exhibiting higher patron traffic than others. Notably, FMMs attract patrons from diverse zip codes, suggesting varying levels of accessibility across neighborhoods. Our findings underscore the need for strategic FMM placement and targeted interventions to optimize food access in low-income/low-access neighborhood communities.

Keywords

Fresh Mobile Markets, Food Access, Low-Income Communities, Distribution Network, Travel Distance

1.0 Introduction

The challenge of food insecurity in low-income communities prompts innovative solutions that improve food access and address related health disparities. Recent studies highlight mobile markets, especially Fresh Mobile Markets (FMMs), as a promising intervention to enhance food access and increase the consumption of fresh fruits and vegetables among vulnerable populations [1-3]. These small traveling markets improve access to affordable produce by offering a variety of fresh food (at no cost) in lower socio-economic communities with limited access to full-service grocery stores [4]. However, research also highlights the operational challenges of implementing mobile market interventions, including building awareness, establishing trust, and addressing spatial constraints [2, 5]. Despite these challenges, mobile markets expand food access in low-access communities [6]. This study examines the spatial barriers to food access by analyzing FMM location strategies in low-income communities. Using estimates derived from automobile travel time, we explore whether FMMs primarily serve patrons from the local community where they are situated or if they draw recipients from distant communities. We also assess the socio-demographic landscape of the FMM locations. The aim is to provide practical guidance for the strategic placement of FMMs to optimize hunger relief efforts and promote equitable food access.

2.0 Problem Description

This study assesses the demographic landscape of existing FMM locations in Greensboro, NC, USA, and analyzes their alignment with community needs. The hunger relief organization under study operates a free mobile food pantry at various locations, serving eligible families fresh produce, bread, meat, and shelf-stable items. Each family receives approximately 65 pounds of food, necessitating transportation via car for collection. Based on our observation of the distribution process, we note that some patrons travel beyond 20 minutes to visit some FMM locations. Additionally, some vehicles receive food for multiple families, in some cases, neighbors or friends who can not visit the FMM. Since there is an implicit requirement of vehicle transportation to use FMMs, it is imperative to investigate the spatial

distribution of current FMM locations and evaluate the travel burden of patrons. The following questions, therefore, guide our research: 1) How do the locations of FMMs align with community needs? 2) Do the FMMs primarily serve patrons from the local community, or do they draw recipients from distant communities? 3) Finally, what is the average time traveled by patrons from their home residences to the designated FMM locations?

3.0 Related Research

Research suggests that pantry food provision can be unreliable, and access considerations, such as geographic location and hours of operation, can significantly impact the ability of food recipients to obtain food from pantries [7]. Mobile markets provide a means to overcome barriers in access resulting from fixed locations of hunger relief organizations [8]. Research on mobile markets has explored their potential to address spatial gaps in food retail access. Researchers use spatial modeling to explore the effectiveness of mobile markets in improving access to fresh produce in low-income communities. Interestingly, even urban regions have limited access to food [7]. Studies also demonstrate the effectiveness of mobile markets in promoting fruit and vegetable consumption, albeit with a modest impact [9]. Research indicates that households without automobiles encounter challenges in accessing food due to the limited availability of public transportation, exacerbating food insecurity issues [10]. Studies conducted in Vancouver, Canada, and urban areas emphasize individuals' difficulties accessing food pantries without reliable transportation [11]. Furthermore, qualitative and quantitative analyses of urban food pantries underscore the impact of transportation barriers on food access, particularly during inventory closures or when pantries are situated far from individuals' residences [7]. The research objectives of this study align with the goal of enhancing access to healthy food for low-income/low-access communities. This entails addressing transportation, distance, and schedule constraints to ensure that mobile markets effectively serve their target communities.

4 Methodology

4.1 Data Collection

Using surveys, we collected self-reported home residence information of patrons at FMMs from January through May 2021. Participants completed the survey while awaiting food distribution at the FMM. The study received approval for human subjects research from the researchers' Institutional Review Board (IRB). The schedule of each FMM location was also retrieved from the hunger relief organization's website at the time of the study [12].

4.2 Data Preparation

We cleaned and standardized the structure of the collected data using Microsoft Excel to promote the integrity of our findings. Some approaches used are as follows: 1) verification of the spelling of difficult-to-read addresses using Google Maps, 2) the elimination of addresses not considered the physical location of patrons (e.g., PO Boxes), 3) the removal of observations with missing values pertinent to the current study, and 4) normalization techniques to standardize all addresses used in analyses.

4.3 Patron Classification

For each patron, we estimate car travel and human walking times to each FMM using a Geographic Information System (GIS) software- StreetMap Premium North America, 2023 edition [13]. StreetMap incorporates factors such as traffic delay and terrain conditions in its analysis of travel routes. Travel and walking routes are based on the longitudinal and latitudinal coordinates of the home addresses of patrons and each FMM site.

Using the travel time calculations, we construct a *Neighborhood Index* to provide a benchmark for differentiating between distant and neighboring patrons. This methodology provides a data-driven approach to assess the distribution of patrons based on travel times, facilitating targeted interventions to optimize FMM locations for improved accessibility. The following steps outline the methodology used to calculate the Neighborhood Index.

1. Determine median travel time (MTT_i) or all customers visiting FMM_i .
2. Determine the neighborhood index (NI) as the mean of the median travel times across all n FMM locations, as defined in equation 1.

$$NI = \frac{1}{n}\left(\sum_{i=1}^{n} MTT_i\right) \tag{1}$$

3. Determine the proportion of neighborhood patrons visiting each FMM (P_i) according to equation (2) where C_i is the set of all patrons visiting FMM i, t_c is the travel time for customer c.

$$P_i = \frac{|\{c \in C_i \,|t_c < NI\}|}{|C_i|} \times 100 \tag{2}$$

4.4.1 FMM Classification

The FMMs are classified based on the location type and the demographic qualities.

1. **Location Type** – We denote elementary schools as "SCE", middle schools as "SCM", community centers as "CC", and churches as "CH". A numerical identifier follows all acronyms, and magnet schools (i.e., schools with a larger eligibility zoning area) are dually encoded using an asterisk (*).
2. **Demographic Qualities** – We performed geographic analyses at the zip code level to understand the socio-demographic characteristics of the areas served by FMMs. The zip codes of interest are classified along the following dimensions:
   i. Proportion of Patrons: This metric evaluates the distribution of patrons across zip codes;
   ii. Transportation Insecurity (TI) Index: The TI index, derived from Policy Map data [14], assesses the percentage of households without private vehicles in each zip code, highlighting areas where transportation constraints may impact access to FMMs;
   iii. Low-Income/Low-Access (LI/LA) Status: Zip codes were categorized as LI/LA areas if poverty rates exceeded 20% and residents lived more than 0.5 miles from the nearest food market, shedding light on areas facing economic and food access challenges.

5.0 Results

5.1 Geographic Analysis and Spatial Distribution of Fresh Mobile Markets (FMMs)

Out of seven FMMs under study, four are situated in elementary schools (SCE), one in a middle school (SCM), one in a community center (CS), and one in a church (CH). The visualizations in Figure 1 provide insights gleaned from the current spatial distribution of FMM locations. Notably, our observations indicate that the FMMs attract recipients from 24 zip codes, including communities beyond the target study region.

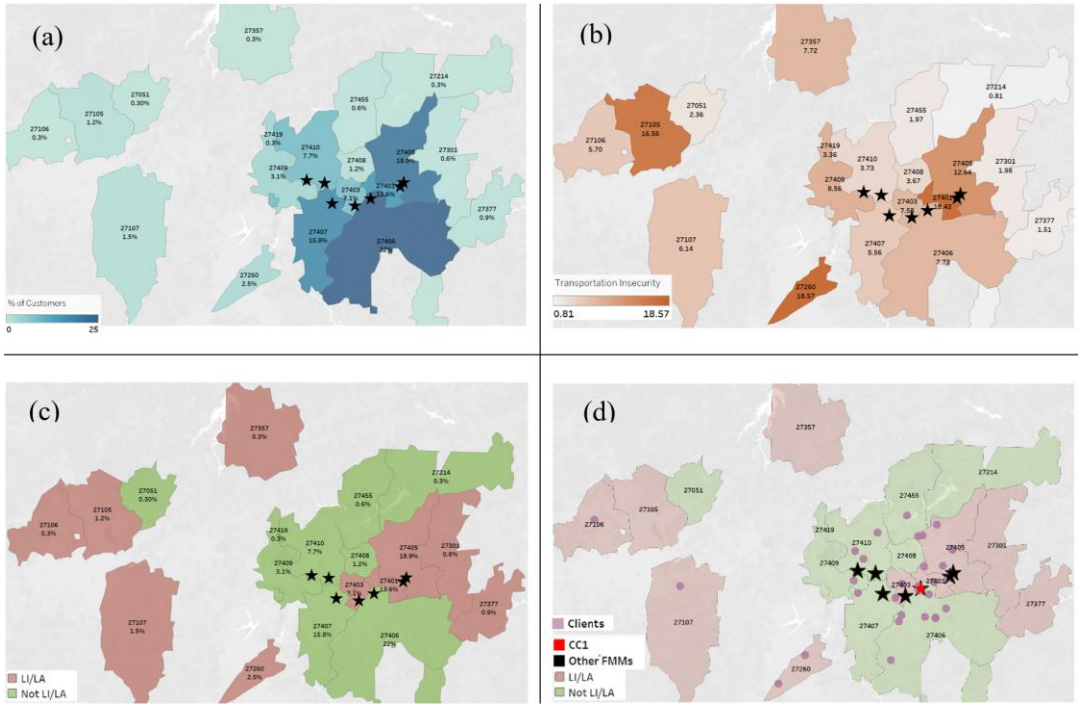

Figure 1: (a) the density of customers traveling from each zip code to the FMMs. (b) % of transportation insecurity in each zip code. (c) LI/LA of each zip code/FMM. (d) FMM Choice of CC1 FMM recipients.

Figure 1a illustrates the uneven distribution of food recipients across zip codes, with some areas exhibiting higher patron traffic to FMMs than others. The color gradient reflects this disparity, with darker shades indicating a greater proportion of potential clients within each zip code. Notably, the FMMs appear strategically placed in zip codes with higher customer concentrations, aligning with existing research suggesting that hunger relief solutions should be placed closer to the populations that need them [10]. In contrast, Figure 1b highlights the percentage of families within each zip code lacking access to a vehicle, indicative of transportation insecurity (TI). Darker shades represent a higher percentage of families without vehicles, posing a significant barrier to accessing the FMMs, particularly in these areas [7, 11]. Positioning FMMs within walkable distances in such zones is imperative to alleviate this burden.

Figure 1c delineates LI/LA zip codes, with red zones indicating LI/LA areas and green zones denoting otherwise. Despite only three FMMs being located within LI/LA zones, a larger proportion of food recipients originate from non-LI/LA areas. This finding suggests that, in urban environments, food recipients are not solely confined to LI/LA areas [7, 15]. Furthermore, Figure 1d examines the distribution of patrons that visited mobile market CC1 (indicated by the red star), revealing customers from various zip codes, both neighboring and distant. This result is consistent with all the FMMs in this study. These results prompt further investigation into why food recipients may bypass other FMMs in favor of a specific one. This investigation will delve into the operational aspects of FMMs, focusing on their scheduling and the various factors that could impact them.

5.2 FMM Neighborhood Classification

As depicted in Figure 1d, FMMs draw patrons from various locations, resulting in diverse travel distances for recipients. Some FMM clients travel shorter distances, termed as neighbors, while others commute longer distances. An analysis of travel times reveals discernible patterns, prompting the proposal of a data-driven neighborhood index to distinguish between neighbor and distant recipients. The neighborhood index represents the median travel time for all recipients to reach the visited FMM, calculated at 10.28 minutes. This benchmark establishes that customers driving within 10.28 minutes to the FMM location are neighbors, while those exceeding this threshold are distant recipients. Table 1 details the estimated percentage of neighborhood patrons visiting each FMM.

Remarkably, SCE4 and SCM1 exhibit fewer close recipients than the other FMMs, whereas SCE3* has the highest number of neighborhood recipients. It is noteworthy that SCE1*, SCE2* and SCE3* are magnet schools, potentially explaining the recipients' willingness to travel longer distances to their children's school for food. Additionally, SCE2* stands out as the only FMM open on weekends, likely influencing the relatively high percentage of neighbors visiting the mobile market.

Table 1 Summary of FMM and Recipient Analysis

FMM	LI/LA	% TI	Schedule Day	Schedule Time	# Total Recipients, $\|C_i\|$	% Neighborhood patrons, P_i	Max travel time (mins)
SCE1*	No	18.43%	Tue	1:30 PM	49	59.2%	41.69
SCE2*	Yes	7.58%	Sat	10:00 AM	58	59.3%	95.97
SCE3*	No	3.73%	Thurs	1:30 PM	27	65.5%	23.13
SCE4	Yes	5.56%	Thurs	11:00 AM	38	29.6%	30.45
SCM1	Yes	3.73%	Thurs	12:00 PM	52	32.7%	196.64
CC1	Yes	7.73%	Tue	2:30 PM	59	55%	87.35
CH1	Yes	18.43%	Thurs	11:00 AM	40	55.3%	42.16

Figure 2 highlights a significant proportion of customers classified as distant, suggesting that approximately 47% of potential customers traveling to these FMMs originate from more distant locations. Addressing this disparity requires strategic FMM positioning to enhance accessibility and promote equitable service distribution.

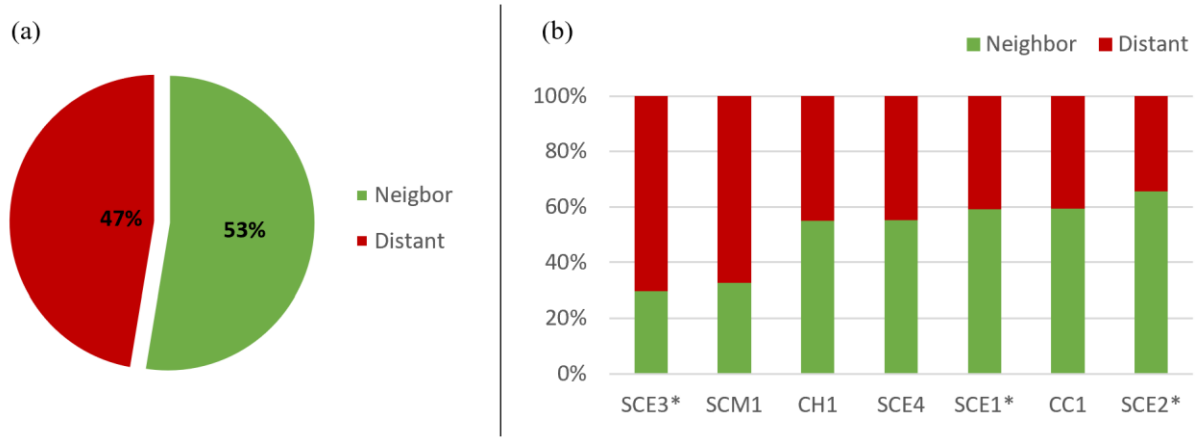

Figure 2: (a) Proportion of Neighborhood recipients to Distant recipients. (b) Neighborhood pull of each FMM

6.0 Discussion and Conclusion

Though proximity partly explained why patrons went to specific FMMs, there were cases when survey participants went to a site that was further than an existing site hosted by the FMM organization we evaluated. Our preliminary findings suggest that other factors potentially determine why patrons visit particular mobile markets. Of note, several of the FMM school sites were designated as magnet schools where all prospective students residing in Greensboro, NC, are eligible to attend. In contrast, students attending traditional public schools must report a home address within the community of the school. Our findings suggest that the structured food environment is larger for magnet school students, which means there may be a broader range of pantries and FMMs accessible to these groups.

While collecting data at the FMM school sites after a school day, the researchers noticed that the logistics of distributing food was a challenge because parents were also on the premises to pick up children from school. Future optimization models designated to determine FMM sites must account for this factor, as this issue may deter prospective FMM patrons on a busy schedule. It is also important to note that these FMM sites were close to each other in distance. This finding may suggest that reducing the sites in this zone area and adding sites in the outer periphery in Greensboro, NC, may expand access to free food to the broader region.

We are currently developing and evaluating preliminary models using the floating catchment area method [16-18] as an objective function to better allocate FMM sites. This GIS method is well established in the healthcare field and used as an approach to equitably distribute healthcare resources given supply, demand, and the existing transportation network [19]. To the best of the researchers' knowledge, existing optimization models do not simultaneously account for these factors. An omission to do so may result in missed opportunities to promote access to food for people in need.

As with any study, the current analysis has limitations. First, the findings of this study are highly reliant on the accuracy of self-reported data. Though previous studies suggest that estimates such as ours are highly reliable, there is a chance that responses were not reported accurately. Second, our transportation-related estimates assume that FMM patrons attend sites immediately after leaving their home residence. It could be that some patrons attended the FMM site after leaving another location. Despite these limitations, we believe that the strength and novelty of the presented findings and in-development optimization model supersedes these limitations. Our study's next step is to complete the development of an optimization model based on the floating catchment method and to compare those findings with those generated using existing approaches.

References

[1] M. L. Horning *et al*, "Full-Service Twin Cities Mobile Market Impact: Qualitative Findings From Focus Groups With Customers - ScienceDirect," *Journal of the Academy of Nutrition and Dietetics,* vol. 120, *(9),* pp. 1548-1556,

2020. Available: https://www.sciencedirect.com/science/article/pii/S2212267220302008. DOI: https://doi.org/10.1016/j.jand.2020.02.016.
[2] C. M. Kasprzak *et al*, "Operational challenges that may affect implementation of evidence-based mobile market interventions | BMC Public Health | Full Text," *BMC Public Health,* 2022. Available: https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-022-13207-8. DOI: https://doi.org/10.1186/s12889-022-13207-8.
[3] B. Hsiao *et al*, "Mobile produce market influences access to fruits and vegetables in an urban environment," *Public Health Nutrition,* vol. 21, *(7),* pp. 1332-1344, 2018. Available: https://www.cambridge.org/core/journals/public-health-nutrition/article/mobile-produce-market-influences-access-to-fruits-and-vegetables-in-an-urban-environment/19DBEC4855EB255DEE6689D6A03224E4. DOI: 10.1017/S1368980017003755.
[4] R. Lyerly *et al*, "Effectiveness of mobile produce markets in increasing access and affordability of fruits and vegetables among low-income seniors," *Public Health Nutr,* vol. 23, *(17),* pp. 3226-3235, Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10200560/. DOI: 10.1017/S1368980020002931.
[5] M. J. Widener, S. S. Metcalf and Y. Bar-Yam, "Developing a Mobile Produce Distribution System for Low-Income Urban Residents in Food Deserts," *J Urban Health,* vol. 89, *(5),* pp. 733-745, 2012. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3462830/. DOI: 10.1007/s11524-012-9677-7.
[6] L. Zepeda and A. Reznickova, "Potential demand for local fresh produce by mobile markets | agricultural marketing service," 2017Available: https://www.ams.usda.gov/publications/content/potential-demand-local-fresh-produce-mobile-markets.
[7] Z. A. Ginsburg *et al*, "Unreliable and Difficult-to-Access Food for Those in Need: A Qualitative and Quantitative Study of Urban Food Pantries," *J Community Health,* vol. 44, *(1),* pp. 16-31, 2019. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6330151/. DOI: 10.1007/s10900-018-0549-2.
[8] I. Sengul Orgut, J. Ivy and R. Uzsoy, "Modeling for the equitable and effective distribution of food donations under stochastic receiving capacities," *IISE Transactions,* vol. 49, *(6),* pp. 567-578, 2017. Available: https://doi.org/10.1080/24725854.2017.1300358. DOI: 10.1080/24725854.2017.1300358.
[9] B. Hsiao, L. Sibeko and L. M. Troy, "A Systematic Review of Mobile Produce Markets: Facilitators and Barriers to Use, and Associations with Reported Fruit and Vegetable Intake," *Journal of the Academy of Nutrition and Dietetics,* vol. 119, *(1),* pp. 76-97.e1, 2019. Available: https://dx.doi.org/10.1016/j.jand.2018.02.022. DOI: 10.1016/j.jand.2018.02.022.
[10] F. Bertmann *et al*, "The Food Bank and Food Pantries Help Food Insecure Participants Maintain Fruit and Vegetable Intake During COVID-19," *Front Nutr,* vol. 8, pp. 673158, 2021. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8378669/. DOI: 10.3389/fnut.2021.673158.
[11] D. Rajasooriar and T. Soma, "Food access, mobility, and transportation: a survey and key informant interviews of users of non-profit food hubs in the City of Vancouver before and during the COVID-19 crisis | BMC Public Health | Full Text," *BMC Public Health,* vol. 22, 2022. Available: https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-021-12434-9. DOI: https://doi.org/10.1186/s12889-021-12434-9.
[12] Anonymous (). *Fresh Mobile Markets*. Available: https://outofthegardenproject.org/programs/fresh-mobile-markets/.
[13] Anonymous (). *On-Premises and Offline Routing, Geocoding & Mapping | ArcGIS StreetMap Premium*. Available: https://www.esri.com/en-us/arcgis/products/arcgis-streetmap-premium/overview.
[14] Anonymous "PolicyMap - Dig Deeper," 2024. Available: https://ncat.policymap.com/newmaps#/.
[15] M. Winters *et al*, "How Far Out of the Way Will We Travel?" *Transportation Research Record,* vol. 2190, *(1),* pp. 1-10, 2010. Available: https://journals.sagepub.com/doi/full/10.3141/2190-01. DOI: 10.3141/2190-01.
[16] P. L. Delamater, A. M. Shortridge and R. C. Kilcoyne, "Using floating catchment area (FCA) metrics to predict health care utilization patterns," *BMC Health Serv Res,* vol. 19, pp. 144, 2019. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6399985/. DOI: 10.1186/s12913-019-3969-5.
[17] D. Lewis Jr *et al*, "Analytic Framework to Improve Access for a State Medicaid Agency," *INFORMS Journal on Applied Analytics,* 2023.
[18] J. Luo, "Integrating the huff model and floating catchment area methods to analyze spatial access to healthcare services," *Transactions in GIS,* vol. 18, *(3),* pp. 436-448, 2014.
[19] J. Luo, "Integrating the huff model and floating catchment area methods to analyze spatial access to healthcare services," *Transactions in GIS,* vol. 18, *(3),* pp. 436-448, 2014.