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The role of food ordering systems in the efficiency of food distribution through food banks: A case study

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Abstract

Introduction: Food banks face pressure to support an increasing number of food-insecure individuals, and to increase operational efficiency. This study reviewed the role of ordering systems in a food bank through a literature review and analysis of past ordering data.

Methods: A literature review was conducted on the role of food ordering systems on efficient food delivery. Order data were categorized by month, county, and product category to assess transaction patterns. Analyses involved total pounds of food received by each county and a formula to calculate the percent of food insecure individuals served by county. Additional analyses compared items that were free to agencies vs for a cost, categorized by county, and product category. An ANOVA test examined differences in costs of product categories between counties. An Analysis of means (ANOM) identified significant differences in group means by county, product category, and month.

Results: The case study highlighted inefficient naming and quantity measurements while literature highlighted delivery routing and supply chain unpredictability. In 9 out of 10 counties the estimated mean percentage of the food-insecure population served was over 75%, with Monroe County receiving the most items over the 8-month period. The ratio of free to paid items was not associated with food insecurity rates, although two counties with higher food insecurity received a higher ratio of free items. Cheaper items such as produce were more likely to be distributed for free. The highest number of transactions occurred from November through February. Cost differences were significant for all product categories except miscellaneous.

Conclusions: Key gaps identified include data presentation (nomenclature and units of measure), delivery routing efficiency, and value chain analysis of the food supply chain. Addressing these gaps will enhance efficiency and guide data-driven decision-making in food banks.

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Acknowledgments

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Topic: **The role of food ordering systems in the efficiency of food distribution through food banks: A case study.**

Introduction

As of 2022, food insecurity is defined by the USDA as a "household-level economic and social condition of limited or uncertain access to adequate food"[1]. Household food insecurity plagues the United States at a rate of 12.8%. Further, 41.1 million individuals living in America receive food assistance from the Supplemental Nutrition Assistance Program (SNAP)[2]. The main role of food banks and associated agencies (including but not limited to soup kitchens and local food pantries) is to provide food to combat existing food insecurity. The distinction between food banks and food pantries, or agencies as they are referred to in this document, is important for the topic of this project. A food bank is a non-profit that stores food to be delivered to local entities. These entities consist of congregate meal sites (sometimes called soup kitchens) or food assistance agencies which are the distribution centers responsible for the disbursement of food directly to recipients[3]. Thus, food banks and agencies work together as one but are separate operations.

Food banks are at the heart of the process of distributing food to those in need. Food insecurity and corresponding food bank usage have gradually increased over time, with food banks struggling to fully support the need[4]. In 2022, roughly 12.8% of households (17 million) were food insecure, compared to 10.2% (13.6 million) being food insecure the previous year. Thus, food insecurity has increased in the past few years, meaning the need for food banks will only increase[2]. A significant factor contributing to an increase in food insecurity is the COVID-19 pandemic. From 2018 to the onset of the pandemic in 2020, food insecurity grew by 27%[5]. Additionally, food production was impacted by the COVID-19 pandemic[5]. Reliefs such as the

Health and Economic Recovery Omnibus Emergency Solutions Act provided added funding for SNAP and other food programs in the US, which was attributed to improve food security[6]. Once these programs are removed, food insecurity problems may remain. One means for enhancing the benefit that food banks provide is via the efficiency of food distribution, which is already necessary to improve to support a growing quantity of customers[7]. To do so, current ordering systems, supply chain management, optimization modeling, and the surrounding environment must all be understood.

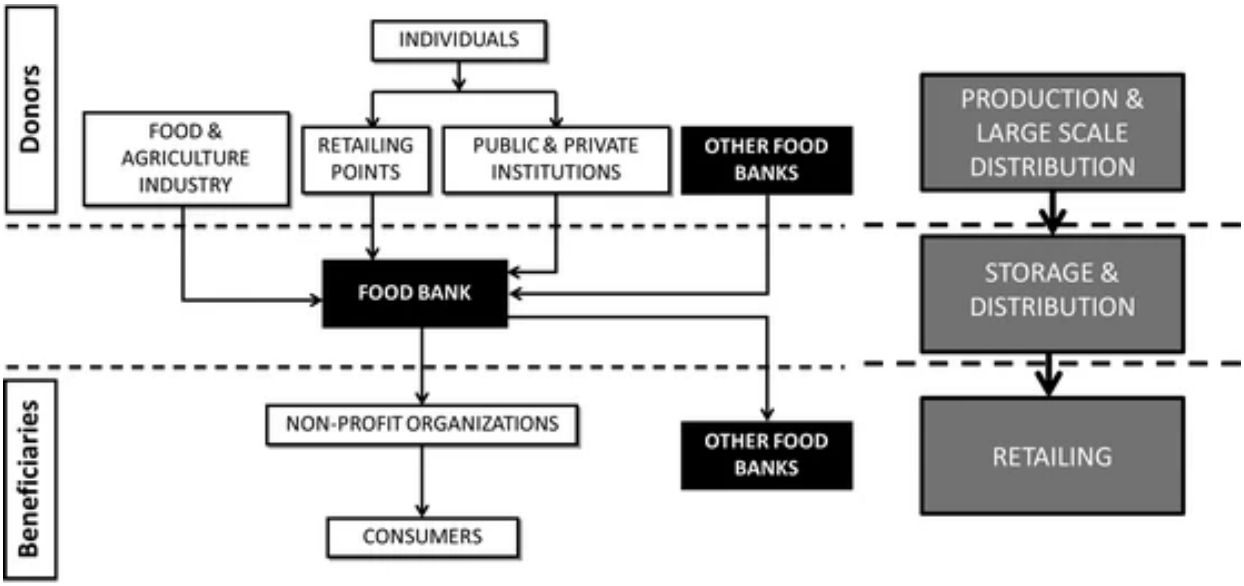

Figure 1: Food banks and Food ordering in a typical supply chain. Adapted from González Torre et al (2016).[8]

The figure depicts a sample food supply chain as it relates to food banks. Food travels from donors to food banks, and then onto the beneficiaries. In this model food, ordering systems play an important role in efficient distribution to the food bank beneficiaries. A food ordering system is the process by which food is ordered by agencies and its accompanying distribution from the food bank.[9] This constitutes the ordering, reception, storage, and onward distribution or retailing.

Efficient and effective food distribution by food banks is a crucial component of combatting food insecurity, as over 46.5 million Americans receive grocery items from food banks and agencies yearly[10]. Food ordering systems are in place to ensure efficient distribution of large portions of food. Thus, the organization of goods received, distributed, and current stock better helps food banks streamline the food aid process[11]. Additionally, digital data management of food ordering systems is an important component of a successful ordering system but can be overlooked. Gaps in the system can lead to inefficiencies in food donations and distribution[11]. Overall, food-ordering systems are necessary for the efficient operation of a food bank, especially in terms of food distribution coming from a food bank, which is the focus of this paper.

Foodlink, based in Monroe County, New York is the regional food bank for a 10-county region spanning Allegany, Genesee, Livingston, Monroe, Ontario, Orleans, Seneca, Wayne, Wyoming, and Yates counties of New York[12]. Foodlink distributes food to agencies throughout their 10-county service area. In the food assistance landscape, Foodlink is a large-scale distribution center that obtains, stores, and distributes food to various local agencies but does not distribute food to individuals. Distribution to individuals is done by community-based organizations operating food assistance agencies. Foodlink has a warehouse that serves as a headquarters, collection, and distribution point for all the food entering their possession. From that point, the food may be distributed to individuals.

The increasing food insecurity needs in the community implores a need to optimize the operations of food banks to increase efficiency and conserve resources and time. However, limited published data on food ordering systems exists to provide helpful suggestions for organizations serving large groups as it occurs in a food banks.

The research objectives for this study are:

1. Describe the role of food ordering systems in food distribution in food banks using published literature.
2. Assess community agencies' ordering patterns using historical data from the ordering systems of Foodlink.
3. Assess participant reach (such as the number of individuals or household size) of community agencies using historical data from an ordering dataset from Foodlink.
4. Identify gaps in the ordering system that could improve efficiency or optimize use of data.

This paper will assess all the factors that influence the ability of a food bank to operate efficiently, especially as it pertains to fulfilling orders. The literature reviewed includes existing technologies in food banking, food allocation, supply chain integration, and optimization models. Later the background methods are discussed, along with the process for performing this analysis, and the analysis used for the work. The results chapters highlight findings and future considerations. The data from this work will contribute to the limited published data on food ordering systems and provide helpful suggestions to individuals using systems such as food banks.

Literature Review

History of Food Banking and Structure

Food banks strive to alleviate hunger, lowering food waste, and provide for the community[13]. Food banking began in the 1960s when a businessperson began to collect food products that were going to waste and use them for a soup kitchen[14]. Eventually, donations and waste became frequent enough that they needed to be stored in a larger area, so operations switched to a warehouse. Thus became the first food bank[14]. Later legislation would support the growth of food banks and support of those who donated to them via direct funding and tax benefits. That legislation was pulled a few years after in 1982[14].

In more recent times, funding may come from the government, private donations, foundations, grants, and fundraisers[14]. More legislation exists today via the Good Samaritan Act, which protects the food provided and waives liability if recipients are harmed by donated food. That particular legislature however does not necessarily cover the nutritional value of food that is donated, which can vary depending on the source of the donation[14]. [14] A source that ensures healthy foods are distributed is The Emergency Food Assistance Program (TEFAP). TEFAP is a federal program that "supplements the diets of low-income Americans, including seniors, by providing them with emergency food assistance at no cost[15]." TEFAP donates more nutrient-rich food than retail stores, for example. Retail food provides roughly 33% of donations, the federal government provides 23% and farmers provide 14% of donated food[16].

Additionally, food banks have varying programs in place to raise funds or donation capital on their own, while most other food is provided by Feeding America. Food is either distributed via bidding systems or need-based systems. Food provided to food banks is comprised of produce,

drinks, snacks, dairy, meat, and rice, among others. Other products are sometimes available, such as diapers, cleaning supplies, plates, and cutlery[17]. Food banks can provide a wide variety of items outside of food but cannot be consistently relied on for everything given the high need.

Management of food banks requires understanding and involvement in the supply chain. An example is presented by Gonzalez-Torre et al[8], featuring a three-step process. It goes from "production & large-scale distribution" to "storage & distribution" to the last step of "retailing". The main aspects of the production & large-scale distribution part of the chain are the agriculture and food industry, retail points, and public and private institutions, the latter two being contributed to by individuals. Food banks solely occupy the storage and distribution piece, and non-profit organizations and their direct relationship with consumers occupy the retailing section. Food banks can play a role in any of the three sections by working with one another[8].

Typically, a group of employees manage the operations of a food bank on the ground on the day-to-day. This can include program management, community outreach, warehouse supervision, and volunteer work, among other tasks to ensure the operation is running smoothly.

The Impact of External Factors on the operations of food banks

The COVID-19 pandemic greatly impacted food bank operations. First, it caused the loss of volunteers, which contributed to significant work hours for some operations. Second, food banks needed to be responsive to an increase in demand. Third, COVID-19 caused food supply and distribution problems all over the world[18]. These three issues combine to form a significant barrier to food bank operations. The issue was further challenged by the variety of governing and

structure of food banks so no two operations may run the same, but all are influenced by social, economic, and governmental occurrences[19]. Work has been done to help food banks deal with sudden disastrous events by streamlining their processes. In any unexpected event, such as COVID-19, a natural disaster, etc., it is important to have a process for how the situation will be handled. This is especially true for food banks, which may be the main point of contact in the event of a disaster. The results from a study by Ogazon et al found helpful insights for food bank managers to adapt day-to-day operations by understanding demand satisfaction[20]. Demand satisfaction is a measure of how a company meets a customer's demand. Ogazon and co-authors found that demand satisfaction is impacted when food supply changes and impacts food bank operations if demand satisfaction is low. Food banks may experience stressors related to increased demand, especially during a crisis.

In another study[21], three observations from the pandemic were made. The first is that food insecurity reinforces inequity, meaning that in a time of increased need such as during the COVID-19 pandemic, this inequity was clearer to see. The pandemic caused undernutrition for roughly 100 million people in addition to those already suffering, also reinforcing the point that any increase in hardship is amplified for those already experiencing some level of it. The second observation is that the struggles of food bank employees were made apparent during the pandemic, as many were perceived to be under stressful circumstances regarding their personal finances and workload. Missing benefits such as lack of sick days and temporary benefits are another two reasons food bank employees may struggle. The third point expands upon the second. The author maintains that there is strong inequity faced by food workers of all kinds[21]. Food banking works with individuals who are in need, so extra caution must be used to ensure

these needs are wholly accounted for. Food banks are subject to changes that may be related to economic and political factors. An event such as a recession or new political sanctions may have a significant impact on demand, so recognizing such things is helpful for food banks to shift their focus accordingly[22]. As for any establishment, the existing economy can provide unique circumstances that require adaptation.

Supply Chain Management and Logistics

The supply chain has a significant impact on the availability of resources to food banks. Research has found that supply integration is positively associated with internal integration. Supply chain integration is the cooperation of buyers and sellers with the goal of mutual success[23]. Internal integration is the coordination and integration of logistics with other areas of an organization and promotes a cohesive working unit[24]. This relationship means that customers and suppliers work as one to optimize their work together to support a better product, whatever that may be. In this case, it is the supply of goods. The same conclusion was reached for demand integration. When demand is coordinated between supplier and consumer, it also increases internal integration[25].

For a food bank, products that customers receive are relayed in some way so that suppliers know what is popular and needed. To make this happen, multiple departments of the food bank must be in collaboration. One problem that food banks can have is related to the availability of food and products to distribute. There is often a heavy reliance on donated goods, which are known to have constant variation. This can provide problems related to low availability as well as low variation in options for consumers. There are additional problems regarding demand. Sometimes

consumers are not satisfied with the selection of food available, other times there is a knowledge gap, and the consumer may not know how to prepare the food they receive.

The most significant problem as it relates to demand is the drastic increase in demand and food bank usage[11]. As mentioned earlier, this has been on the upswing since the COVID-19 pandemic. One method to alleviate some stress of distribution is by optimizing routes and efficiency of delivery vehicles. In one instance, a mathematical formulation was used to calculate the best distribution of delivery routes. This helps to improve their coverage without much more strain on their resources[26]. Another publication developed a mathematical formulation to help redesign a food supply chain network but did not apply it to any specific circumstances[27]. A third publication uses a mathematical formulation to help manage supply chain bottlenecks. They considered transport capacity, storage capacity, and donations received in the calculation, three factors that determine a food bank's distribution. The formulation helps determine which of the three factors is most important to fund and in what order[28]. The food bank supply chain consists of supply, inventory management, and demand. Between each of these, there is the transportation of goods and logistical organization of what has been delivered between donors, food banks, and agencies. This can work and be managed in several ways.

Role of technology in food bank operations

The use of technology in food bank operations is a key part of their success & development. Technology is still a growing part of food bank management, so it is mostly in the development stage. The use of technology is actively contributing to food acquisition, volunteer and staff management, client services, reporting, and emergency preparedness. A scoping review from

Martin et al. shows that digital tools look to improve the acquisition of food from donors, education for management, and management of food pantries, particularly on volunteer and inventory management[29]. Multiple studies included in the review used various software to manage inventory and volunteers. This was generally done through either smartphone apps or websites. One paper constructed a software to assist a Los Angeles food bank make decisions on distribution of food boxes, thus helping efficiency[30]. Other proposed ideas involve digitalizing everything including inventory, client management, customer records, and donation tracking. In the review, all aspects of food bank operation are covered in regards to ideas for digitalizing food bank operations, including but not limited to, smartphone apps, websites, software and machine learning[30].

One use of technology developed by Desai et al. explores the different ways to utilize dashboards for food bank users[31]. There were 3 modes, with 3 different ways of categorizing and presenting the data. The modes of this dashboard were tested via various statistical analyses used to measure satisfaction and time. These measures gave authors a valid reason to favor one mode of the dashboard over the rest to use for future research[32]. A user dashboard can be extremely beneficial for organizational purposes for both producers and consumers. Another struggle that a food bank may have is with efficient collection and distribution of goods. Multiple authors have come up with methods to optimize this process, whether via mathematical equations or computer programs[11,26,27,33].

Ordering Systems: Design and Functionality

Ordering systems are a key enabler of the ability of a food bank to provide for its users. These systems can be operated in a number of ways, although limited published evidence is available on how they are employed by food banks. There are methods by which food assistance establishments place orders with food banks and also receive food elsewhere, such as from direct disbursement via Feeding America[17]. The aforementioned user dashboard also provided some benefits to users, although this was agency-to-customer transactions[32].Some organizations have utilized an online ordering process for the organization and distribution of goods. One food pantry in Georgia used a version of an online ordering app for tracking donors, clients, inventory, and volunteers[34].Various other food pantries used digital tools to help simplify ordering processes and keep track of clients[29]. As discussed previously, ordering systems involving food banks mainly focus on the orders placed by the customer and not between the food bank and the agency.

Role of ordering systems in enhancing the efficiency of food supply and delivery

In summary, food banks have a significant role in combatting food insecurity and other accompanying factors. In changing times, this may come with increasing difficulty, which justifies the need for optimization of operations. Many models and theories have been created in various contexts, so they must be put to the test so that it can be decided which may be the most viable option.

Summary of literature, and identified knowledge gaps

A few gaps that were found in the research include particular case studies involving ordering practices of food bank member agencies. Additionally, there does not appear to be any published work covering the direct application of any models created for optimization or simplification. Limited data exist for case studies to show the actual application of the limited research data on the use of ordering systems.

Table 1: Five key papers addressing varying stages of food ordering systems

Author (year)	Objective	Relation to ordering systems	Key findings
González-Torre et al. (2016)[8]	Analyze the impact of food banks on the supply chain	Discusses key components of food distribution, storage, and retailing	Highlight features of the most successful food banks from two groups of banks
Ogazon et al. (2022)[20]	Develop methods for food bank operations in the wake of disaster	Adjustment of operations to keep supply adequate in case of disaster	Mathematical formulation keying in on optimization of donations when supply is low
Reusken et al. (2023)[28]	Optimization model that develops investment budget to increase beneficiaries	Helpful when obtaining food to use this model	Results increase beneficiaries by 32%
Blackmon et al. (2021) [30]	Help Los Angeles Regional Food Bank figure out the process for distributing boxes to agencies	A key part of the ordering system optimized quickly in times of need	Software developed in record time to make the food bank able to complete tasks assigned during pandemic
Chen et al. (2021)[35]	Minimize distance traveled by distribution vehicles, and increase agency reach	Optimization of tasks related to food distribution and efficiency	Able to cut down mileage and add 8 agencies to route

Methods

Study Design

The study design is a retrospective time series and uses the order data to detect patterns, make comparisons, and draw conclusions about the agencies' ordering routines.

Sampling and Study Population

The historical data was provided by Foodlink on March 15, 2024, in the form of a Microsoft Excel file, with inputs spanning from June 27, 2023, to March 15, 2024. Each input consisted of the food item that was distributed, its weight in pounds, the date it was distributed, the agency the item went to, and the amount the agency paid. For data analysis, only months with complete data were used, which in this case was July 2023 to February 2024.

The population served in this project is all member agencies included in the 10-county service region covered by Foodlink. Those counties are Allegany, Genesee, Livingston, Monroe, Ontario, Orleans, Seneca, Wayne, Wyoming, and Yates, all being from New York state[12,36]. [37]

Inclusion Criteria

To be included in this project, agencies must have received a product from Foodlink in the 9-month window, where their transaction would appear on the master ledger used by Foodlink. This is categorized as a “distribution”.

Exclusion Criteria

Exclusion criteria for this project included not having received a product from Foodlink in the past 8-month window. Incomplete monthly reports were excluded from the analysis.

Ethical considerations

A formal consent and approval were provided by Foodlink to use their historical data and publish Foodlink member agencies. Only de-identified individual or household data was shared and used for analysis.

Data collection

Data was recorded by Foodlink over 9 months, tracking the item quantity, weight, and shipment details of every item that was received and distributed. Only 8 full months were used in analysis.

Data Analysis

These data were analyzed using JMP Pro 16[37] to determine how quantities and qualities of foods ordered by agencies varied over time and to examine any similarities and patterns. An item ledger dating back to June 27, 2023, provided by Foodlink consisted of a list of every transaction that Foodlink had made from the date in June up until March 15th, 2024, in a Microsoft Excel sheet. This ledger was copied and changed to only contain items that Foodlink distributed to agencies, classified in the sheet as "agency distribution". Then, using the agency codes attached to each item and a master sheet for all agencies, the agencies were grouped by county and given a corresponding number of 1-11. 1 through 10 were the counties, and 11 categorized agencies not listed on the master sheet. Then, every food item found on the provided ledger was also filed into 1 of 8 categories. These categories are meat, fruits, vegetables, dairy, snacks, non-food, miscellaneous, and assorted bulk produce. Each county has measurements of the 8 categories over the 9 months in both weight in pounds as well as the cost of the food. An additional column was added with a 0 for items that were free of charge and a 1 for those that cost a fee, which would allow for the creation of a binary variable for graphing. All categorizations in Microsoft Excel were computed for variable simplification in JMP Pro 16.

Formulas used for estimation of food insecure individuals served were developed using the assumption that the average American consumes 2,000 pounds of food yearly[36]. Given that Foodlink member agencies are supplemental, each individual helped will be allocated 200 pounds of food per year for 10% of someone's yearly consumption[36]. The formula for estimated individuals served is = (total pounds – pounds of Non-food items)/200. The formula for % of food insecure population uses the food-insecurity rate of each county multiplied by the population of that county.[38] That number is divided into the estimated individuals served number to get a percentage. The cost per person is "Estimated individuals served" divided into the total amount paid for all food items in the accompanying county. The cost per person column represents the estimated cost the agency would have to incur to support another person over the year. County population estimates are from the New York State population as of 2020[39,40].

In JMP Pro 16, the graph builder function was used to generate Figures 2-4. Variables used included transactions, month, County, and cost to agencies (two outcomes, paid or free). The average costs of product categories per county uses the tabulate feature in JMP to organize mean costs by product category for each county. P-values and F ratios were generated by use of ANOVA analyses of each separate product category in JMP. Figures 5-7 track and analysis of means (ANOM) of transactions per month, by product category, and by County. ANOM is a method used to determine whether there is a difference between a group mean and an overall mean from a set of data and is intended to build upon the ANOVA[41]. The graph is meant to be easily interpreted[41]. This is done within JMP. Anything outside of the Upper (UDL) or Lower (LDL) decision limits in the ANOM analysis is considered statistically significant. Table 4 contains identified gaps within the food ordering system from the literature and data, along with

an interpretation of how efficiency will be impacted. Table 4 was synthesized based on deductions from the literature on food ordering systems and similar subjects, along with inductions from the data set from Foodlink.

Results

Background characteristics of the 8-month Foodlink order data set

From July 1, 2023, to February 29, 2024, 295 agencies from 10 different counties placed 72,173 orders for food items and accompanying non-food items, such as paper plates. A total of 564 different items made up the 77,714. Those items were grouped into 8 unique categories as follows: Assorted Bulk Produce (n=25), Dairy (n=39), Fruit (n=33), Meat (n=70), Miscellaneous (n=183), Non-food (n=67), Snacks (n=83), and Vegetables (n=94). Only data for full months, i.e., data from July to February was used, resulting in 72,173 data points.

Potential participant reach of community agencies

Every county except Monroe could have potentially served over 75% of the food-insecure population in their respective county with the food received from Foodlink according to the study calculations. Most counties with lower numbers of individuals served are on the lower end for cost per person and also cover a higher percentage of the food insecure population in their county. This can be seen in Livingston, Genesee, Wayne, Wyoming, and Yates counties. The two highest costs per person come from the two most populous counties, Monroe and Ontario. Allegany and Orleans counties have two of the highest food insecurity rates of the 10 counties, while also having the second and third lowest food-insecure coverage rates of the 10 counties. This means that per food insecure household, they receive the least amount of food. Table 2 shows the predictions and potential reach based on the weight of food items received by agencies.

Table 2: Potential number of individuals served (10% of yearly food intake) and estimated cost agencies spent to serve each client (N=72,173 orders)

County (# of agencies)	Estimated individuals served*	% of food-insecure population	Estimated cost per person ($)
Allegany (13)	5,032.1	77.2	79.28
Genesee (15)	5,966.7	88.0	68.94
Livingston (18)	6,559.2	94.7	59.03
Monroe (165)	54,510.7	60.8	97.51
Ontario (23)	10,371.0	84.9	100.41
Orleans (9)	3,878.9	77.0	66.34
Seneca (11)	3,374.5	75.8	86.87
Wayne (20)	8,422.4	82.7	76.07
Wyoming (6)	4,544.5	100.1	62.40
Yates (9)	4,128.8	136.6	54.26

*Food eaten per year, population and food insecurity data were extracted from the USDA, Feeding America and the New York State Department of Health[36,38,39]. Individuals served was estimated using assumptions of 10% of yearly food intake from the USDA Economic Research Service[36]

The two most populous counties, Monroe and Ontario received the most items in total. Counties such as Seneca, Livingston, Wayne, and Monroe have the greatest differential of free to paid items, meaning agencies within these counties pay for a higher percentage of items than agencies in the other counties. Genesee, Yates, Wyoming, Ontario, and Allegany have the highest rates of free food received respectively, but only Allegany and Yates counties are in the top four most food-insecure counties. Every county except Genesee and Yates County received more items they had to pay for than ones that were free. They are both near the median food insecurity rate. The 3 most food-insecure counties were all in the lower half of free food rates. Figure 2 depicts ratios of items received in each of the counties for free or that were paid for by Foodlink.

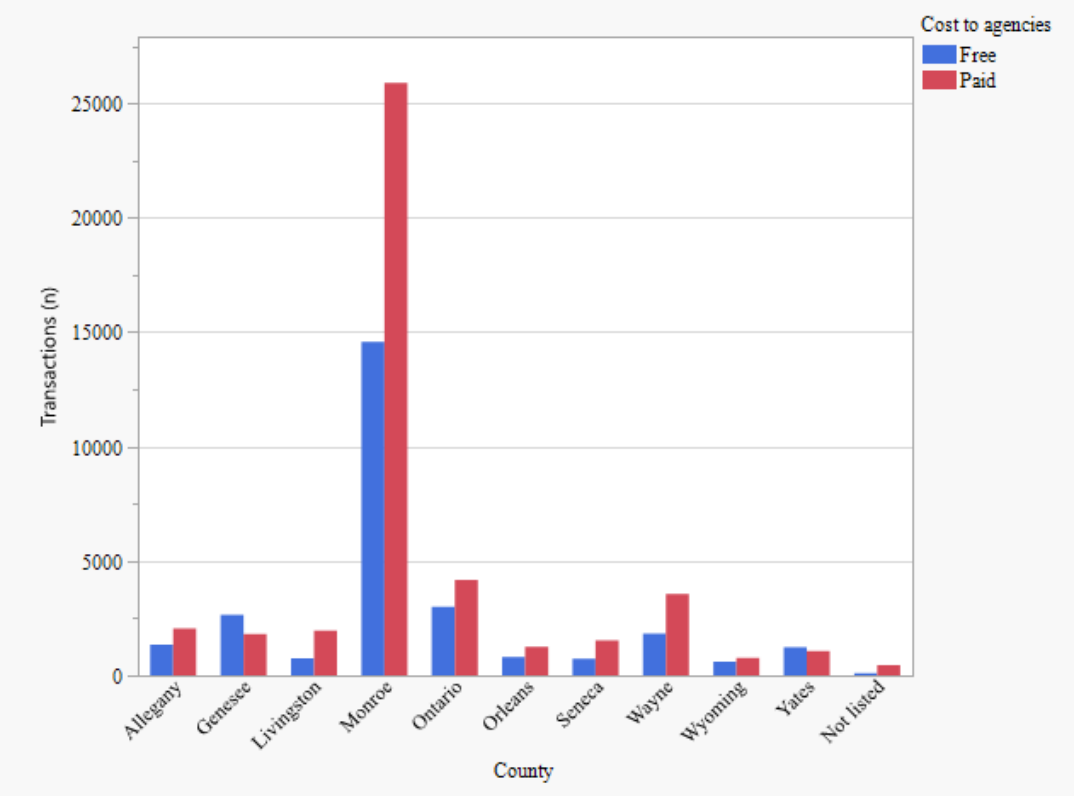

Figure 2: Total number of free and paid items received by agencies in 10 counties (N= 72,173 transactions)

Vegetables, bulk produce, and fruit were the items more oft provided to agencies free of charge, while the remaining categories were more frequently paid for. The miscellaneous, meat and non-food categories had a significantly higher rate of being paid for than the other categories. Figure 2 shows the ratios of free and paid items once again, but grouped into item categories rather than by county.

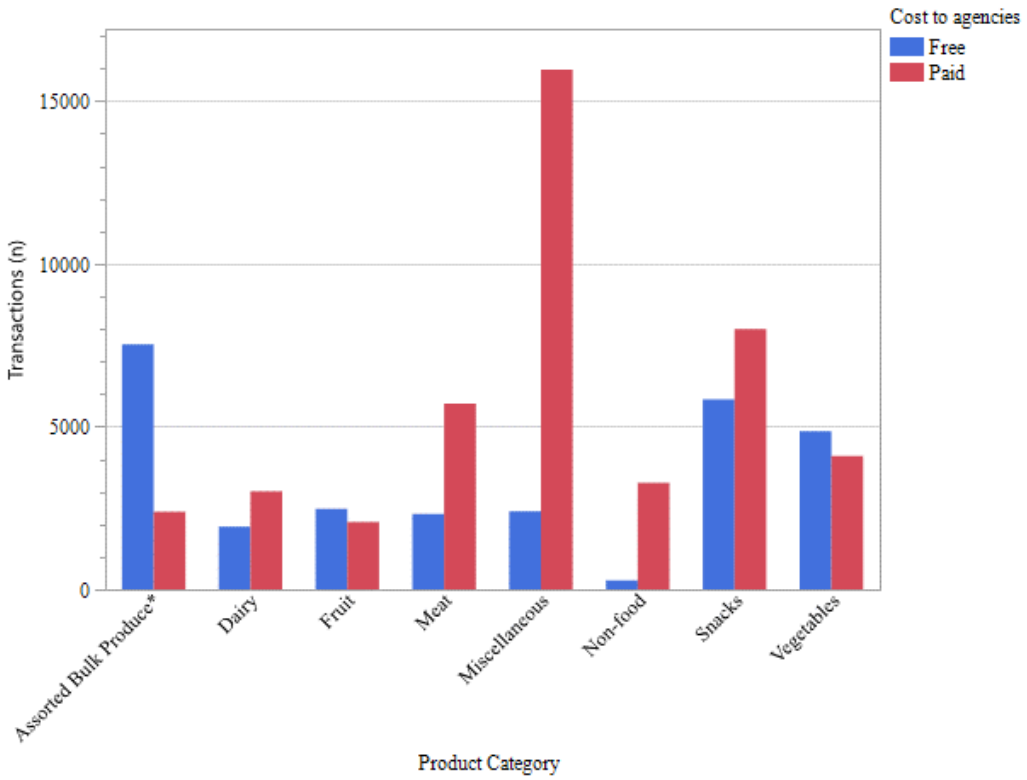

Figure 3: Comparison of free and paid items received by agencies in each of 8 product categories (N= 72,173 transactions)

Note: *Some items listed on the ledger were assorted unspecified produce items, which are all grouped into this category

Community agencies' ordering patterns

The summer and early fall months had a lower number of orders than November through February, except for December, which was lower. These months, including December, are considered the "holiday season". December appears lower quantity-wise; however, orders were typically larger in weight and more costly during this month, which does not appear on the graph. In Figure 3, the total number of orders (n=72173) from July to February is shown and grouped by month.

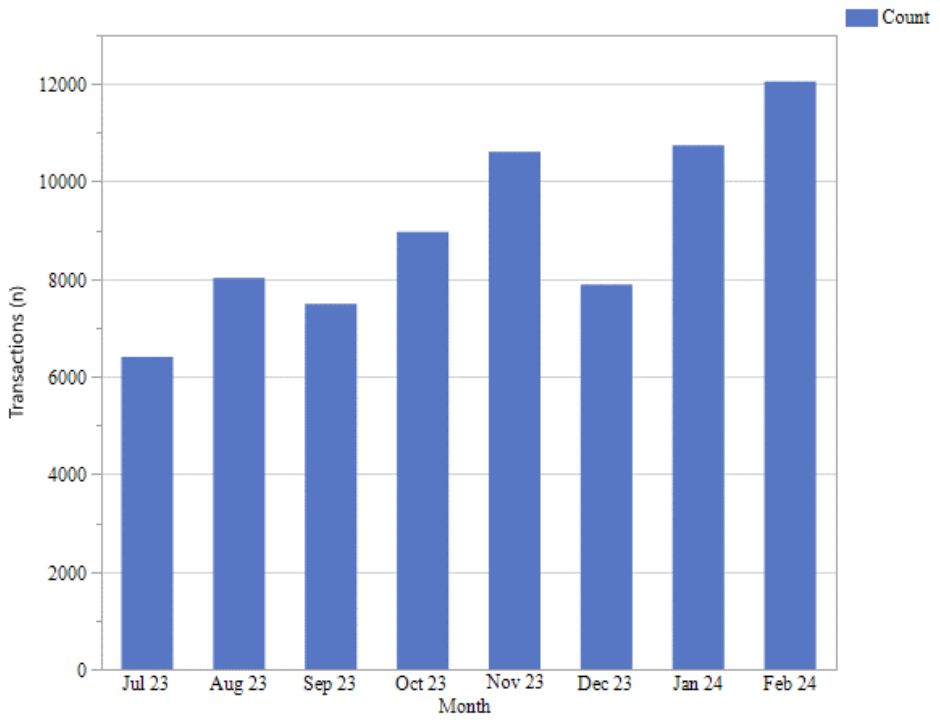

Figure 4: Quantity of orders from June 2023 to March 2024 (N= 72,173 transactions)

Significant differences are found from county to county in prices of all categories except Miscellaneous. The significant p-values (<.05) indicate a difference in means between at least two counties. Higher F ratios, also from the ANOVA test, indicate a higher variation among means, meaning assorted bulk produce and non-food items have the highest variation in price from county to county. That is followed by snacks, with the third highest variation among means. The vegetables, fruit, and meat categories all have similar significant variations in mean price, while Miscellaneous does not have a significant price variation. Table 3 compares the costs of each product category as it relates to the County.

Table 3: Differences in average cost of product category per county as determined by ANOVA (N=72,173)

		County										
	Allegany	**Genesee**	**Livingston**	**Monroe**	**Ontario**	**Orleans**	**Seneca**	**Wayne**	**Wyoming**	**Yates**	**Not listed**	
Product Category	**Mean ±Standard Deviation**											**p-value F ratio (ANOVA)**
Assorted Bulk Produce	170.40 ±358.07	37.41 ±195.94	340.43 ±448.92	211.26 ±729.53	130.56 ±516.78	168.62 ±312.63	178.95 ±379.37	198.52 ±419.97	213.93 ±413.73	85.08 ±281.79	1791.46 ±1710.34	<.0001 64.0500
Dairy	54.14 ±115.06	134.83 ±180.55	100.03 ±187.39	72.37 ±144.59	77.62 ±161.45	105.68 ±195.02	82.47 ±106.33	77.98 ±130.03	142.76 ±227.76	61.55 ±120.59	28.7 ±31.96	<.0001 8.0460
Fruit	34.51 ±84.64	44.88 ±85.72	33.65 ±62.35	47.39 ±105.25	66.87 ±123.53	18.47 ±37.91	34.63 ±59.99	43.38 ±63.36	54.31 ±134.78	28.26 ±70.42	57.14 ±55.87	<.0001 4.6143
Meat	96.00 ±193.03	132.44 ±216.63	106.43 ±195.98	141.01 ±334.03	158.24 ±274.77	92.97 ±173.1	124.35 ±193.02	108.31 ±203.68	211.74 ±343.68	143.70 ±233.22	101.36 ±205.49	<.0001 3.6037
Miscellaneous	119.94 ±750.99	125.16 ±698.21	91.56 ±556.17	116.09 ±783.55	148.06 ±1014.98	106.17 ±595.02	131.56 ±761.6	116.40 ±812.76	191.12 ±650.34	103.80 ±479	53.68 ±119.86	.6597 .7683
Non-food	15.04 ±17.52	42.52 ±81.9	27.13 ±30.03	36.95 ±79.88	25.17 ±32.62	17.36 ±17.62	23.83 ±29.04	23.26 ±42.33	22.77 ±31.58	46.42 ±66.33	289.09 ±483.65	<.0001 38.1818
Snacks	17.67 ±35.69	32.05 ±78.93	27.12 ±52.38	37.11 ±118.29	26.28 ±68.98	15.06 ±33.53	30.71 ±56.37	18.56 ±33.4	42.43 ±125.72	14.88 ±50.32	20.45 ±34.57	<.0001 9.2283
Vegetables	34.54 ±72.56	46.03 ±93.08	26.08 ±49.05	32.66 ±94.24	48.55 ±104.83	24.81 ±45.41	24.73 ±44.06	22.82 ±40.51	44.22 ±126.65	37.13 ±59.79	20.79 ±34.21	<.0001 5.0197

Note: ANOVA analyses were computed. Anything outside of the Upper (UDL) or Lower (LDL) decision limits is considered statistically significant.

All months fell within the decision limits. February is the highest performing month in regards to total transactions, and also average per county per product category. November and January are also above the overall mean, but less so. Additionally, July is lower than the other 7 months. The summer and early fall months all are below the overall mean. Deviation from the mean spans 30-40 transactions at most. Figure 5 shows an ANOM graph, where the means of each month are compared against the group mean.

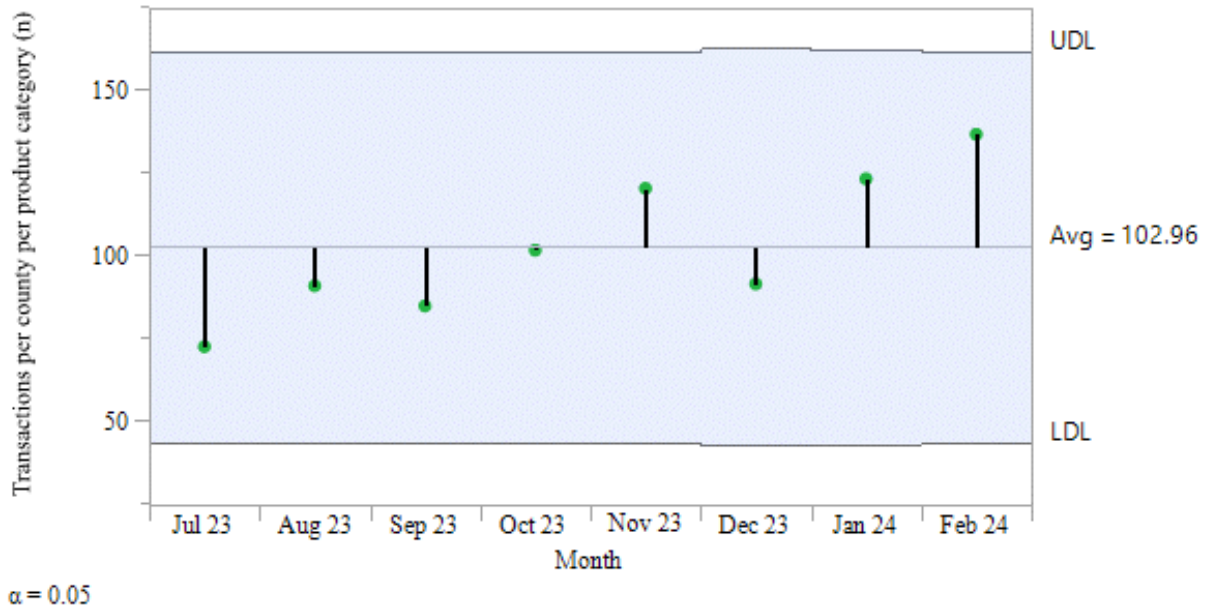

Figure 5: Analysis of means of months in the 8-month time period (N=72,173 transactions)

UDL and LDL (Upper and lower decision limits) - boundaries that determine if the mean is significant (outside bounds)

The miscellaneous and snack categories are higher than the group average, but only miscellaneous is significant. Bulk produce, meat, and vegetables were all within the decision limits. Dairy, fruit, and non-food item transactions were towards the lower decision limit, but only non-food was below it and thus is statistically significant on the low side. Figure 6 shows an ANOM graph, this time featuring product categories.

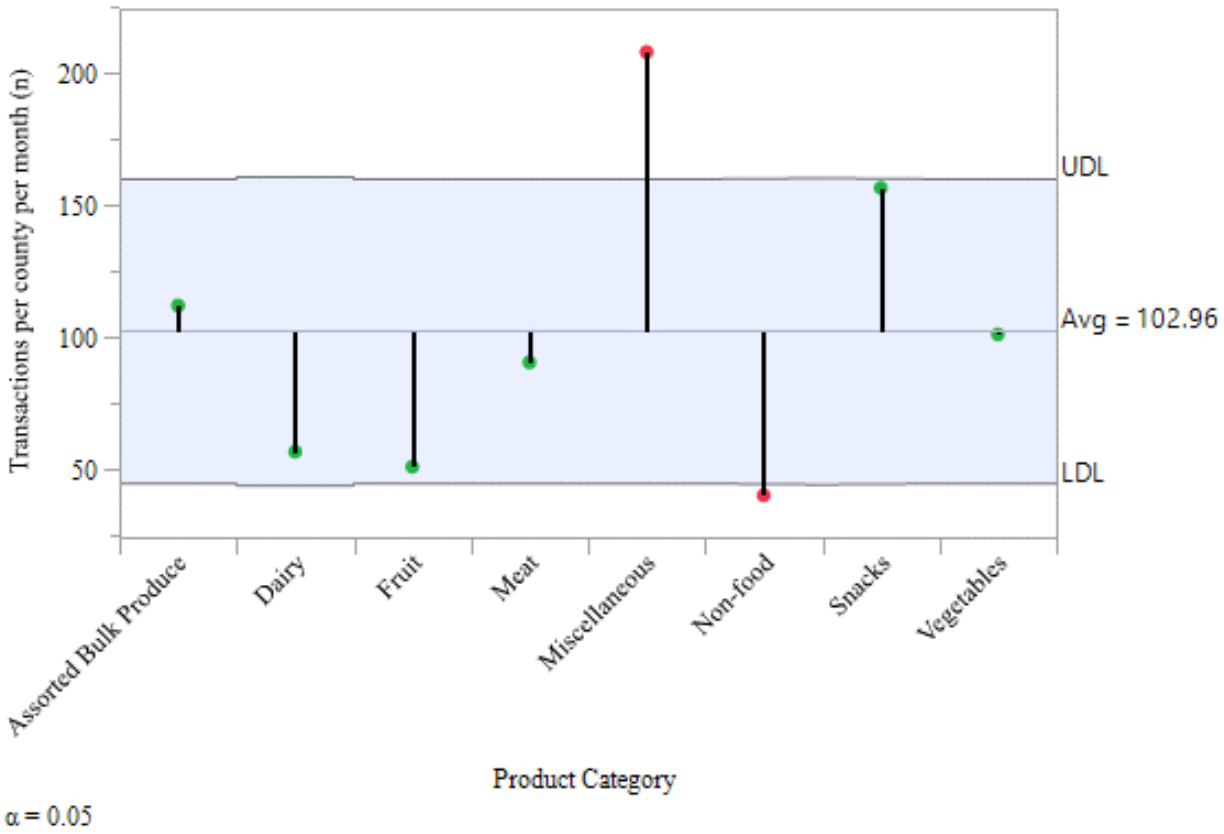

Figure 6: Analysis of means of each of 8 product categories (N=72,173 transactions)

UDL and LDL (Upper and lower decision limits) - boundaries that determine if the mean is significant (outside bounds)

Monroe County was by far the highest county in terms of transactions, so much that nearly every other county was significantly lower than the group mean. The only other three counties within the decision limits were the two with the second and third highest populations and Genesee County. Genesee County was close to falling below the lower decision limit, but ultimately ended up making it in.

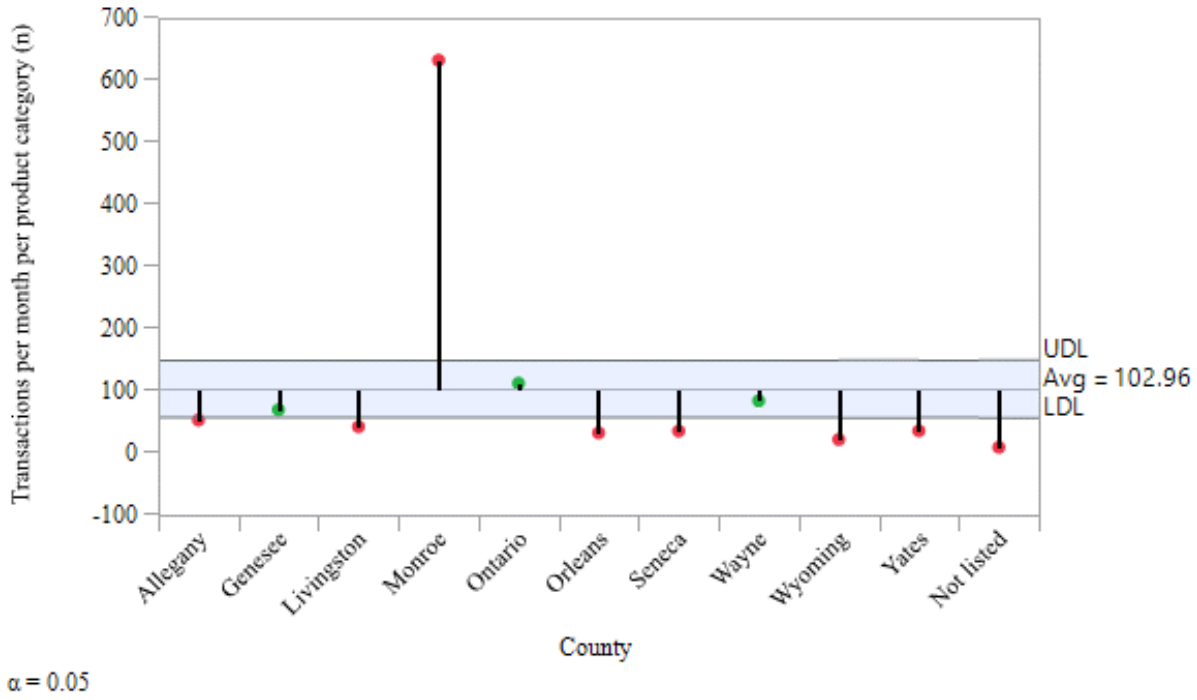

Figure 7: Analysis of mean transactions of the 10-county service area (N=72,173 transactions)

UDL and LDL (Upper and lower decision limits) - boundaries that determine if the mean is significant (outside bounds)

Identify gaps in the food ordering system

The gaps include unclear naming systems affecting both agencies and products, weight measurements, delivery routing, and supply chain concerns. Some effects of this are data usability, difficulty with comparisons from product to product, food waste, and speed of distribution. Table 4 contains some gaps that were generalized based on the literature review and case study analysis.

Table 4: Gaps identified in the efficiency of food ordering systems from literature review and case-study data

Identified Gap	Source identified (Literature/data)	Effect on efficiency
Unclear naming system (Agencies)	Data	Multiple steps to categorize agencies into county or type of agency. Data is difficult to use for forecasting.
Unclear naming system (products)	Data	Variations of names of the same or similar food items pose a challenge for generalizing and reporting. Data usability is impacted due to this high number of items
Quantity/weight measurements and units	Data	Challenges in the comparisons across items, i.e. Pounds of milk vs pounds of food.
Inefficient Routing of deliveries	Literature	Inefficient transportation routing can impact the total output of the food bank, lead to waste, and limit service area.
Supply chain unpredictability	Literature	Unexpected factors impacting supply chain and availability can slow down the process of distribution and efficiency.

Discussion

This project investigated the role of food ordering systems in the efficiency and ability to move food through food banks. Results show that many different aspects must be accounted for to ensure proper function and allow for the improvement of processes. Main findings from the literature review include a need for digitalization and efficient use of technology to improve food bank operations. This finding matches up with the findings of this case study which explain the necessity for efficient organization of products. Additionally, food banks need to have a plan relating to significant changes in the supply chain, so that they may increase or decrease operations effectively. Participant reach of Foodlink is expansive based on total pounds of food distributed over 8 months and estimations of populations served.

From the data, a few things are apparent. Monroe County is far and away the most frequent receiver of goods from Foodlink, which makes sense since Foodlink is located in Monroe

County[42]. They have the highest amount of individuals served but the lowest potential percent of the food-insecure population served. This is likely because of the sheer size of Monroe County and the fact that their food insecure population is greater than the total population of all but one other (Ontario) county. Additionally, the higher quantity of products required and the increased amount of agencies may jointly lead to higher costs of distribution for the agencies within Monroe County. Due to the expansive agency network set up in Monroe County, Foodlink has developed a method for efficient distribution within the county relating to vehicle route optimization, and scheduled orders. This could be confirmed in a future research project. Counties outside of Monroe are less likely to have this set up and thus receive lower quantities of food.

Overall, every county except Monroe could provide 200 pounds of food to at least 75% of the food-insecure population over a year. There is an opportunity for this number to increase in Monroe County as over half the agencies active in the 8 months were from Monroe County. However, supply chain issues and a lower supply of food may be the reason Monroe County couldn't receive more[43]. Seneca County has a higher percentage of food insecure population served, but also a higher estimated cost per person, which may reflect a commitment to making sure they have enough food to support their people. Generally, food distribution in the 10-county service area was consistent, with no real counties lagging, however, food insecurity remains prevalent in New York[38].

Additionally, there was a seemingly random distribution of counties that received items for free. Two of the top four most food-insecure counties received the highest rate of free food, while the other two were further down the list in terms of food insecurity. Some counties with a higher rate of food insecurity received a higher ratio of free items, but other counties with similarly high rates received less free items. A likely reason for the distribution of items received for free is varying costs, as well as feasibility. For example, a county far from the food it is to receive may still need to pay a higher fee even if it has a high food insecurity rate. A balance is necessary to ensure Foodlink makes enough money to continue to operate, that the agencies also can do so, and so that as much food can be distributed to individuals as possible. As this expansion occurs, it is important to consider that some agencies may have limited space to store certain items, and thus expansion may not benefit them.

As it pertains to product category, readily available and non-shelf-stable items such as fruits, vegetables, and assorted bulk produce were more likely to be distributed for free. All of these items are typically overflow items from other vendors and can be donated easily, so that is likely why they were given away free in such quantities. Additionally, being able to distribute produce aligns with Foodlink's mission to build healthier communities[42]. The rest of the categories are harder to come by and are calorically dense. Thus, these items are less likely to be let go for free. The Miscellaneous category featured many different entrée and high protein items that are more costly than other items. By charging more often for those high-profit items, Foodlink may be able to give more items away for free.

Over the 8 months, a pattern became visible. Transactions were more frequent in the winter months, likely due to the financial hardship of the holiday season (November through January)[44]. This is reflected in the increase in transactions from September to November.

Average prices of items saw significant differences in every category across counties except for miscellaneous items. As seen in the paid versus free graphs, Figures 2 and 3, variation between counties was demonstrated. Different counties agencies may be buying different items within the categories contributing towards the differences in the cost, as well as the fact that different counties will have different order sizes. A larger order is more likely to cost more and increase the average. Most inputs in Table 3 had a standard deviation larger than the mean as a result of the aforementioned information. Free items being factored into the average price can cause this.

Analysis of mean transactions per month found that February is the only month with a statistically significantly high mean. Limited data means that finding a real reason is difficult, but it may be that the small data sample shrinks the mean, and thus other winter months are just within the limit, but are close to being significant. The mean transactions of the miscellaneous and snack categories are significantly high because those categories had many items within them, so they were more likely to be more frequent off the bat. Additionally, products that can easily be transported will be transported, and since most of the items in those two categories were shelf stable, they featured in plenty more transactions. Regarding the counties, Monroe had so many transactions that the decision limits were skewed, with only the second and third most populous

counties within the expected range. The counties outside of the lower decision limit all hover around the same area, linking back to a relatively well-distributed number of transactions.

Results from this study are consistent with the themes of other published works. First, the COVID-19 pandemic aftermath could be seen throughout this project, as food insecurity and food availability have decreased since that time[18,43,45]. The consistency of the % of food-insecure population column in Table 2 signifies that some sort of optimization has occurred to make sure each county is taken care of to at least a certain level, as all but one maintain above 75%. Additionally, the use of digital tools to track food bank management is the main way that this project has been able to be done, which is key in the advancement of food bank management[29,32].

Study Strengths and Limitations

Strengths of this project include that it is the first of its kind and focuses on the statistics of just one food bank to provide meaningful feedback. The outside approach may help them gain a new perspective. Some limitations of the project include that there was a limited amount of time to complete it. Additionally, the data received only spanned 8 full months, which made prediction of patterns challenging, and there was limited knowledge of the food ordering process that took place to create the data points received. In addition, food insecurity estimates are merely estimates and not actual measurements through interviews. Since food insecurity can fluctuate throughout the year, and the nutritional value of the items are not known, future studies may address nutritional value of food distributed, as well as participant reach and experiences.

Conclusion and Implications

Overall, the 10-county service area covered by Foodlink appears to be capable and meeting the needs of the communities it serves. An impressive network of over 500 agencies currently

receives food, and an estimated 106,000 individuals can receive up to 10% of their yearly food weight from Foodlink. To expand their reach, a focus on the optimization of routes and looking to find more agencies in counties outside Monroe will be beneficial. A robust ordering system that includes organized item management, comparable sizing, and clear location distinction will allow them to take the next step in their work. Many findings from this project will help Foodlink learn how to forecast in the future.

Recommendations and future research directions

Based on the data and conclusions from this work, future projects can work on similar topics with an inside role. This will allow an understanding of the ordering process and what it looks like from the inside, as that was missing with this project. Additionally, we recommend research at the agency level to assess the community impact using qualitative methods. Based on the gaps identified related to inconsistent naming of food, an improved nomenclature and organizational system within the ledger will make analysis easier. Additionally, it is recommended that size/weight measurements are not used universally for all items so that liquids are not measured the same way as solids for efficient use of data and comparison. Finally, efficient delivery and the ability to cope with emergencies in the supply chain issues will create robust food distribution systems and provide immense benefits to clients.

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