ANALYZING COLLABORATION IN FOOD ASSISTANCE NETWORKS USING AGENT-BASED MODELING

by

JOYITA MOSTAFA

Presented to the Faculty of the Graduate School of

The University of Texas at Arlington in Partial Fulfillment

of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

THE UNIVERSITY OF TEXAS AT ARLINGTON

August 2019

Acknowledgements

Foremost, my sincere gratitude goes to both of my advisors, Dr. Jamie Rogers and Dr. Caroline Krejci. I would like to thank Dr. Rogers for her continuous support throughout the years, for always being patient, positive, and providing great insights into my research work with her expertise. I consider myself exceptionally lucky to have had the chance to work with Dr. Krejci, who has exposed me to new ideas, motivated me to explore them, and given me her generous support and guidance in every little step. I couldn't have asked for better mentors. I also thank Dr. Yuan Zhou for her kind consent to review my dissertation and for being on my Ph.D. committee.

I am very grateful to Tarrant Area Food Bank (TAFB) for supporting this research project. I would specifically like to mention Mr. Bennett Cepak and Ms. Vicky Martinez who have helped me with their time and expertise. I am also thankful to 4Saints Episcopal Food Pantry, Eastside Ministries, and the United Methodist Church Pantry for their support in this project.

Special thanks go to Anuj Mittal from Iowa State University, for providing his technical guidance and resources. I thank my coworker Amin Gharehyakheh for his advice and hands-on help during my research.

I would like to take this opportunity to thank the staff of the Department of Industrial, Manufacturing, and Systems Engineering and UTA Libraries.

My deepest gratitude to my family and friends for their continuous support and kindness.

August 01, 2019

Abstract

ANALYZING COLLABORATION IN FOOD ASSISTANCE NETWORKS USING AGENT-BASED MODELING

Joyita Mostafa, PhD

The University of Texas at Arlington, 2019

Supervising Professors: Jamie Rogers and Caroline Krejci

To address the issue of food insecurity, many small independent agencies, known as food pantries, collect and distribute donated food to food-insecure clients. However, the supply of donated food varies significantly from week to week, leading to frequent mismatches in supply and demand. One approach to addressing this problem is to facilitate greater food pantry collaboration, such that they are able to balance supply and demand among themselves. However, their interpersonal relationships and the additional costs associated with transshipments can be a barrier to collaboration. The objective of this research is to use modeling to gain a better understanding of the conditions that facilitate food pantry collaboration, the degree to which collaboration can improve overall food assistance system efficiency and effectiveness, and the kinds of collaborative structures lead to the best outcomes. This paper describes a conceptual agent-based model of a food assistance network in Tarrant County, Texas, as well an extended model. The conceptual model was developed to test the effects of different collaborative group sizes and different levels of weekly supply variability on overall service levels (i.e., percentage of client demand filled) and transportation cost. Results

suggest that the benefits of increased service levels may outweigh the cost of increased transportation for small collaborative groups. The extended model allows the pantries to choose their collaborating partners according to their preference. Results show a significant reduction in food waste and an increase in service level, but with transshipment costs. This study also provides collected data from 52 pantries under Tarrant Area Food Bank, on their demand and supply, operations, current collaborative behavior and their perspectives on collaboration.

Table of Contents

List of Illustrations

List of Tables

Chapter 1

Introduction

Food insecurity is a serious humanitarian issue in the U.S. According to the U.S. Department of Agriculture (USDA), 15.6 million American families were food insecure in 2016, which means that 41.2 million people in the U.S. did not have consistent access to a sufficient quantity of nutritious food [1]. This number is outrageous, given that approximately 30-40% of the U.S. food supply is wasted [2]. Texas has more food insecure households than any other state (approximately 1.4 million) [3]. To address this problem, the USDA supports multiple initiatives, including food distribution programs, child nutrition programs, the Supplemental Nutrition Assistance Program (SNAP), a special SNAP for women, infants and children (WIC). However, 27% of individuals who are food insecure may not qualify for federal assistance because their gross monthly income is higher than the maximum allowed income for the eligibility for these programs [4].

Extra-governmental, community-based, charitable programs have emerged to fill the gap by providing food assistance to clients in need by rescuing and distributing a large amount of donated food that would otherwise be wasted [5]. For example, Feeding America is a nonprofit organization that rescues excess food from farms, food manufacturers, and retailers in an effort to mitigate food insecurity. It is a nationwide network that comprises more than 200 food banks, which rescued a total of 3.3 billion pounds of food in 2017 [4]. Each food bank has warehousing and transportation infrastructure to facilitate the collection and pooling of donated inventory, much of which is surplus food that manufacturers and retailers are unable to sell. Inventory from the food banks is distributed to a large number of independent and small-scale partner agencies,

also known as food pantries, which then distribute food to individual clients in need. Food pantries often receive donations directly from local retailers, as well.

However, much demand still goes unfilled, not entirely because of a lack of supply, but also because of inefficiencies in distribution and logistics. In particular, while the demand for food at a pantry is generally stable and predictable, donor supply can be highly variable. As a result, in a given week, a pantry's inventory levels for some items can exceed demand by a large margin, while the availability of other items is insufficient. This imbalance often leads to both food waste and unmet client demand.

One approach to addressing this problem is to facilitate greater food pantry collaboration, such that they are able to balance supply and demand among themselves. Some pantries are currently doing this on an informal basis – they share information via phone calls and emails when they have either an oversupply or insufficient quantities of certain highly-demanded items, and they redistribute as necessary via transshipments. However, this process is informal, inefficient, and not widely or systematically adopted. Further, each pantry has different objectives and capabilities, and competitive attitudes can inhibit collaboration. Neighboring pantries often share the same suppliers, and although the food bank tries to be equitable by providing food to pantries on a first-come-first-serve basis, donations from food retailers may depend on their relationships with particular food pantries. Thus, pantries may be competing with one another for resources. Additionally, the pantries incur additional transportation costs associated with transshipments.

The research objective of this dissertation is to use agent-based modeling to gain a better understanding of the conditions that facilitate food pantry collaboration, the degree to which collaboration can improve overall food assistance system efficiency and effectiveness, and the kinds of collaborative structures lead to the best outcomes. Agent-

based modeling (ABM) is a computational tool that can be used to model social phenomena using agents, which are autonomous software entities that can be used to represent individual human actors and organizations. Agents can be programmed to make decisions and to adapt dynamically, based on their individual objectives and their interactions with one another and their environment. ABM has been used to model the relationships and interactions among members of supply networks. In a supply network, where individual firms or groups of firms work as agents, relationships between them change dynamically due to frequent reassessment [6, 7]. Similarly, a food assistance network is composed of food banks, retailers, pantries, and clients, with interrelationships that are continuously reassessed, leading to the dynamic formation of mutually beneficial alliances, as well as adversarial relationships. ABM is particularly useful for representing and analyzing such patterns of relationships among supply network actors.

The structure of this dissertation is as follows: Chapter 2 provides a review of the literature. Chapter 3 describes survey design and collected data. Chapter 4 describes the conceptual model. Chapter 5 describes the experiments on the base and extended model and their results. Chapter 6 provides discussion and conclusions. Recommendations for future work are provided in Chapter 7.

Chapter 2

Literature Review

2.1 Food Insecurity

Food insecurity is a serious problem throughout the U.S. In 2016 12.9% of the U.S. population was food insecure. According to the U.S. Department of Agriculture (USDA), 15.6 million American families were food insecure in 2016, which means that 41.2 million people in the U.S. did not have consistent access to a sufficient quantity of nutritious food [1]. USDA defines food insecurity as a lack of consistent access to an amount of nutritious food which is necessary to have a healthy and active life [1]. Although hunger and food insecurity are closely related terms, the concepts are distinct. Whereas hunger is mainly a physical sense of discomfort, food insecurity is a situation where there are not enough financial resources to get food at a household level. Another closely related term to food insecurity in the U.S. is poverty. Although, many people living below the poverty line do face food insecurity, some of the people above the poverty line also do. Many critical expenses, for example, unexpected medical expenses, paying off debt, expenses due to natural disaster or some accident can lead people to food insecurity [1].

Food insecurity varies regionally throughout the U.S., from extreme points of 36% in Jefferson County, Mississippi to 4% in Loudoun County, Virginia. Although counties with higher populations have relatively low food-insecurity rates, they have some of the largest numbers of food insecure people. Figure 2-1 shows the counties with the highest number of food-insecure individuals, with Dallas at the 6^{th} position and Tarrant County at the 10^{th} [8].

State	County (metro area)	Food Insecurity (#)	Food Insecurity (%)
NY	New York (five boroughs, collectively)	1,215,440	14.4%
CA	Los Angeles	1,147,010	11.4%
TX	Harris (Houston)	738,140	16.6%
IL	Cook (Chicago)	659,990	12.6%
AZ	Maricopa (Phoenix)	585,330	14.3%
TX	Dallas	442,920	17.6%
CA	San Diego	379,130	11.7%
MI	Wayne (Detroit)	366,690	20.7%
PA	Philadelphia County	327,320	21.0%
TX	Tarrant County (Fort Worth)	323,840	16.6%

Figure 2-1 Counties with the highest number of food insecure individuals [8]

To address the problem of hunger, the USDA supports multiple initiatives, including food distribution programs, child nutrition programs, the Supplemental Nutrition Assistance Program (SNAP), a special SNAP for women, infants and children (WIC) [4]. But these programs cannot provide any assistance to many of food insecure people, let alone providing enough assistance. According to Map the Meal Gap project (based on 2016 data), 27% of the food insecure population may not be eligible to receive any kind of federal food assistance. According to the project report, for 104 counties, most of their food insecure population are not likely to receive any kind of federal food assistance. Many urban counties are in this list, as the living expense is much higher there. For example, in Tarrant County, Texas, 36% of the food insecure individuals may not be eligible for any federal food assistance program [9]. In different states, gross income limits are different to be eligible for federal food assistance as living costs are different in different states. In Borden County (TX), 80% of the food insecure individuals are not eligible for any federal food assistance, whereas in Bronx County (NY), 100% of the food insecure individuals are likely to be eligible for some kind of federal food assistance. Figure 2-2 shows different statistics for food insecurity in different counties. Ineligible food

insecure individuals have to depend on family, friends, and charitable assistance when they need help [8].

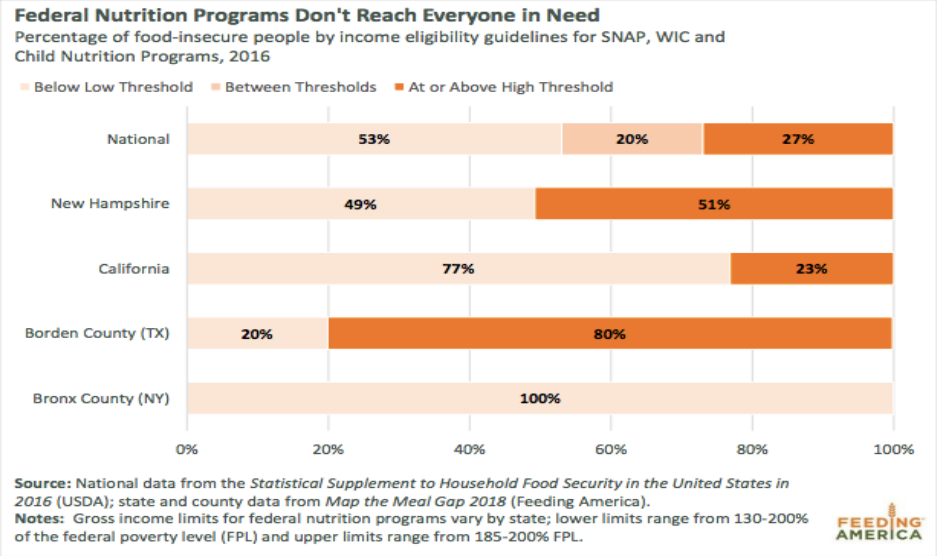


Figure 2-1 Eligibility for nutrition programs for different counties [8]

These statistics related to food insecurity seem more shocking when we consider the fact that there is plenty of supply of food, and there is also a tremendous amount of food waste. $218 billion worth of food loss happens from different stages of food production and distribution, excluding the consumer waste. As Figure 2-1-3 indicates, manufacturers, grocery stores, and restaurants are responsible for 52 billion pounds of food waste. Farms add more 20 billion pounds to the food waste by discarding fruits and vegetables or leaving them on fields. 72 billion pounds of food waste, are perfectly edible [8]. Gustavsson (2011) mentioned in the U.S. food waste and losses including consumer level and retail sums up to 188 kg per capita per year, which has a value equivalent to $165.6 billion [10].

Rescuing and redistributing this food to people in need can help a great deal to alleviate a giant problem like food insecurity. Food banks have warehousing and transportation infrastructure for inventory pooling, sorting and distribution. Food banks collect and store donated food by USDA as well as food retailers as inventory and distributes it to different small independent charitable agencies (also known as food pantries). These small agencies then redistribute among the people in need. One well-known example of a food banking organization is Feeding America. Feeding America, a network of 200 food banks and 60,000 food pantries and meal programs, is the largest hunger-relief organization in the U.S [4]. Feeding America mainly works with three surplus food sources: farms, consumer facing businesses (e.g., food retailers and restaurants), and manufacturers. In 2017, the network was able to rescue 3.5 billion pounds of food [4] and serve 46.5 million people in need of food, including 12 million children and 7 million seniors.

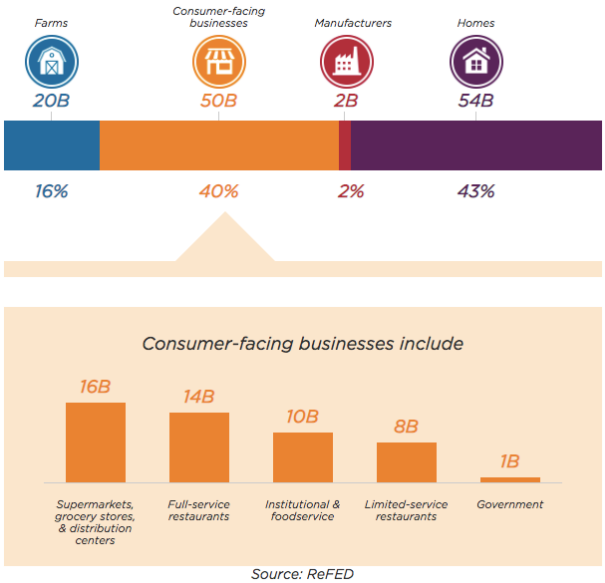


Figure 2-3 Different Sources of Food Waste [8]

Food insecurity is a big problem for many developed countries where food supply and waste are abundant. The idea and implementation of food banks and pantries exist in many of them. Although the existing literature on food banks includes some qualitative studies and some analytical models, there is hardly any published work which takes into consideration the behavior of these various agencies, the interactions among them, and how they can share their existing resources to serve more efficiently.

2.2 Food Bank Studies

Tarasuk et al. (2005) carried out an ethnographic study of food bank work in Ontario, Canada, to explore the effects of a food bank's food donation process on the issue of food insecurity. Their method of study included observations of day-to-day operations and interviews with the staff and volunteers of the food banks, which they carried out in 15 food banks in and around Toronto. They uncovered many challenges, including arguments about quality of work and lack of motivation among food bank volunteers, as most of them are serving in the food banks as mandatory community hours, the quality of the food, and the difficulties in getting quality food in the right quantity, in the right amount, and in the right frequency to clients. Finally, researchers argued that there should be more effective responses from the government of Canada to solve the problems of hunger and food insecurity [5].

Tarasuk et al. (2014) studied 517 different food donation agencies in five cities in Canada. They performed telephone surveys and found that supply is not sufficient for 72% of those agencies and the number of clients served in a month was proportional to the donated food supply on that specific month. They conclude that food banks in Canada largely depend on food donation and volunteering efforts. Because the capacity of volunteers to address client demand is limited, researchers recommend that the government promote and fund more food assistance programs [11].

Warshawsky explored the roles of food banks in the emergency food service system in Chicago, their influence on the institutional structure and stability of member agencies, and institutional relationships among food banks. The authors analyzed key food insecurity studies, food insecurity statistics, and non-profit financial data, and they conducted semi-structured interviews with stakeholders in food security system of Chicago. They found that food banks in Chicago have evolved as institutions that have public and private partnerships and are in control of hunger conceptualization due to their wide delivery system, poverty management as well as organizing distribution of food [12].

Middleton et al. (2018) studied client experiences and perceptions of food banks in developed countries by reviewing 20 qualitative studies. They explored the clients' point of view: how they feel about being fed by the food bank, how they view operations and the attitude of food banks, and the socio-psychological impact of seeking and getting help from food banks. They found that clients had mostly positive experiences with the volunteers and they appreciate the help food banks offer, but there was significant evidence of problems with the quality and the amount of food they received. The issues of social stigma and embarrassment are also very evident [13].

Depa et al. (2018) studied the population characteristics of food bank clients in Germany. They pointed out that there is not enough research and empirical data on food insecurity in Europe. A sample of 1033 food bank clients filled out a questionnaire, which yielded data on the demographics of the clients, as well as the relationships between food insecurity and clients' health, education, and gender [14].

Although the primary goal of food banks is to alleviate hunger, obesity and health-related diseases are a serious issue among food insecure people. Handforth et al. (2012) carried out a qualitative study on food banks in the Feeding America network to gain an understanding of their efforts to serve more nutritious food to their clients. They

interviewed 20 food banks and found that food banks are aiming towards two potential changes. One is nutrition profiling, which includes ranking food according to nutrition, and the other is having some nutrition policies, like not distributing some harmful products which are low in nutritional value, like sugary drinks and candy. Food banks are also focusing on distributing more fresh produce and trying to manage a balance with associated costs [15].

A food bank serves many small independent agencies. For regulation purposes, these agencies receive on-site audits to meet reporting requirements by the food bank. Managing an efficient schedule for the audits often poses a problem. Schneider et al. (2018) developed a multi-criteria vehicle routing model with multiple time windows in an effort to create a more efficient auditing schedule for the food bank, using real data from the Foodbank Inc., in Dayton, OH. The model uses exact and heuristic methods to solve the scheduling problem [16].

Food banks frequently use their own vehicles to collect large donations and to deliver food to rural charitable agencies. These locations sometimes are at a distance which is far enough to worry about the safety of the perishable food items. Davis et al. (2014) developed a set covering model that locates and assigns the agencies to specific food delivery points where they can receive food, subject to vehicle capacity and food spoilage. Then, using the optimal assignment of the agencies, they developed a weekly transportation schedule for the food bank to collect from local donors and deliver it to different charitable agencies, subject to food safety requirements, limited working days for the operators, and collection frequency requirements [17].

Orgut et al. (2018) developed two robust optimization models using historical data from a food bank: one that seeks to maximize the amount of distributed food while maintaining a user-specified level of robustness, and another that places an upper bound

of the level of allowed inequity. The model considers uncertainty in donated food accommodation which can arise from factors like budget and workforce, which vary with different food banks [18].

Food banks receive large donations from supermarkets, and much of the time they do not have any prior information about these donations. This can be a problem in term of managing their inventory and transportation. Brock et al. (2014) evaluated four approximate forecasting methods to estimate the food that will be available for donations from supermarkets, using historical data from the Food Bank of Central and Eastern North Carolina (FBCENC). Results show that projections by the MLR models are poorer than MLP-NN models [19].

Mohan et al. (2011) focused on operational planning issues for a non-profit food supply chain. They developed a discrete event simulation to build a base model that replicates existing warehouse operations, including food supply, process times, layout, and transportation distances as input parameters. Using the model, they experiment with several changes, such as adding a second dock, adding a dedicated storage area, adding length to conveyors, and adding a quality station, in an effort to increase operational efficiency, in terms of handling additional product volume with the same warehouse space [20].

2.3 Supply Chain Coordination

Chopra and Meindl discussed the negative effects of lack of coordination in supply chain. Obstacles that are in the way of achieving coordination in the supply chain and managerial skills to overcome the obstacles are included in the discussion. Actions that are important for strategic partnerships and building trust in the supply chain are also discussed in the same context. Supply chain coordination is present when every stage of the supply chain considers the effect of its actions on other stages, which leads to an

increase in the total supply chain profit. On the other hand, very often different stages of the supply chain have different owner and thus different objectives. Each stage only focuses on maximizing its own profit. Also, they don't share all the important information with each other and they get distorted among these stages. This exaggerated information is a reason for huge amount of product variety in the supply chain. Distortion of the information about demand increases with the upper stages of supply chain leading to large fluctuation between order quantity and forecasted demand. This phenomenon is named as bullwhip effect. [21]

The bullwhip effect minimizes the total profit of the supply chain. It typically increases the manufacturing cost, as firms do not have the proper information about the demand, they tend to produce more than may be required. The mismatch between demand and production fluctuates with variability and increases the inventory cost. It also increases the costs related to replenishment lead time including the transportation and labor cost for expedited shipping and receiving. As a result of larger product variety, scheduling and handling gets even more complicated. Firms must balance the risks of stockouts with the risks of overproducing. This effect effectively hurts every stage of the supply chain and relationships among them [21].

Chopra and Meindl defined obstacles to supply chain coordination as factors that are responsible for local profit optimization for the stages, hinders effective information sharing, such as delay in information sharing, information distortion and increases variability in the supply chain. They have divided them into five different categories and described many possible factors under each category [21].

- Incentive obstacles
- Information processing obstacles
- Operational obstacles

- Pricing obstacles
- Behavioral obstacles

Having identified the obstacles, managers can work towards better supply chain coordination by overcoming them. Authors have categorized different related managerial actions into five categories, they are following.

- Aligning of goals and incentives
- Improving information accuracy
- Improving operational performance
- Designing pricing strategies to stabilize orders
- Building partnerships and trust

2.4 Building Strategic Partnerships and Trust within a Supply Chain

Trust in relationships among different stages of a supply chain results from sharing accurate information sharing and results in dependability. This trust includes believing each stage is looking out for the others welfare. Building trust is beneficial for the overall supply chain. It helps to taking into objectives of other stages in the decision making process. When different stages trust each other, they tend to share more accurate information, as well as they tend to implement appropriate pricing schemes and operational improvements. Building trust also eliminate the effort of duplicating tasks. Overall, it brings a better understanding of demand and facilitates efficient production and distribution decisions [21]

Chopra and Meindl have identified four key steps in forming partnerships in the supply chain. They are following.

- Assessing the value of the relationship
- Identifying operational roles and decision rights for each party
- Creating effective contracts

- Designing effective conflict resolution mechanisms

Identifying the benefits each stage will bring to each other is an important primary step while forming trust-based relationships. It is also important to clarify the contribution from each stage. When each stage has different operational roles, they become dependent on one another, it is important to identify the degree of that, because if one party is more dependent than the others, it may rise conflicts. Contracts for cooperation among partners are beneficial and often lead to effective negotiations for potential future unplanned situations. They are most effective when information is available to every stage completely. Although, conflicts are impossible to avoid, effective resolution mechanisms can strengthen the relationship. If one party is not satisfied by the resolution, it would hurt the long term capabilities of the partnership [21].

2.5 Supply Chain - Horizontal Collaboration

Audy et al. (2011) studied four Canadian furniture companies in their case study emphasizing on their transportation system to the market and how potential transportation collaboration can be useful in time and cost savings [22]. Bernabeu et al. (2015) explored the area of horizontal cooperation for road transportation, which is beneficial in terms of cost savings as well as greenhouse gas emissions. To find the savings in costs, routing costs and environmental costs, they have examined different scenarios and applied different algorithms for various vehicle routing problems [23]. Hezerkhani et al. (2016) proposed a solution for sharing truckloads for delivery using cooperative game theory [24]. Furtado et al. (2014) presented a transportation model for resource sharing using Netlogo and compared and analyzed their model with traditional transportation model. Their findings suggest that resource sharing is beneficial from financial, operational, social and environmental perspectives over the traditional model [25]. Krajewska et al. (2008) analyzed the benefits from freight sharing in terms of profit,

for the entire coalition as well as for each participant. They have used features from routing and scheduling problems as well as cooperative game theory [26].

Verdonck et al. (2013) mentioned scarcity in the available research in horizontal cooperation in logistics. Horizontal cooperation can be hugely beneficial for the companies working in the same level of the supply chain and have similar activities in terms of logistics. As the available research is also scattered, they have performed a scientific literature review and organized them into order sharing and capacity sharing [27].

Hingley et al. (2011) explored the idea of using fourth-party logistics management in horizontal collaboration of grocery retailers. They took a qualitative approach and carried out semi-structured interviews three suppliers, three logistics service providers and one grocery retailer. Their found that establishing fourth-party logistics management can be very expensive, large LSPs can afford them for some major potential benefits but it can also be a hindrance for the dynamic of supplier-retailer [28].

2.6 Horizontal Collaboration - Regional Food Supply Chain

Mcadam et al. (2014) mentioned horizontal collaboration is helpful for small and medium-sized enterprises, even though the competition among them exist, but they need more resources and innovative products. They explored this sort of collaboration in a network of bakers, a part of UK agri-food sector. They have studied the network for 27 months and summarized the life cycle development of the network in their developed conceptual model [29].

Bosona et al. (2011) studied a local supply chain and proposed a coordinated supply chain with more logistics efficiency, reduced environmental impact, increased market and increased the transparency about the origin of the food for the customers to

track. The study took place in Sweden and they used data from 90 local food producers and 19 food distribution centers [30].

The new emerging food consumption patterns include consuming local products, which make the food supply chain short. As a contrast to globalized food model, short food supply chain is facing many challenging, among those logistics is prominent. Nsamzinshuti et al. (2017) studied the literature relevant to short food supply chain and identified and descried collaboration as a solution to the logistics related problems as a result of their desk research and semi-structured interviews they conducted with different stakeholders from the related supply chain and proposed a framework to establish collaboration in logistics of short food supply chain effectively [31].

2.7 Supply Chain Collaboration and Competition

Collaboration and competition affect the supply chain performance in different and important ways. Whereas collaboration is commonly considered a key success factor, competition among the organizations can be viewed as a major hindrance to the way of collaboration. However, some studies found the competition factor to be beneficial to the supply chain. Arvitrida et al. (2016) took an agent-based modeling (ABM) approach to explore the effects of collaboration and competition. The model is a theoretical model, not an empirical one, as that would be limited to a specific supply chain. They have mentioned, although, discrete-event simulation and system dynamics are common tools to analyze supply chains, ABM is not. They simulated collaboration and competition in two stages of supply chain. The agents of the model are suppliers, manufacturers and customers. This research has studied how various firms perform considering their responsiveness and efficiency with different levels of collaboration and competition. The inputs and the basis of experiments were collaboration strategy and competitive behavior. Collaboration strategy involves duration of collaboration between suppliers and

manufacturers and competition was driven by the desire to earn more revenue. One of the outputs of their model are the resulting service level which is computed by dividing the number of customers served by the total number of customers in the system. The other output of the model is manufacturer's revenue. Their results suggest that with higher level of "customer willingness to compromise" which means, customers choosing products that were not necessarily exactly what they wanted, results in a higher service level for the system. Whereas, higher level of "customer loyalty" which is the probability of choosing manufacturers they have chosen previously, doesn't always have positive impact on service level and revenue for the manufacturers [32].

Liao et al. (2017) studied relationships between supply chain collaboration, supply chain capability, and competitive advantage for the networking communication industry in Taiwan. They studied 74 firms in that industry and their method of research was structural equation modeling, which basically is a set of different mathematical models, different statistical methods and computer algorithms. They have reviewed related literature and developed related hypotheses. These hypotheses suggest the positive influence of supply chain collaboration on supply chain capabilities and competitive advantage, they also include the relationship between supply chain collaboration, supply chain capability and competitive advantage. Figure 2-4 shows their conceptual framework.

The measurements they considered for the supply chain collaboration were information sharing, incentives alignments, individual supply chain member behavior and behaviors between the members. They have used the measurement table for supply chain capability which was proposed by Morash et al. (1997) and Lynch and Ozment (2000) [34, 35]. They referred to the study by Hill and Jones (2001) to study competitive advantage. Their method of data collection was to survey. Their samples included

upstream, midstream and downstream members of the supply chain network. Their research framework is shown in Figure 2-5.

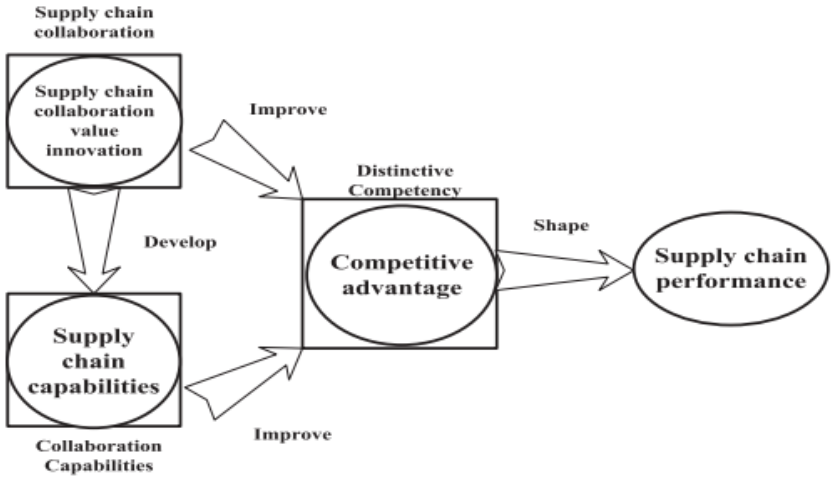


Figure 2-4 Conceptual frame work [33]

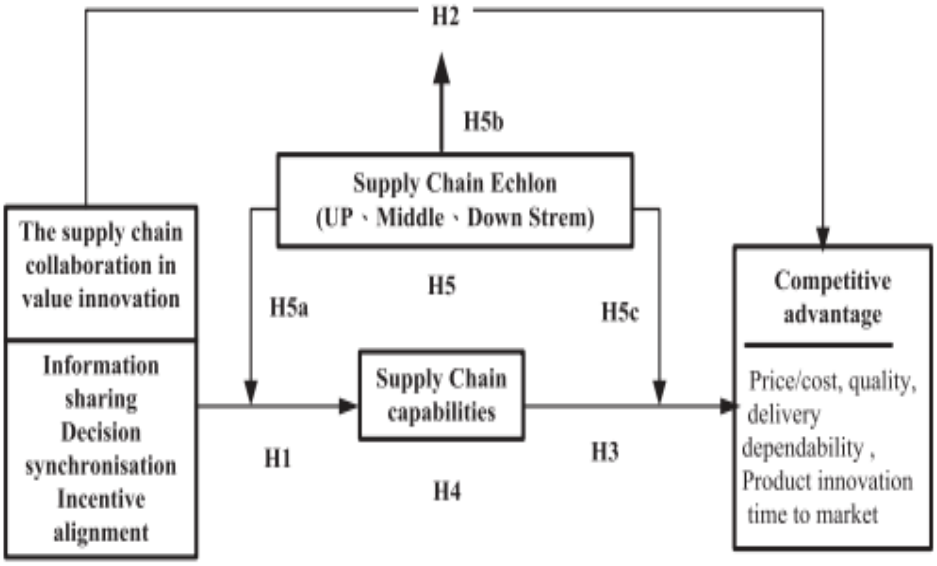


Figure 2-5 Research Framework [33]

From the collected data, they studied different relationships between supply chain collaboration, capability and competitive advantage. They concluded that, Taiwan networking communication industry should pay more attention to supply chain collaboration to gain more competitive advantage, although they have mentioned that they have studied only a small part of industry [33].

2.8 Understanding Collaboration among Non-Profit Organizations

Guo et al. (2005) studied 95 non-profit or charitable organizations from urban areas and found that formal collaborations are more likely to happen with bigger organizations with larger budgets. They have studied the existing literature and explored different forms of collaborating among non-profit organizations. They have mentioned that existing literature for collaboration among organizations has two major limitations. First, they did not take into consideration the difference between within-sector and cross-sector collaboration and second, the focus lies mostly on the theoretical framework for the organizations. Pfeffer et al. (1978) studied the resource dependence among non-profit organizations, they proposed, collaboration among the organizations is a strategy to manage the external dependency and uncertainty in their resource environment. [37] Williamson (1975, 1985, 1991) studied transaction cost theory and concluded that collaboration results in maximized economic or psychological benefits by reducing transaction costs [38]. But these theories have critics, as there is not enough consideration of institutional environments of organizations and the effects they have on making strategic decisions (Galaskiewicz (1985) [39]. Gio et al. considered these limitations and agruments from Galaskiewicz and Bieflefeld (1998) because considering institutional environments is important in non-profit collaboration as these collaborations are very often can be explained by mandated inter-organizational relationships. This study explored two areas: 1) the reasons behind unique kind of collaborations among

non-profit organizations and 2) the inter-organizational relationship dimension considering resource dependence. Through studying literature, they have identified eight different activities to form collaboration. Depending on the formality level in the collaboration, organizations perform a subset of these activities including informal collaborative activities like information sharing, referral of clients to formal collaborative activities like joint program, joint venture, merger, etc.

They then seek to identify under which circumstances non-profit organizations form formal collaboration. Studying relevant literature, they formed five hypotheses. The hypotheses are following:

Hypothesis 1: “An organization with greater resource scarcity (or smaller resource sufficiency) is more likely to develop formal types of collaborative activities.”

Hypothesis 2: “The likelihood of developing formal types of collaborative activities is curvilinearly (taking an inverted U shape) related to the number of an organization’s government funding sources.”

Hypothesis 3: “The likelihood of developing formal types of collaborative activities is associated with an organization’s industry of operation.”

Hypothesis 4: “The more linkages and organization has with other nonprofits through its board, the more likely it will develop formal types of collaborative activities”

Hypothesis 5: “An older organization is more likely to develop formal types of collaborative activities.”

They then collected data through survey to examine these hypotheses. They randomly sampled 376 non-profit organizations of Los Angeles, California. They considered two categories of variable. Dependent variables were- formal collaborative activities and informal collaborative activities. Independent variables were- resource sufficiency, diversity of government funding streams, social and legal services industry,

education and research industry, health services industry, arts and culture industry, board linages, organizational age, board size. With their collected data, they have performed logistic regression analysis. They tested resource dependency to test the hypothesis 1 and their result was contradicting to their hypothesis. Their result shows, firms with higher budget are more likely to engage in formal collaborative activities. Their results support their second hypothesis partially. For hypothesis 3, their results suggest social services, educational and research organizations are less likely to form formal collaboration with other organizations. Hypothesis 4 was removed because they had identified it to be less significant. They tested hypothesis 5 and found older organizations has a higher chance of developing formal collaboration [36].

Inter-organizational collaboration and trust

Tsasis (2009) took a qualitative approach to study the social process for inter-organizational relationships in nonprofit organizations. The findings show that a balance between autonomy and dependence is necessary to form collaborative relationships and to sustain these relationships positive attributes like attitudes, perceptions and trust are important [40].

Snavely and Tracy (2002) explored the importance of trust and influencing factors for developing trust among nonprofit organizations for collaboration. They collected data from two rural regions of the U.S., southern Illinois and Delta region of Mississippi. They have found the rural location as a positive factor in building trust, the organization leaders often get to know each other, thus they feel a common connection and are more cooperative towards each other. Other factors they have mentioned influence the collaborative activities and development of trust among the organizations are race relations, government policies and mandates, leadership and financial and political resources of the organizations [41].

2.9 Agent-based modeling

Models represent abstract descriptions of processes, objects or events and there are many distinctive forms of models. Some models can be manipulated to bring outputs. Computational models require specific inputs which then use relevant algorithms to generate specific outputs. Agent-based models are a kind of computational model that simulates and represents agent behaviors and interactions between them and their environment. These agents are autonomous individuals, elements of a computer simulation and have properties, states and distinctive behaviors [42].

2.9.1 Agent-based models and complex systems- Emergence and randomness

Agent based modeling (ABM) can be useful for various situations but mostly for complex systems composed of many components, whose agents probably interact with each other. Emergence is a common characteristic for complex systems, which can be described as the appearance of complex patterns in the system. ABM is very useful to display these patterns or emergence in a system and can bring out the possibilities of different occurrences, which are rather hard to conceptualize otherwise.

Since agent-based models are not deterministic, it is not difficult to have randomness in them. Whereas deterministic or equation-based models (EBM) demand decisions in the model to be deterministic, ABM can work with stochastic decisions. In case of complex systems, it is very likely that we do not know the deterministic answer for most of the decisions, hence a deterministic model is not feasible.

2.9.2 Comparison of ABM with Equation Based Modeling (EBM) and Systems Dynamics modeling

Equational models are a kind of scientific models which are widely used. Parunak et al. (1998) and Wilensky & Reisman (2006) [42, 43, 44] has explored and identified differences between ABM and EMB and appropriate situations for them. Firstly, with

ABM, agents have individual characteristics, so, it does not require the agents to be homogeneous. On the contrary, EBM works on assumptions of homogeneity. In many real world situations, mostly for the social situations, interactions among the individuals are not continuous, they are mostly discrete. EBM falls short in those situations. Another advantage of ABM over EBM is that, ABM works with simple rules for individual agents and can provide us with the emerging pattern without knowing the aggregate phenomena. Whereas, EBM cannot work like that, knowing the aggregate phenomena is necessary while modeling with EBM. ABM works with individuals with distinct behavior, it does not require an aggregate description. Thus, models are closer to real world situations, which makes them easier to understand for people who do not have technical training.

ABM also provides results with a great amount of details compared to EBM. EBM only provides aggregate results. ABM includes detailed results for individual level as well as for aggregate level, which makes it possible to examine individual's behavior and relationships.

For some cases, benefits of using ABM cannot justify the cost of it. ABM software are expensive and it requires significant amount of training to use them. Situations with large number of homogeneous agents can be modeled more efficiently with some aggregate modeling techniques. Also, situations with a little number of agents can be modeled with detailed equations for each of them. Casti (1995) mentioned ABM to be an useful and justified tool for interacting agents, while the number of agents neither is too large, nor too small, with a range of tens to millions [42, 45].

As discussed above, ABM has a major advantage for modeling non-homogeneous agents. This advantage makes it more appropriate choice over system dynamics for particular situations, situations those demand to examine behaviors of

individual agents and interactions between them and this heterogeneous property of agents is a significant factor for the outcomes. Systems dynamic modeling needs to make separate groups for agents with different behaviors, which is described by Sternam (2000) [42, 46].

ABM makes sense, when interaction among the agents are complex. Heterogeneous agents have different interactions among them which tend to be very complex, which is possible to model using ABM. It is also possible to keep track of the history of behaviors and interactions of the agents and change their behaviors as a result of past interactions among them. This also works, when the agent environment is complex, as with ABM, environments can be modeled as stationary agents, thus can have autonomous behavior and distinctive interactions with non-stationary agents.

ABM also maintains time in a more detailed way. In ABM, interactions among agents are temporary and happens in different times, it does provide a way to understand the system and sequence and tracking of time rather giving a static shot of the whole system.

2.9.3 Limitations and trade-offs of ABM [42]

ABM has many advantages over other modeling techniques in appropriate situations. In some situations using ABM is not efficient. Following are the limitations of ABM [42].

ABM can involve intensive computations as it simulates huge number of agents and that requires great computation power. Whereas, EBM can be simple to run and involve repetitive calculations. Running an ABM is expensive, developing the process and keeping track is also expensive. This cost can be justified is keep tracking of the behaviors and interactions of the agents is necessary [42].

As ABM involves a great deal of details of the model, the modeler has to make lots of modeling decisions and it involves lots of free parameters. Whereas with EBM, the model runs with lots of assumptions and less free parameters. To develop a model with ABM, modeler has to learn the process with great details. If these details aren't necessary, using ABM can be extremely inefficient [42].

2.9.4 ABM vs. rational choice theory – rationality

Johnson (2011) explored the benefits and trade-offs of ABM and rational choice theory. He compared these two theories in terms of tractability versus verisimilitude, equilibrium versus emergence, dealing with bounded rationality and insights and presentation. He pointed out that, rational choice theory tends to simply problems which sometimes can be unrealistic, whereas ABM offers a great deal of tractability, the term the writer used to refer having the amount of details in the model. These properties can be beneficial or can add unnecessary complexity given the situation. For ecological models, about using ABM, Belew et al. (1996) said, "These models offer the greatest promise of realism. But this promise is often not attained because the complexity of the model precludes diagnosis of problems when something goes wrong and inhibits understanding of why interesting results emerge as they do"[43, 44]. Models with great details might not be desirable or efficient for many scenarios, according to Axelrod(1998), "But if the goal is to deepen our understanding of some fundamental process, then simplicity of the assumptions is important, and realistic representation of all the details of a particular setting is not" [43, 45].

The objectives of rational choice theory and ABM are different. The objective of rational choice theory is to seek for equilibrium and for ABM it is to seek emergence, the outcomes or manipulation of the inputs through algorithms are not for to find an

equilibrium, rather to find patterns or emergence. Emergence is an aggregate outcome, driven by simple interactive rules.

Rational choice theory and ABM deal with rationality differently. Rational choice theory models make assumption to have an equilibrium and works to have it as the outcome, by making more and more assumptions. These assumptions aren't realistic in most of the cases.

Arthur (1994) discussed inductive reasoning and bounded rationality in economics theory. He mentioned, assumption of rationality is very helpful to solve theoretical problems. Although, deductive rationality does not always work. He pointed out that human rationality is bounded and it needs certain level of complications and they have to guess other individual agent's behavior, they cannot just assume they would react rationally, many of the times, inductive thinking drives human behavior [46].

2.9.5 Different ABM applications- social science

Schelling (1971) explored different forms and reasons for segregation, specifically individual choices that lead to segregation. These unorganized individual behaviors bring out collective results. He introduced an agent based simulation model with members of two groups as agents and simulated how they choose different locations in the neighborhood [47].

Nowak and Szamrej (1990) build agent based model to explore the effects of individual interactions and opinions on social environment. These opinionated interactions have their contexts and can lead to emerge of a social impact. This impact is the aggregate result or consequence of these interactions, which is not explainable directly, rather is an emergent pattern [48]. Gotts et al. (2003) discussed the application of agent based models for studying social dilemmas [49]. Macy et al. (2002) studied the effects and influence one's individual behavior has over other agent's behavior and how

these simple adaptive interactions lead to unexpected and surprising global patterns using ABM [50].

Axtell (2000) studied and identified the reasons and motivations that lead to use of ABM in social sciences. He identified three motivations, first, ABM is quite similar to conventional simulation modeling techniques, second, it is not always possible to solve a problem analytically, in that case ABM can help to explore possible outcomes, third, it is not always efficient and realistic to try to solve problems analytically [51].

Smajgl et al. (2011) developed a framework for human behavior parameters for agent-based models and also identified twelve different sequences for these human behavior attributes, which serves as a guideline for human characterization [52].

Epstein (2011) took an ABM approach to model civil violence. He modeled two variations of the model, one with the element of revolution with no social and political order. The second model, there is a centralized authority that intend to work against communal violence [53].

Chapter 3

Data Collection

We have collected data in two stages. First we have conducted informal interviews with three food pantries and then we have surveyed 52 pantries.

3.1 Informal Interviews

We have visited three pantries and conducted informal interviews with the managers of those pantries to have a better understanding of their respective processes.

4 Saints Episcopal food pantry

4 Saints Episcopal food pantry was started on January 2017. It is one of the smaller food pantries. They don't have paid staff; the workforce is comprised of approximately 20 regular volunteers.

Service

They distribute food to their clients every Friday from 12pm – 2pm. They serve three specific zip codes in Tarrant County, specifically the east Fort Worth zip codes of 76103, 76112 and 76120. Each client must provide their ID as a proof of address. They serve 550 families per month. They provide clients with a menu, there are few options for the clients to select from the menu. Their volunteers will then shop for the clients according to their choice. Bread and fresh produce items are put out for grabs on a first come, first served basis.

Supply

They get 60% of their food supply from Tarrant Area Food Bank. They pick up their supply on every Tuesday using their own pickup truck. They place an order to TAFB once a week, two days before they need to pick up the order. TAFB does not always fulfill

the complete order, but the volunteers don't know about the supply details until the supply is received. Some items are free from TAFB, other items cost approximately $0.18/pound or less. Other nearby large pantries contribute 30% of their food supply on a weekly basis. Davis Memorial United Methodist Church is the largest contributor and items supplied from other pantries is highly variable. The remaining 10% of their food supply comes from donations. Figure 3-1 shows different sources of food supply for this pantry.

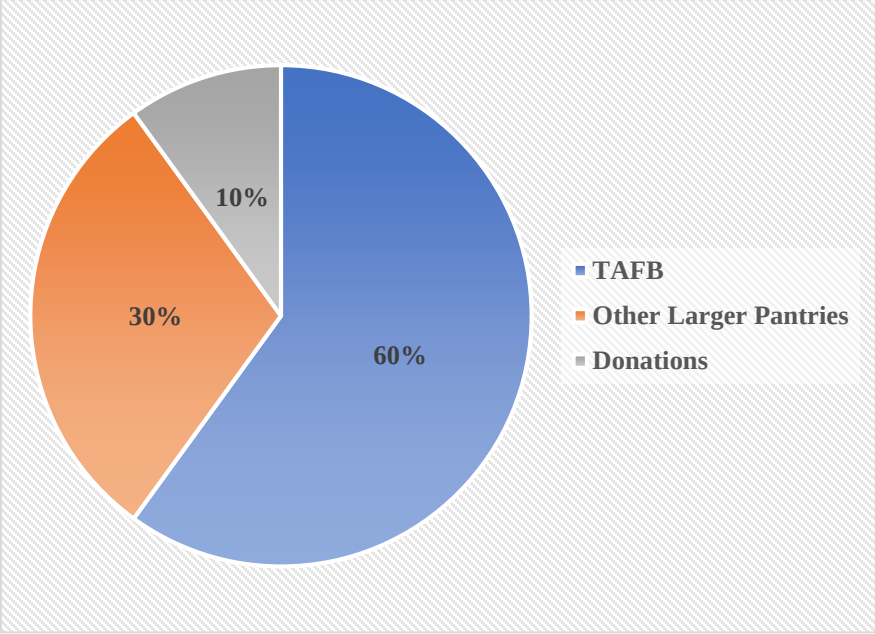


Figure 3-1 Different sources of food supply for 4 Saints Episcopal Food Pantry

Davis Memorial United Methodist Church

Davis Memorial United Methodist Church is one of the larger pantries. This pantry has 56 volunteers, 1 store pickup driver, as well as housekeeping staff.

Service

They serve every Monday 1pm- 2pm and Tuesday and Thursday evening. They also serve specially on Sunday for five families. They do not have any geographic restrictions on clients. Clients can come once per week. Clients can shop themselves inside the pantry with the help of volunteers. They serve 385 households per month.

Supply

They receive food from 7 different food retailers. They have two drivers to pick up food on different days of the week. They also get supply from TAFB once a week. They place order on every Tuesday and pick up on Thursday from TAFB. They also receive deliveries from Walmart and Sam's Club, A TAFB driver picks up those deliveries for them. Their problem with supply is also inconsistency, they wouldn't know what will they get until they have them. They are funded through grants and donations.

Eastside Ministries

Eastside Ministries was started in 1985, it is one of the larger pantries. They have four paid staff and three trainees from SER.

Service

They operate Monday-Friday 9am – 12pm. They serve clients from four zip codes. Eligible clients can get food as well as clothing once a month. They do not offer any menu or choice for the clients. They serve 45 clients/day and more than 600 households per month.

Supply

They receive 75% of their supply from TAFB. The supply is unstable in terms of groceries. Their other 25% supply comes from 5 food retail stores. They have pickup truck and paid staff driver to pick the supply.

Table 3-1 Summary of the Operational Data for the Pantries

	4 Saints Episcopal food pantry	Davis Memorial United Methodist Church	Eastside Ministries
Workforce	All volunteers, approximately 20 regular volunteers.	56 regular volunteers, 1 store pick-up driver, housekeeping staff.	4 paid staffs, three trainees, pick-up driver.
Food Supply	TAFB, other large pantries, other donations.	TAFB, 7 food retail stores, TAFB, Donations.	TAFB, 5 food retail stores.
Service	Once a week.	3 days a week.	5 days a week.

3.2 Survey

3.2.1 Pantry sizes in terms of staff members/ volunteers

We have surveyed 53 pantries under TAFB network. We have divided them into two separate categories based on the number of their staff members and volunteers. Most of their work-force are volunteers, few larger pantries has few paid staffs. We have categorized pantries, who have less than 35 monthly staff members and volunteers, are small size pantries. Pantries with more than 35 staff members and volunteers are categorized under medium-large sized pantries. We have categorized 30 pantries as small size pantries, with staff members and volunteer number as low as 4. 23 pantries

are mid-large size pantries, with maximum number of staff members and volunteers 100+.

3.2.2 Demand and Supply

Frequency of distributing food

Figure 3-2 shows different frequency of distributing food. 26 of the pantries distribute food on a monthly basis.

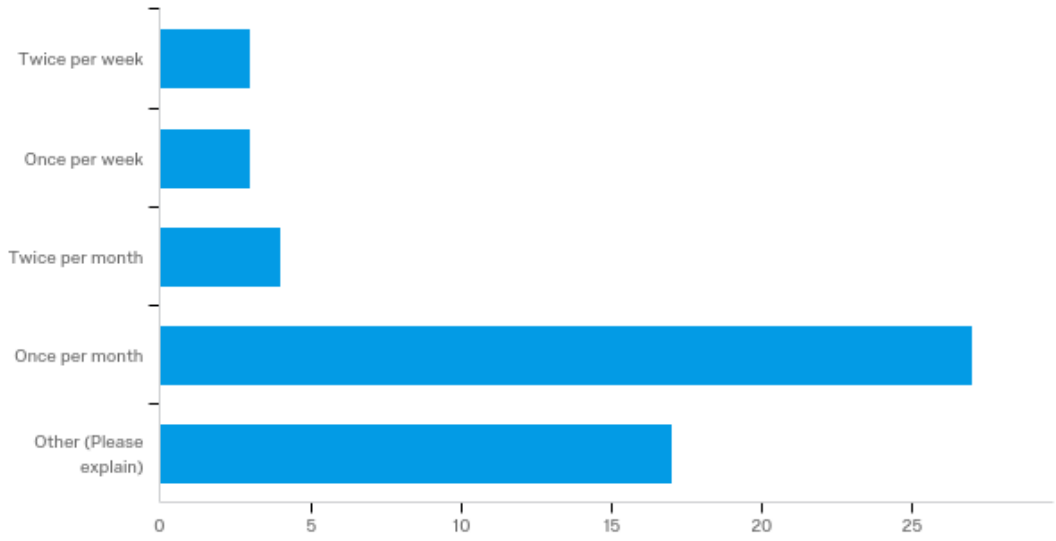


Figure 3-2 Frequency of distributing food

Other option includes:

- 3-5 times a week
- Daily emergency meal supply
- Emergency basis
- 6 times per year

If clients can customize their options?

85% (45 pantries) of the pantries answered, they don't provide a shopping list to their clients, that means, clients cannot customize their order. 15% (8 pantries) of the pantries provide a shopping list to their customers, which provides some options for the clients to choose from.

Demand variability

Figure 3-3 shows demand variability. Only 5 pantry said their client's demand for food varies greatly over time.

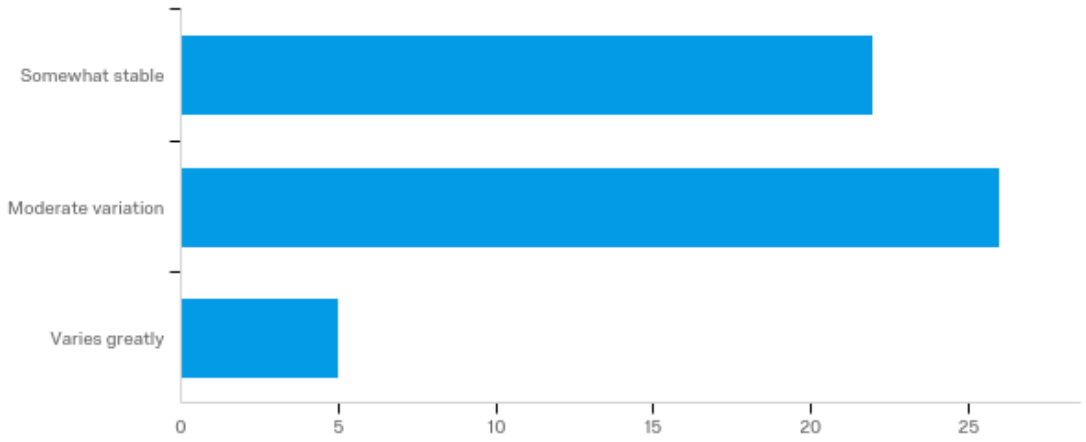


Figure 3-3 Demand variability

Supplier

Figure 3-4 shows the average percentage of food pantries get from each supply source. Although, these numbers varies greatly for each pantries. Some pantries get their total food supply from TAFB or TAFB direct pick up, few pantries get a smaller portion of their supply from them.

58% (30 pantries)of the pantries mentioned some of their supplier provide delivery for them. 42% (22 pantries) mentioned their suppliers don't provide any delivery.

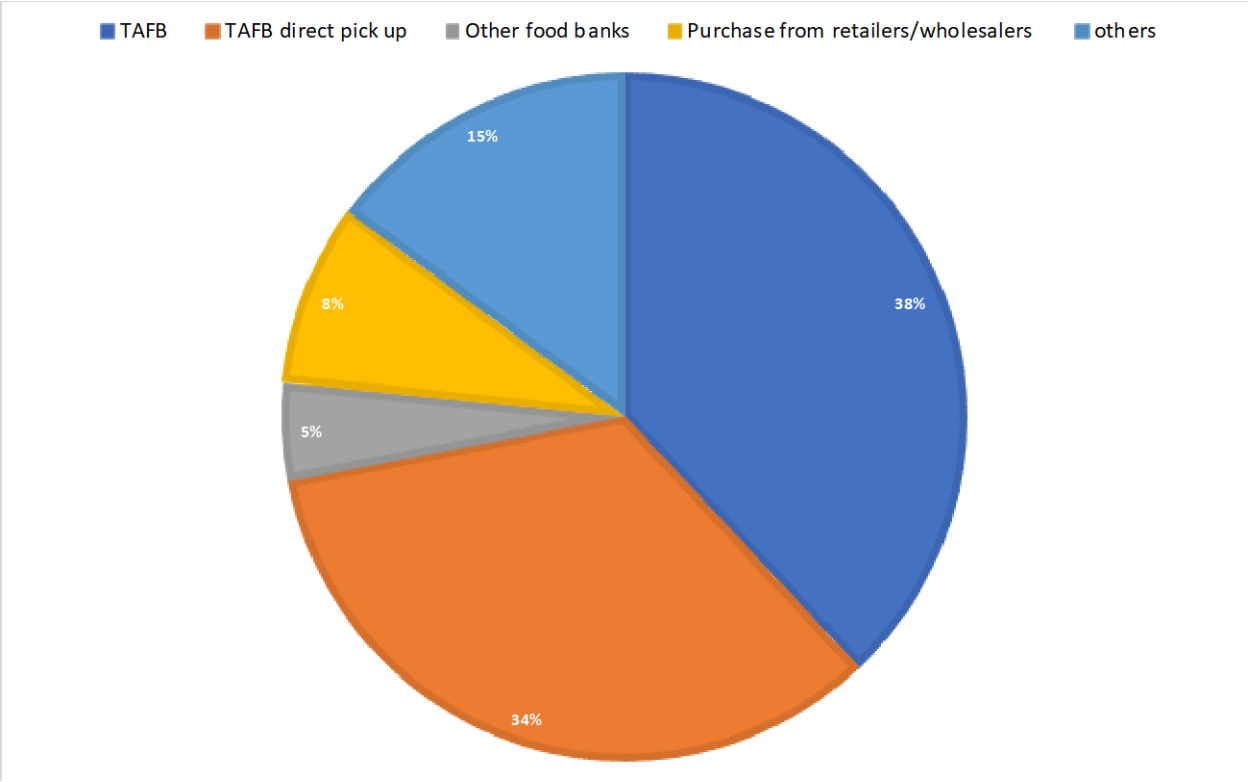


Figure 3-4 Suppliers of the pantries

3.2.3 Food Waste

31 pantries have mentioned their food waste (from spoilage and shrinkage) is between 0-50 lbs. Some of the pantries have little to no waste at all. Whereas, 17 pantries mentioned their food waste per month is more than 50 lbs. Some pantries waste is as high as 1600lbs per month.

3.2.4 Capacity and barrier

Public/ private support

75% (39 pantries) of the pantries mentioned they have enough public/private support to run the pantries. 25% (13 pantries) of mentioned they need more support.

Space and equipment

67% (35 pantries) of the pantries said they have sufficient space and equipment, 33% (17 pantries) of the pantries said, they don't.

Expanding capacity

55% pantries said they are interested in expanding their capacity, 45% said they are not. Many of them provided a brief description, which are provided below:

"Yes. If we could get majority perishable food."

"Yes, more space and resources needed."

"Plans to expand our pantry are under way."

"Yes. We see the need but do not have the space or volunteers to expand at this time."

"I know that I would love to have more room to sort and store more product. We get over crowded almost everyday."

"It would be nice to have more display storage."

"We will be moving to a larger facility on our campus this year."

"We would be interested in perhaps a staple goods pantry that people could come to weekly. It would most likely outgrow the room we have available because of the needs of the community."

"We are always interested in expanding our capacity and serving our clients more efficiently. We are in the process of adding more case management so that some of our clients can move beyond needing a food pantry."

"We need bigger facilities. We need more room for food storage and display including more space for refrigerators."

"We are hopeful to get walk in freezer and a walk in refrigerator."

"We are already in the process of obtaining permits for an expansion of our current building."

"We could use more storage space"

"No. We have a small amount of clients."

"I feel like we are at a good place with the numbers we are now serving."

"We have enough space at this time."

"We can serve as many as come and we have food for at our church location."

"No. limited volunteers available."

"Sorry, we have just the amount of expanding capacity we need."

"No, not at this time. I have adequate space to do our current mission. If the demands of the community changes, we do have adequate space to accommodate more."

"Not at this time, we do not have much traffic and do not need to expand."

3.2.5 Single largest barrier to providing more nutritious food

We have divided the responses to this question into three categories. The responses are following:

Lack of resources:

- "Funding"
- "Cost"
- "Storage space and refrigeration"
- "We are in need of a new box refrigerated truck to take more food into the neighborhoods. We also need funding to maintain daily operations"
- "Space"
- "For us it is money"
- "Building space and more trained volunteers"

- “Lack of consistent volunteers”
- “Funding”
- “Money, space”
- “Money, not enough funds to buy with”
- “Food sources”
- “Not enough food”

Demand vs. supply miss-match

- “Constantly not being able to order needed products”
- “If the food bank doesn’t have it, we don’t really have the money or volunteers to go buy it in bulk”
- “Choice offered by TAFB. Many times they do not have the canned vegetables we need to fulfill proper orders.”
- “Need more produce”
- “Availability”
- “The food to order is not available for us to order it”
- “The produce we get is usually on its last legs and doesn’t keep long, and people tend to donate the less expensive food items so those are usually the less nutritious things”
- “Having enough food and being able to expedite giving that fresh, nutritious food in a timely manner”
- “Some food not always available from TAFB or store donations”
- “The available nutritious food at TAFB”
- “Not enough life on the perishable donations we currently receive. Dairy is difficult to get donated”
- “More nutritious food is not as easily accessible than non-nutritious”

- “TAFB doesn’t always have the best selection of nutritious food. If they do it is fresh and only in large quantities. We can’t store that properly or distribute it before it spoils so we don’t get it”

Transportation and communication

- “Transportation for our clients”
- “Transportation provided to clients”
- “Having it provided by TAFB”
- “Members ability to reach the locations because of age, travel, and help need to get to food locations. Some folks don’t have transportations”
- “Transportation for clients to pick up food from us”
- “Transportation for the elderly”
- “Getting members of the community to come to our food pantry”
- “Communication with those in need”
- “Advertising and marketing

3.2.6 Current collaboration practice

Communication

- No of pantries each pantry communicate with

Figure 3-5 shows the number of pantries each pantry communicate with.

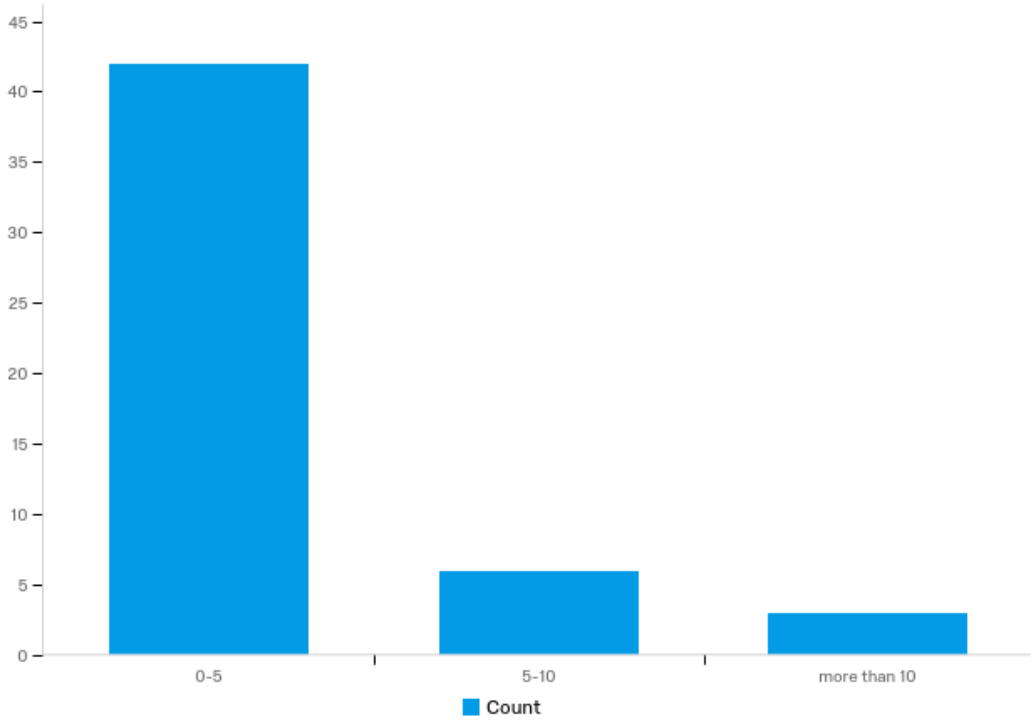


Figure 3-5 No of pantries each pantry communicate with

- Communication medium

Figure 3-6 shows different medium of communication they currently use to communicate with other pantries. The other options include: Hunger coalition meeting 1x per month and flyers.

One pantry has mentioned they use a specific software “slack” to communicate.

- Preferred communication medium

Figure 3-7 shows their preferred communication medium. The other options include: no preference, group meetings set up by TAFB, depends on need, any other electronic means.

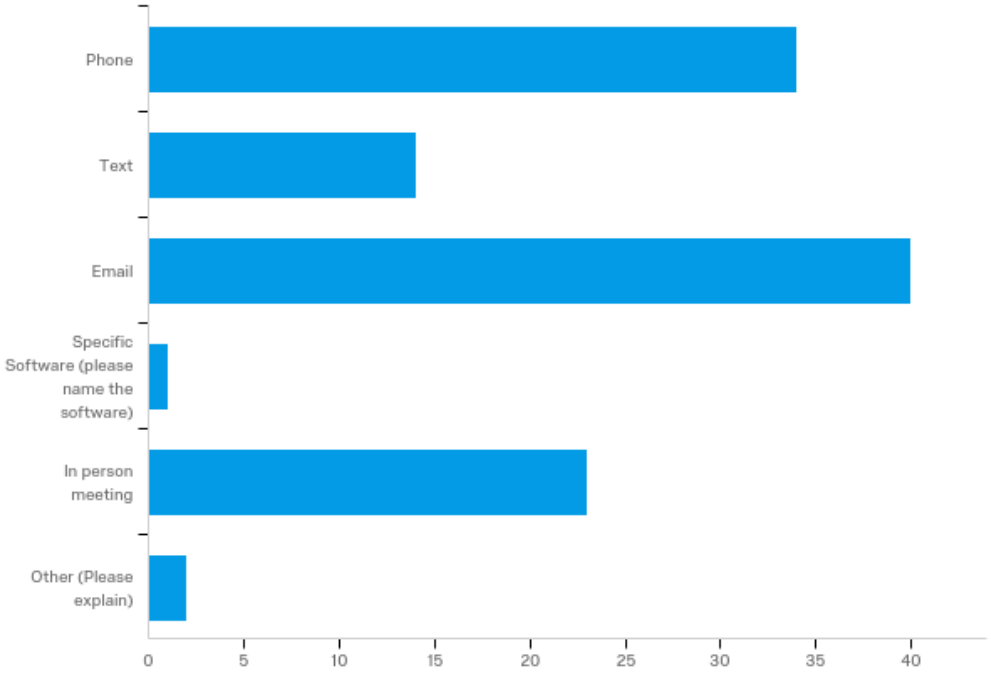


Figure 3-6 Medium of communication

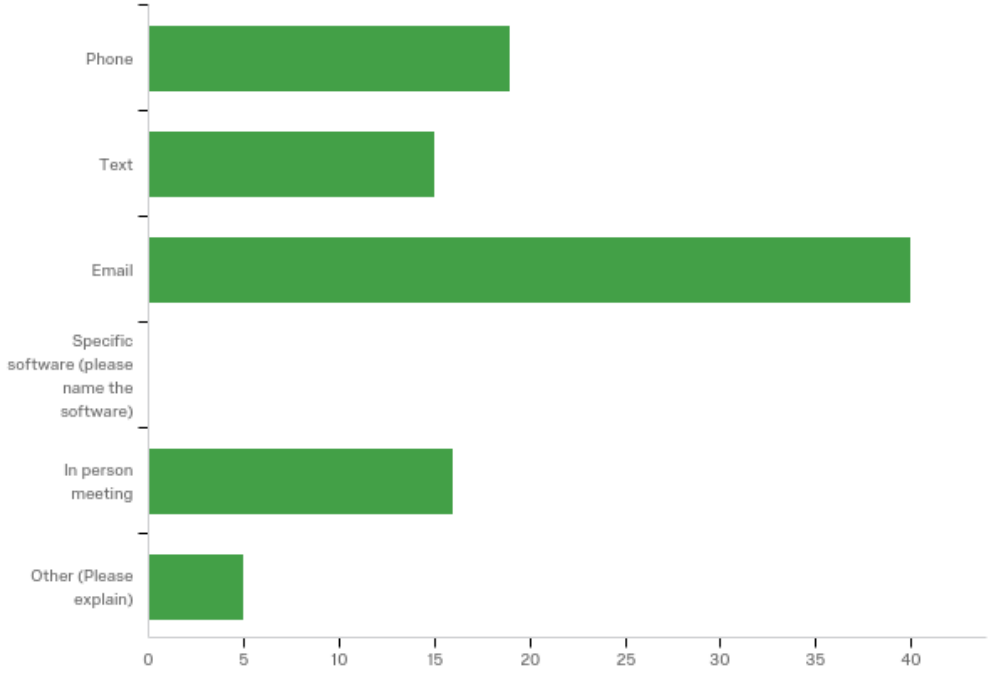


Figure 3-7 Preferred communication medium

- Types of information shared

Figure 3-8 shows the distribution for different types of information they share. Other option includes: reporting, mobile pantry operation, needs, number of families served, non-TAFB sourced stuffs with a few other agencies, legislative related issues, occasional TAFB coordinated meetings of several local pantries, numbers of clients served.

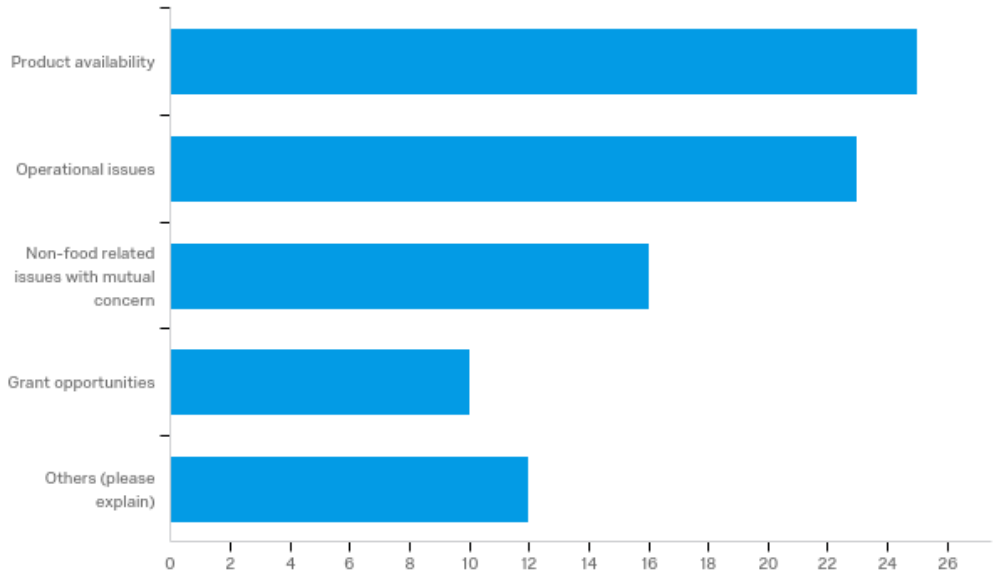


Figure 3-8 Types of shared information

Inventory sharing

- Pantry who shares inventory

25 pantries said they share their extra inventory with other pantries. 26 of them said they don't.

Table 3-2 No of pantries they share inventory with

	1-2 pantries	3-4 pantries	5-10 pantries
No of pantries	14	7	3

- Frequency

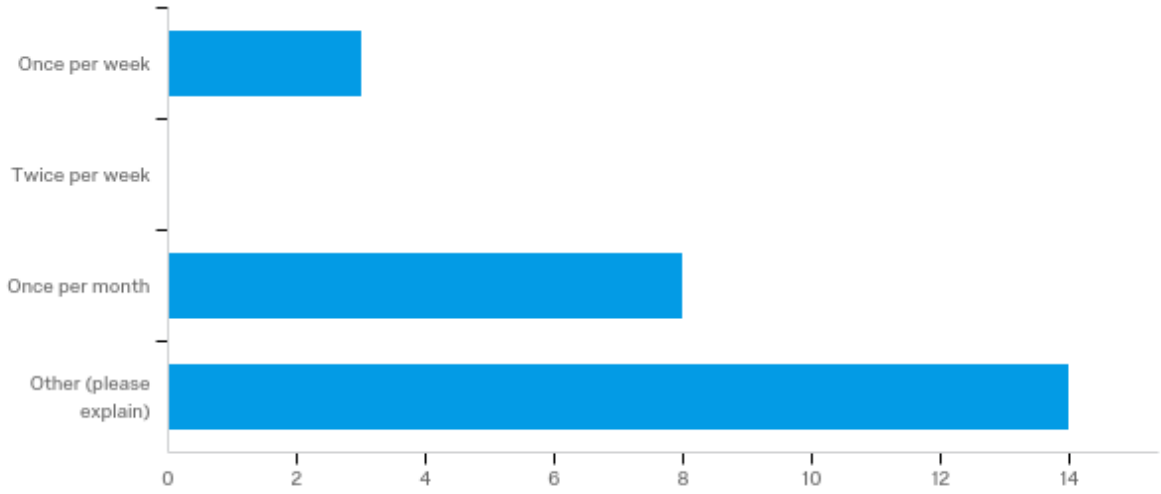


Figure 3-9 Frequency of inventory sharing

Other option includes: “Almost never”, “when excess stock”, “2-3 times a year”,” when we are contacted about a large donation that we do not have room for”,” as needed”, ”sporadically”, “3-4 times weekly”, “when we have extra that is date sensitive”, “on the rare occasion we have excess”.

- Pantry who receives inventory from other pantries

15 pantry said they receive inventory from other pantries, 35 pantry said they do not.

Table 3-3 No of pantries they receive inventory from

	1-2 pantries	3 pantries
No of pantries	10	2

- Frequency

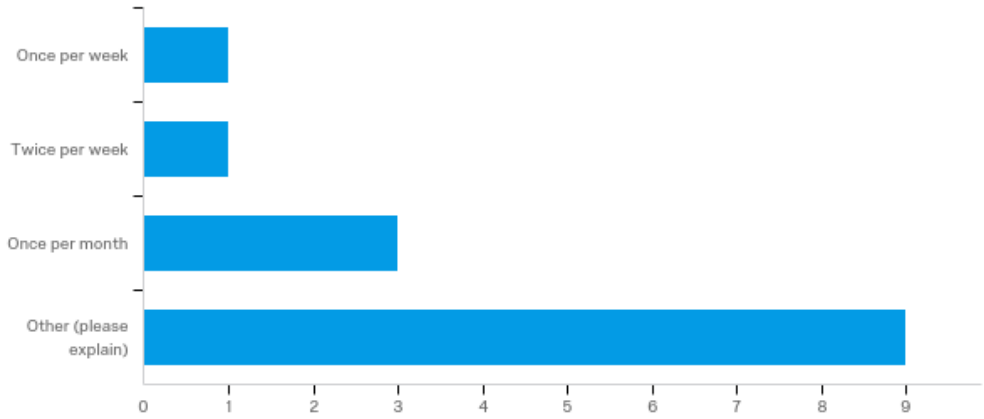


Figure 3-10 Frequency of receiving inventory

Other option includes: “2-3 times per year”, “when available”, “when they have excess”,” as needed”, “occasionally”, “on the rare occasion they have excess”, “when they have extra that needs to go out fast”

3-2-7 Peer Group

Peer group member

29 pantry said they are member of a TAFB peer group, 19 pantry said they are not.

Table 3-4 Peer group meetings

	Yes	No
Attended peer group meetings?	23	2
Find these meetings beneficial for building better relationships with other pantries?	19	5
Find these meetings beneficial for building better relationships with TAFB?	23	1

Perspectives on TAFB's encouragement towards collaboration

If TAFB encourage towards collaboration, responses are shown below.

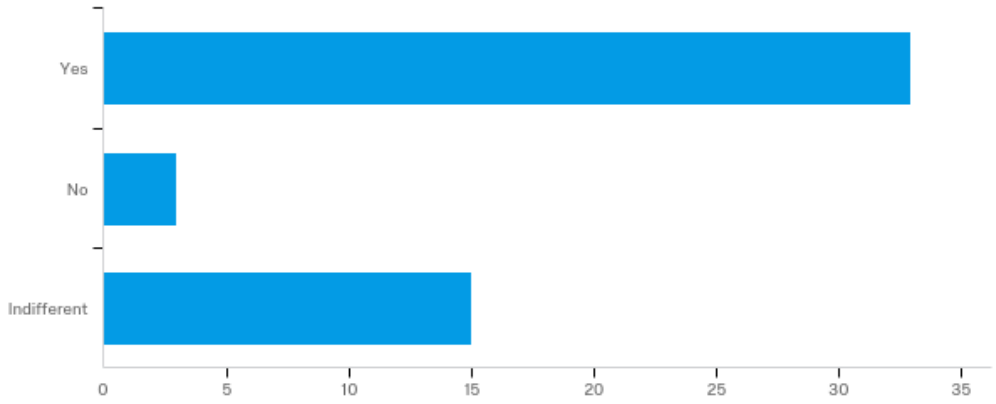


Figure 3-11 TAFB's encouragement toward collaboration

Comments:

- "We feel that collaboration with other agencies connected with TAFB are encouraged by TAFB to work together in their communities to serve they needy public with as much food as possible"
- "We try to meet once a month, share stories, donations, feedback to TAFB what each group is doing at that time."
- "I don't know how much collaboration is encouraged, I hope that they do. We collaborate with some non-TAFB entities in our area that are very helpful to us and supportive of what we do as well"
- "There are a limited number of peer group meetings. Since we only distribute once a month it is slightly more difficult to collaborate with other pantries."
- "Email on attendance of meeting, and training is sent regularly."

- “We are in a fairly remote area and I am unaware of other TAFB pantries close enough to collaborate with.”
- “The meetings have been poorly attended by other agencies which makes them less effective.”
- “They hold several meetings each year for the pantries in our area; the purpose is to get TAFB updates and share best practices with one another”
- “It is at these meetings where I actually meet and find out about the other pantries in my area. Without these meetings, I would not know of their existence. It is also at these meetings where I get the only face-to-face contact with TAFB representatives. I feel these meetings have improved my abilities to serve our neighborhood.”
- “There have been some collaborative meetings between TAFB agents and our local pantries for the purpose of instruction, Q&A, and status of TAFB reconstruction.”
- “I am unaware of pantry collaboration efforts.”

3.8 Attitude towards collaboration

Major benefits of collaboration:

We have divided the responses into different categories. They are as follows.

Serve more people and better service

- “Together we feed multitudes of people”
- “Obviously to feed more people and make best use of the resources”
- “It helps each pantry increase the number of people we can feed”
- “More clients are served”
- “Reach more families with better selection of inventory”

- “Access to more food”
- “So that the community will have a more abundant source of food to choose from”
- “Providing more product to families”
- “Collaboration with other pantries helps all of us to provide better service to our clients.”
- **“**Better and more consistent availability of food”

Resource sharing

- “Being able to accept donations that we do not have room for, a call to one or two other food banks to arrange pickup and storage.”
- “It can lead toward more buy-in from the community. There is also the potential to provide more areas of care in an area if there is less unnecessary doubling of efforts”
- “Share responses with more people”
- “When we have food left over, it would be nice to have a place to take it so that others can benefit. We do not throw it away but sometimes it is a challenge to get it to people who need it”
- “It keeps us abreast of current challenges in the fight against hunger and, quite frankly, helps us feel less alone in the fight”
- “Better distribution of food, better knowledge of effective practices for distribution of food, better knowledge of how to record and track food distribution and donations as well as volunteers, better understanding of how food banks and food pantries receive and distribute food to the public, increased understanding of best practices for food donations/ distribution.”

- “Expanding resources”
- “If we had an overage, it could be shared. Perhaps some pantries buy more bulk and have storage problems so that the inventory needs to be placed where it can be used. If there was a database of available inventory, perhaps pantries could make use of such data to make more efficient purchases of nutritious food items. More and more, the available foods are less and less nutritious. Ironically, the less nutritious items seem to be more preferred by pantry clients than healthy produce, etc.”
- “It has helped us to send items that are not leaving the shelf here to be utilized somewhere else”
- “Each pantry can get what they are in need of and give away extra resources to make room for more needed ones.”
- “More distribution for date sensitive products”
- “If we could share with other smaller agencies, we could break larger bulk quantities down and provide fresh produce to our clients”

Waste reduction:

- “Less food waste, less duplication of services”
- “Not letting food go to waste”
- “No food spoils”
- “Network to alleviate food waste”
- “Excess inventory does not go to waste”

Major barriers that discourage collaboration

We have categorized responses, they are following. 9 pantry said there is no significant barrier that discourage collaboration.

Lack of resources

- “Personally, we never have overflow of inventory”
- “Transportation, resources availability, time”
- “Time, availability of volunteers to coordinate these efforts”
- “Time, Transportation”
- “Space is the number one. Dock’s for loading and unloading is a big barrier, forklift and volunteer man power is another one.”
- “The limited times that the mobile pantries operate and not being able to effectively share the inventory”
- “Just strictly time and logistics”
- “Lack of limited resources”
- “Not enough to share”

Behavioral issues

- “People like control, so there is the tension created from who gets to be “in charge”, plus people disagree on what they thing is the best or most helpful practices”
- “Time to time some pantries have a competitive spirit”
- “lack of interest of other providers, lack of knowledge about what is allowed/not best practice as pertains to handling and sharing of donated/purchased food”
- “Fear of losing donors”
- “People don’t take the initiative and if they do, I see no follow through”

Communication and coordination issues:

- “Not knowing where others are or the time of the month they distribute”
- “Time and contact information of various agencies”

- “Knowing who they are and having a contact person with whom to speak”
- “Communication”
- “Distance from other pantries”
- “Shared online database; the need to take inventory of our own products”
- “Moving resources from one pantry to another”
- “Knowing the personal to work with”

Individual’s preference towards collaborative vs independent environment

36 pantries responded, they would like to work in a collaborative environment,

12 pantries responded that they prefer independent environment

Agency’s preference towards collaborative vs independent environment

34 pantries responded their agency prefer collaborative environment,

10 responded, their agency prefer to work in an independent environment.

Chapter 4

Model Description

This section describes a conceptual agent-based model (ABM) of a food assistance network in Tarrant County, Texas, that was developed using NetLogo and an extension of the conceptual model. The model focuses on collaboration among food pantry agents to balance high variability in the supply of donated food with client demand. While the pantries share a common goal of fulfilling as much client demand as possible, their interpersonal relationships and their locations affect the degree of collaboration. Although completely eliminating hunger in Tarrant County is an enormous challenge, effective collaboration among food pantries could help in achieving this goal.

4.1 Conceptual Model

Purpose of the Model

The purpose of this model is to gain a better understanding of the conditions that facilitate food pantry collaboration, the degree to which collaboration can improve overall food assistance system efficiency and effectiveness (in terms of service level and cost), and the kinds of collaborative structures (in terms of group sizes) that lead to the best outcomes.

Agent Description

This model comprises 23 agents that represent the food pantries belonging to a particular peer group in Tarrant County, Texas. A peer group is a sub-group of pantries within a larger food assistance network that are located within the same geographic region (in this case, the City of Fort Worth). The Tarrant Area Food Bank, which oversees the food pantries in Tarrant County, formed these peer groups to encourage member pantries to share information and insights and to collaborate. Each food pantry agent in

the model has a unique identification number and is characterized by its geographic location, in terms of relative distance from other agents. The agents' locations are assigned based on the pantries' actual distances from each other, which vary from 0.2 miles to 10.7 miles apart.

In the real-life system, each pantry divides its food items into categories and distributes them to clients at least once a week. Many of the food items are perishable and cannot be stored for the next distribution period. The model represents a simplified version of this system and assumes that each pantry agent experiences demand for two food categories (i.e., items) in each weekly time-step: 1000 units of item 1 and 500 units of item 2. These values are assumed to be fixed and constant in each time-step. These values are assumed as constants because, in the real-life system, if there is no drastic change in economy or the demographics of the specific area, the number of food insecure people and their demand for food stays more or less stable. By contrast, the value of weekly supply for each item is highly variable, represented by a normal distribution. The supply is assumed to be highly variable because in the real-life system, the supply from donors is unknown to the pantries ahead of time and fluctuates significantly from week to week. The mean of the supply distribution for each item is set equal to the demand for that item, and the standard deviation is varied experimentally.

The food bank and the clients are not represented explicitly as agents but rather are included as exogenous supply and demand sources, as this model is focused strictly on the collaboration among the pantries.

Model Overview

The model is initialized to consist of an experimentally varied number of collaborative agent groups, each consisting of N agents, which are generated based on proximity. If 23 (i.e., the total number of agents in the model) is divisible by N, the number

of collaborative groups that are formed is 23/N; otherwise, it is (23/N) + 1. In order to initiate a transshipment of food between two agents, these two agents must be in the same collaborative group.

Each time step in this model represents one week, since most of the pantries in the real-life system serve their clients on a weekly basis. In each time-step, each pantry agent assesses its current demand and places an order for that amount to the food bank. The supply from the food bank and donor retailers is highly variable, such that some agents may experience shortages and while others have surplus each week. The food is assumed to be perishable; inventory cannot be carried from week to week. After receiving their weekly supply, the agents assess the difference between their demand and their available inventory for each item. Based on this assessment, they either request supplemental food from other pantries if they have a shortage, or they offer transshipments to pantries if they have a surplus. In each collaborative group, the agent that has the highest amount of inventory available to offer will randomly pick an agent within its collaborative group that has requested transshipment. The transshipment occurs, and both agents update their inventory accordingly. This process continues as long as any agent has inventory to offer and there is unfulfilled demand among the agents in the group. Each transshipment has an associated transportation cost incurred by the supplying agent, which is assumed to be one unit cost for per unit distance traveled.

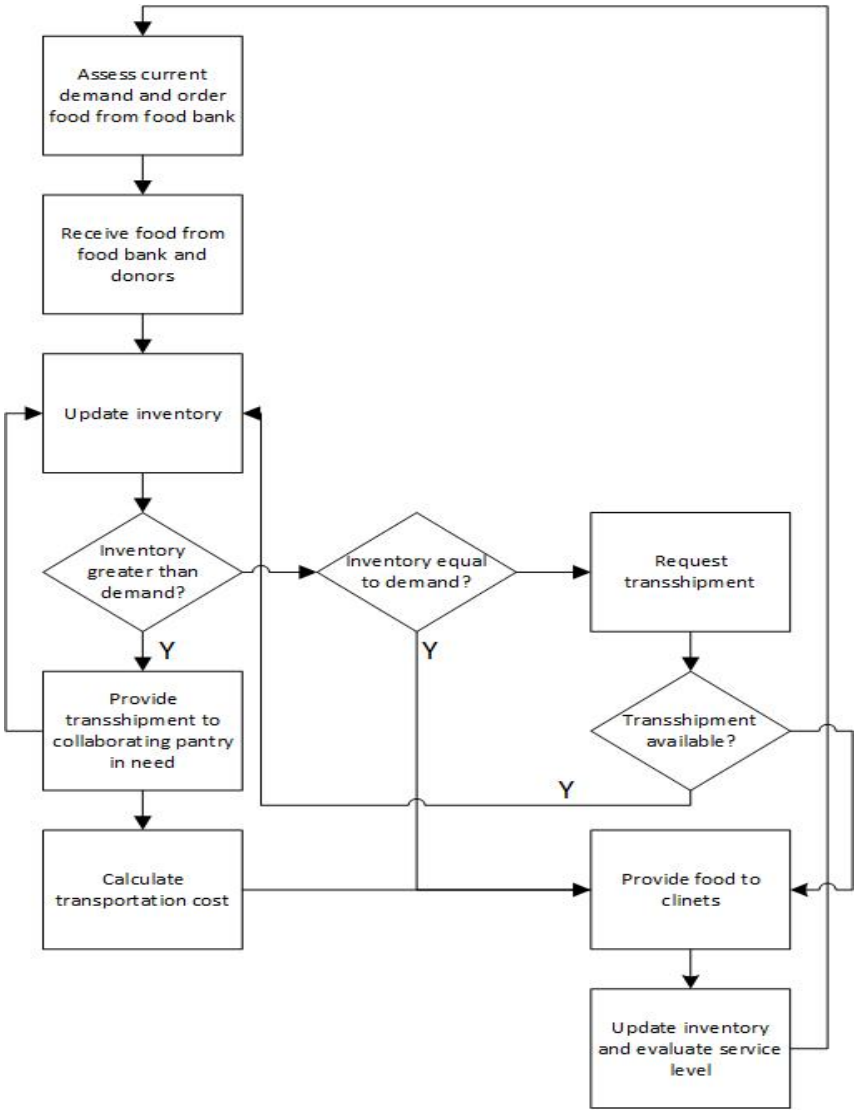


Figure 4-1 Flowchart of the collaboration process for pantry agents in each weekly time-step

4.2 Extended Model

Agent description

The extended model has 100 agents, each representing a pantry in Tarrant county. Each agent has the following key parameters, the value of these parameters are constant over the entire simulation run:

Demand

Each agent has constant demand for two food items for each run. For food item 1 it is 1000 and for food item 2 it is 500. Most of the pantries serve to a specific client base the demand stays somewhat stable over time.

Supply

Supply for this items has a normal distributions with the mean values equal to demand. Since food supply are mainly donated food, the quantity for each item varies a lot with each supply.

Location

Each pantry agent is situated in a specific geographical location. NetLogo GIS extension is used to plot the agents to their specific latitude and longitude coordinates.

Distance

Each pantry agent has specific distances from other pantry agents. GIS extension allowed us to determine distances between any of the pantries at any part of the model.

Satisfaction threshold

Each pantry agent has a satisfaction threshold for other pantry agents, other pantry agents has to satisfy that threshold, for them to collaborate with that specific pantry agent.

Collaboration value

Each pantry agent has a binary value set as collaboration value. For 18 of the agents it is set to be 1 and for others it is 0. Only pantry agents with 0 collaboration value will collaborate with other pantries with the same value. 18 agents will not collaborate with any other agent.

Each pantry agents four state variables that changes with every monthly step.

Offer value

Offer value can be either 0 or 1. If the agent has more inventory than the demand for the item, it will set the value to 1. It will work the same way for each food type.

Request value

Request value can be either 0 or 1. If the agent has less inventory than the demand for the item, it will set the value to 1. It will work the same way for each food type.

Trust value

Each pantry agent has a trust value for other agents, they will update in each time step based on their interaction. If they collaborate with each other, each of them will add value 0.1 to their trust value for each other.

Current utility

Each pantry has a current utility value for the other pantries, this value gets reassessed with each time step. Current utility is a function of distance between the agents and trust value for that agent.

Current utility of agent x for agent y = 0. 5 (distance utility of x for y) + 0.5 (trust utility of x for y)

Distance utility of x for y = (minimum distance between x and other agents) / (distance between x and y)

Trust utility of x and y = (trust value of x for y) / (maximum trust value of x for other pantries)

Model Overview

The model is initialized by setting 100 agents to specific geographic locations. Each pantry has a collaboration value, it is either 0 or 1. Each pantry is initialized with a trust value of 1 for other pantries.

Each time step in this model represents one month. In each time-step, each pantry agent assesses its current demand and places an order for that amount to the food bank. The supply from the food bank and donor retailers is highly variable, such that some agents may experience shortages and while others have surplus each month. The food is assumed to be perishable; inventory cannot be carried from month to month. After receiving their monthly supply, the agents assess the difference between their demand and their available inventory for each item. Based on this assessment, they either request supplemental food from other pantries if they have a shortage, or they offer transshipments to pantries if they have a surplus. The agent that has the highest amount of inventory available to offer will randomly pick an agent within its collaborative group that has requested transshipment. If the pantry who requested the transshipment, satisfy the threshold value, the transshipment occurs, and both agents update their inventory accordingly. Both of the pantry update their trust value by adding 0.1. This process continues as long as any agent has inventory to offer and there is unfulfilled demand among the agents in the group. Each transshipment has an associated transportation cost incurred by the supplying agent, which is assumed to be one cost unit per 20 distance units traveled.

Chapter 5

Experiments and Results

5.1 Conceptual Model

The model was used to test the effects of different collaborative group sizes and different levels of weekly supply variability on overall service levels (i.e., percentage of client demand filled) and transportation cost. Figure 5-1 shows all 23 experimental scenarios, each with different collaborative group sizes, ranging from 23 single-pantry groups (i.e., no collaboration) to one large group that contains all 23 pantries. With collaboration, there is a tradeoff between increasing the service levels and increasing transportation costs associated with transshipments. Two levels of supply variability were considered: low variability and moderate variability. In the low variability scenario, the supply for product 1 is normally distributed with mean 1000 and standard deviation 500, and the supply for product 2 is normally distributed with mean 500 and standard deviation 250. In the moderate variability scenario, the supply for product 1 is normally distributed with mean 1000 and standard deviation 1000, and the supply for product 2 is normally distributed with mean 500 and standard deviation 500. One hundred simulation replications were run for each scenario. Figure 5-2 and Figure 5-3 show the overall service level (i.e., percentage of total client demand filled) for each of the different group structures for moderate supply variability and high supply variability, respectively. For both levels of variability, there is a significant increase in service level from experimental scenario 1 to 2 (i.e., from non-collaborating individuals to pairs working together), particularly for the very high variability case (increase of 9%).

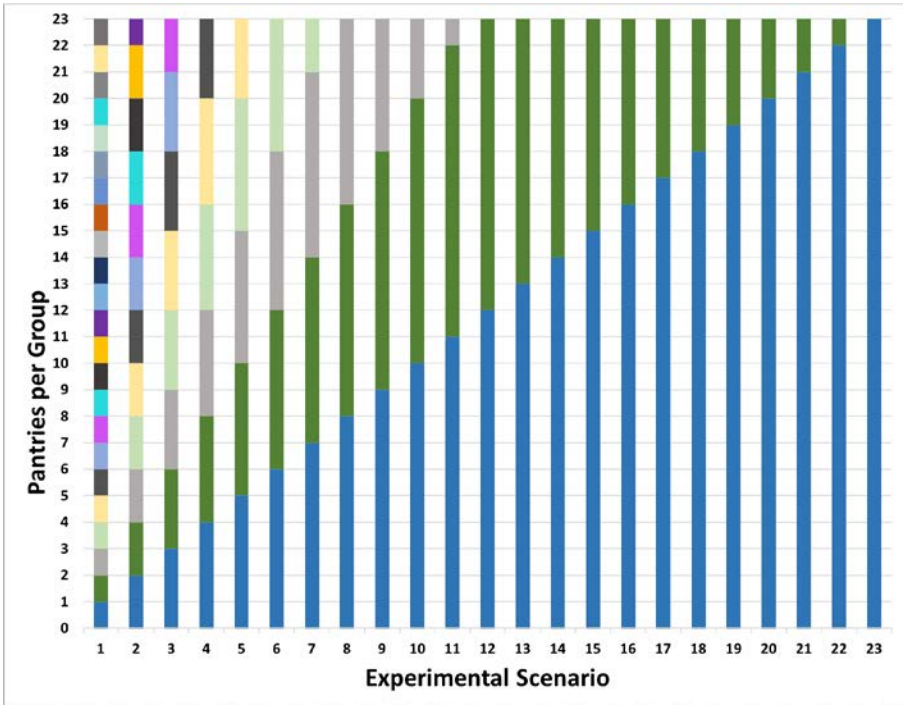


Figure 5-1 Collaboration Group Structures

There is no significant increase in service levels for group sizes greater than 4. With very high variability, which means more discrepancy between supply and demand, the service level is very low for no collaboration (mean of 59%). The effect of variability is also observable among the replications: especially when there is very high variability in supply, there are many specific replications that show a very low service level (i.e., outliers).

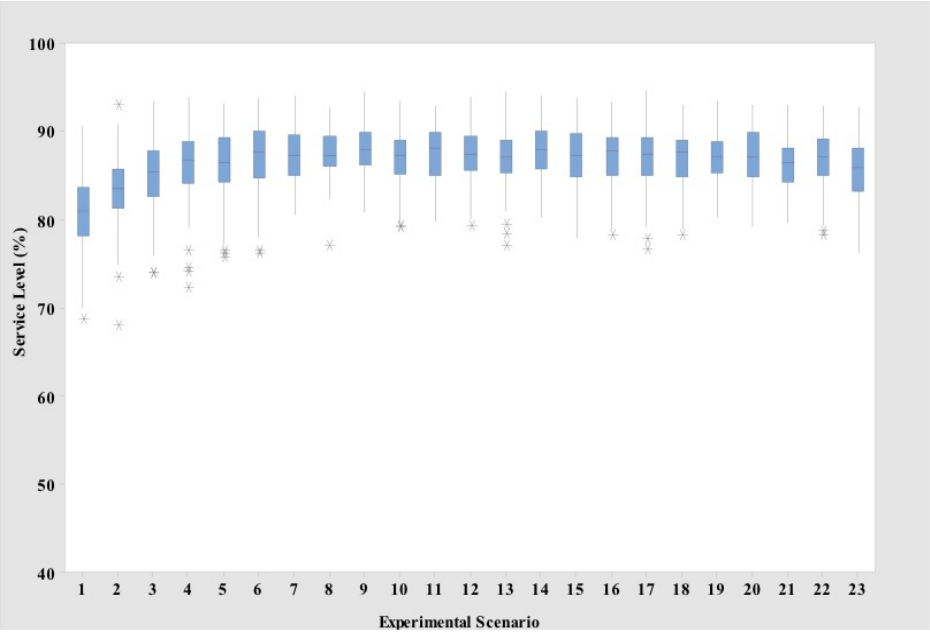


Figure 5-2 Service Levels Under Moderate Variability

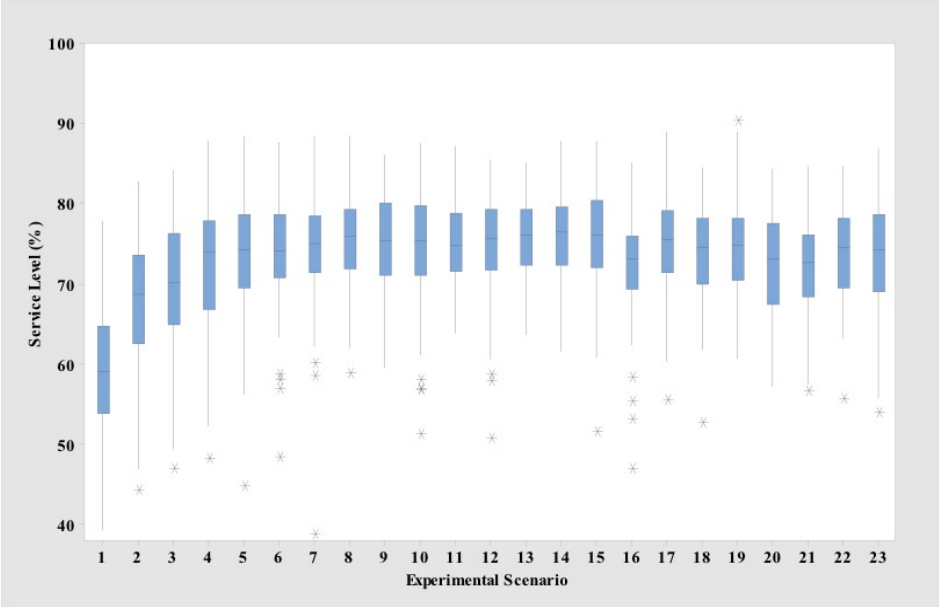


Figure 5-3 Service Levels Under High Variability

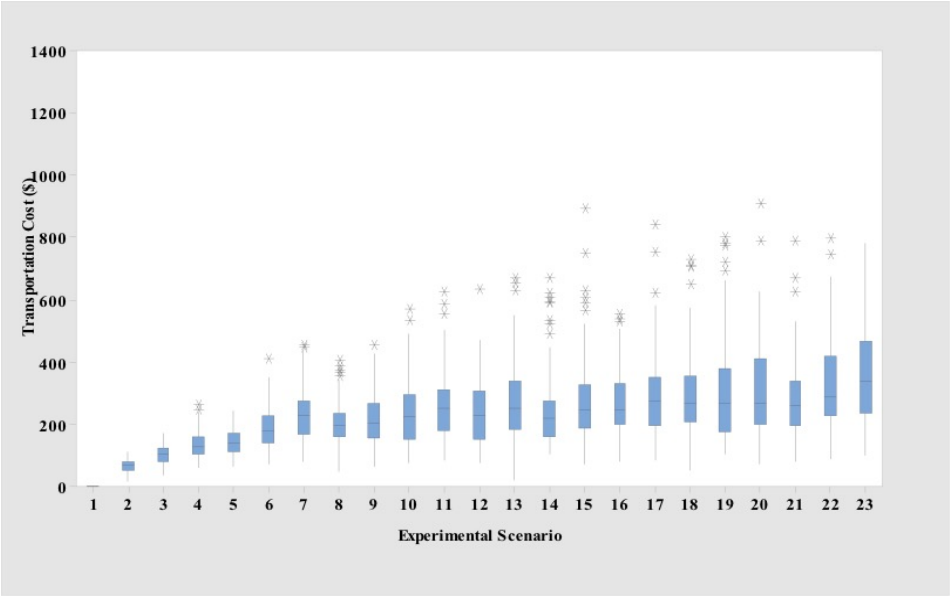


Figure 5-4 Transportation Costs Under Moderate Variability

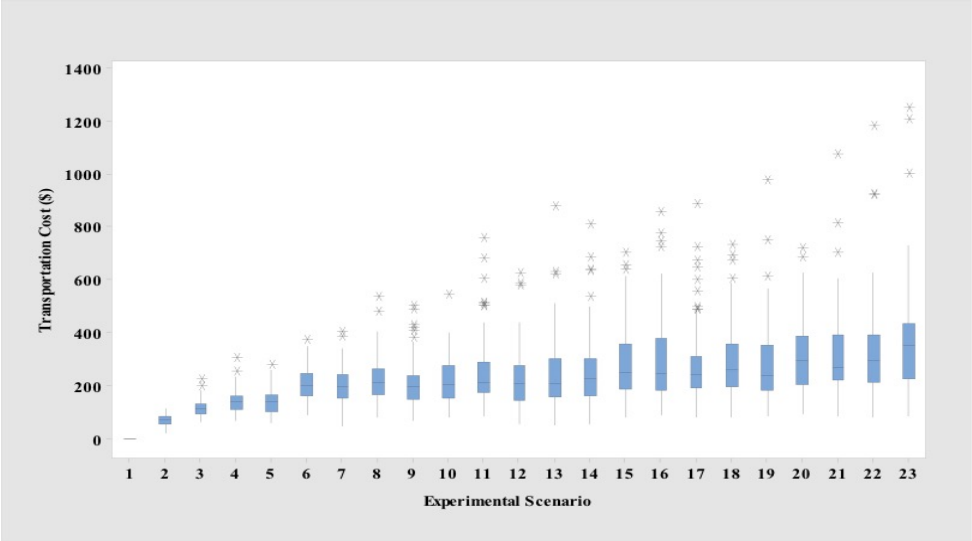


Figure 5-5 Transportation Costs Under High Variability

Transportation costs tend to increase and become increasingly variable as group sizes increase (Figures 5-4 and 5-5). This is partly a consequence of the modeling logic: it is assumed that offering pantries will send transshipments even if they have only one unit to offer or if receiving pantries have only one unit of demand, regardless of the

transportation distance, which results in a greater number of high-cost outliers for increasing group sizes. As Figure 6 shows, increased variability in supply results in increased variability in transportation costs.

5.2 Extended Model

The model was used to test the effects of collaboration under different levels of weekly supply variability on overall service levels (i.e., percentage of client demand filled), percentage food waste and transportation cost on 100 food pantries of Tarrant County, Texas. With collaboration, there is a tradeoff between increasing the service levels, less waste and increasing transportation costs associated with transshipments. Three levels of supply variability were considered: low variability, moderate variability, and high variability. In the low variability scenario, the supply for product 1 is normally distributed with mean 1000 and standard deviation 500, and the supply for product 2 is normally distributed with mean 500 and standard deviation 250. In the moderate variability scenario, the supply for product 1 is normally distributed with mean 1000 and standard deviation 1000, and the supply for product 2 is normally distributed with mean 500 and standard deviation 500, In the high variability scenario, the supply for product 1 is normally distributed with mean 1000 and standard deviation 1250, and the supply for product 2 is normally distributed with mean 500 and standard deviation 750. The model was run for 12 months and one hundred simulation replications were run for each scenario.

Low Variability Scenario

Figure 5-6 shows the service level for the network when there is no collaboration. The median value for service level for each month varies a little around 80%. Figure 5-7 shows the service level for the network when pantries collaborate with each other. The median value for service level for each month varies a little around 85%.

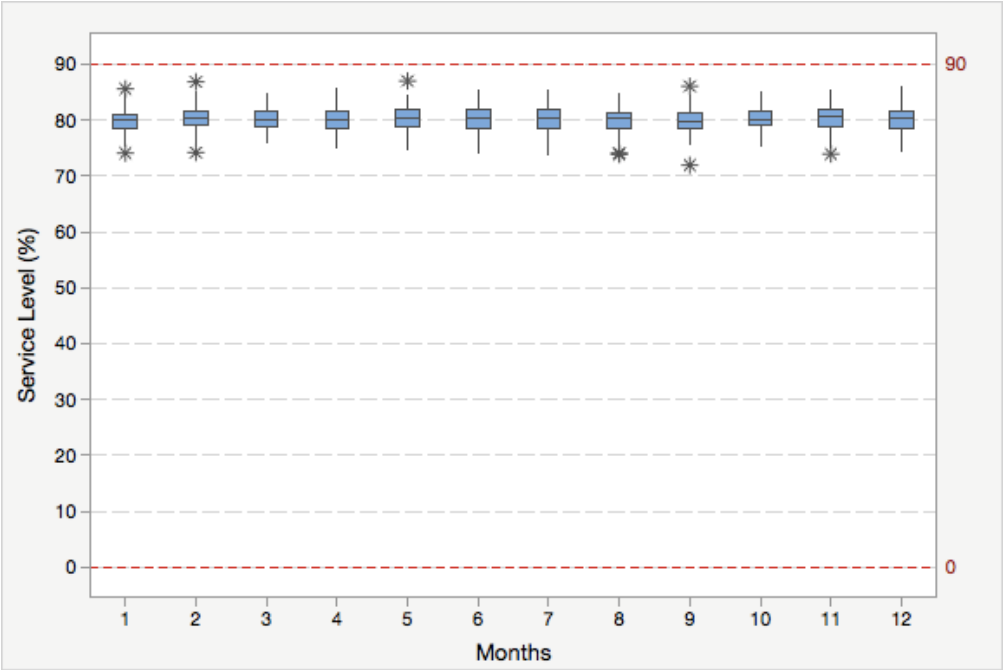


Figure 5-6 Service Level (%) for no collaboration under low variability

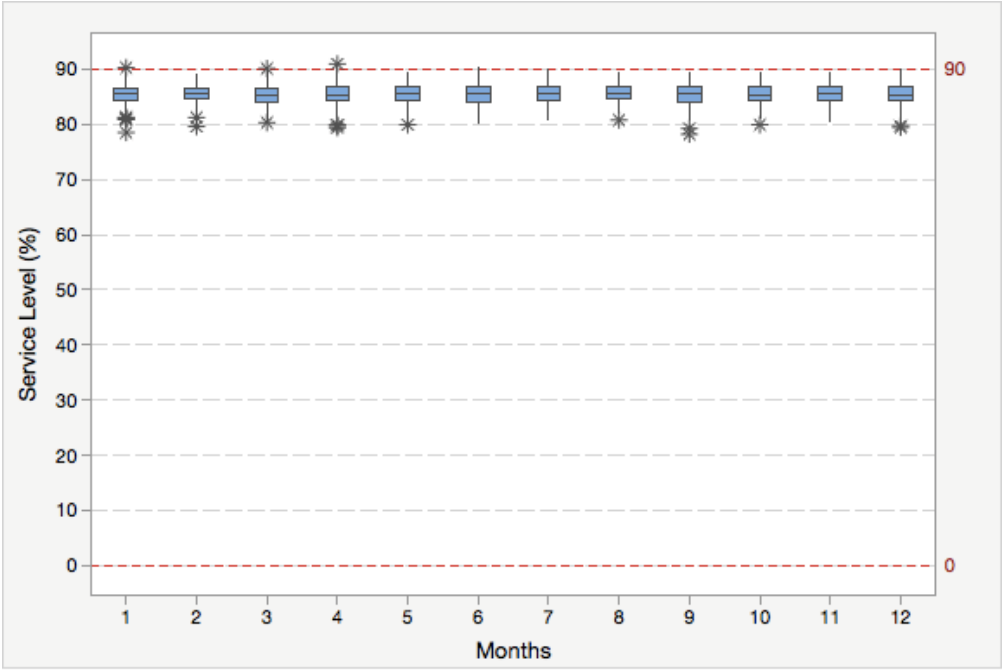


Figure 5-7 Service Level (%) for collaboration under low variability

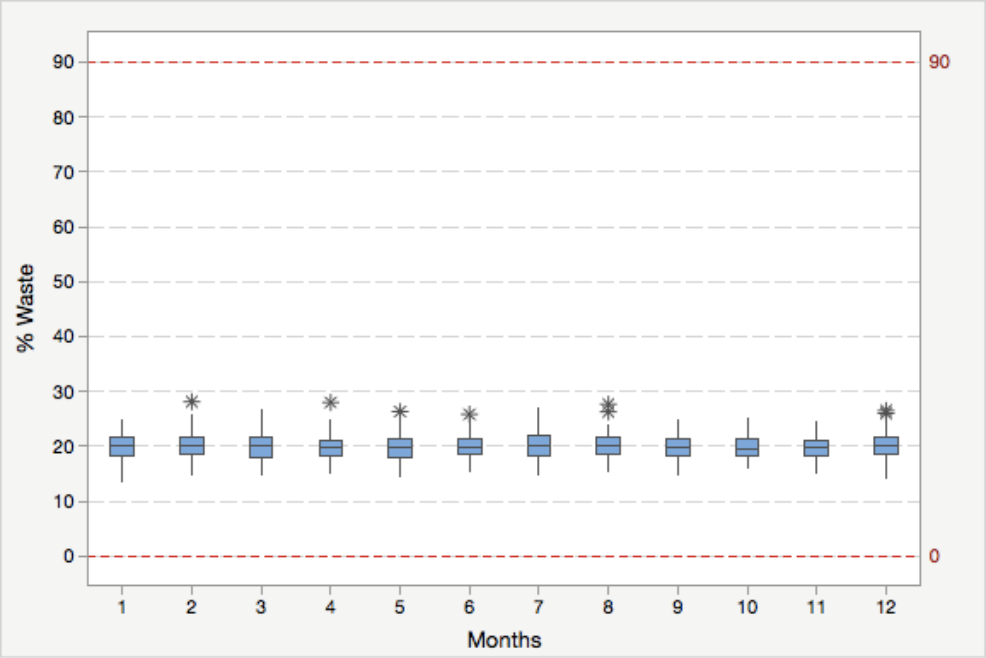


Figure 5-8 Waste (%) for no collaboration under low variability

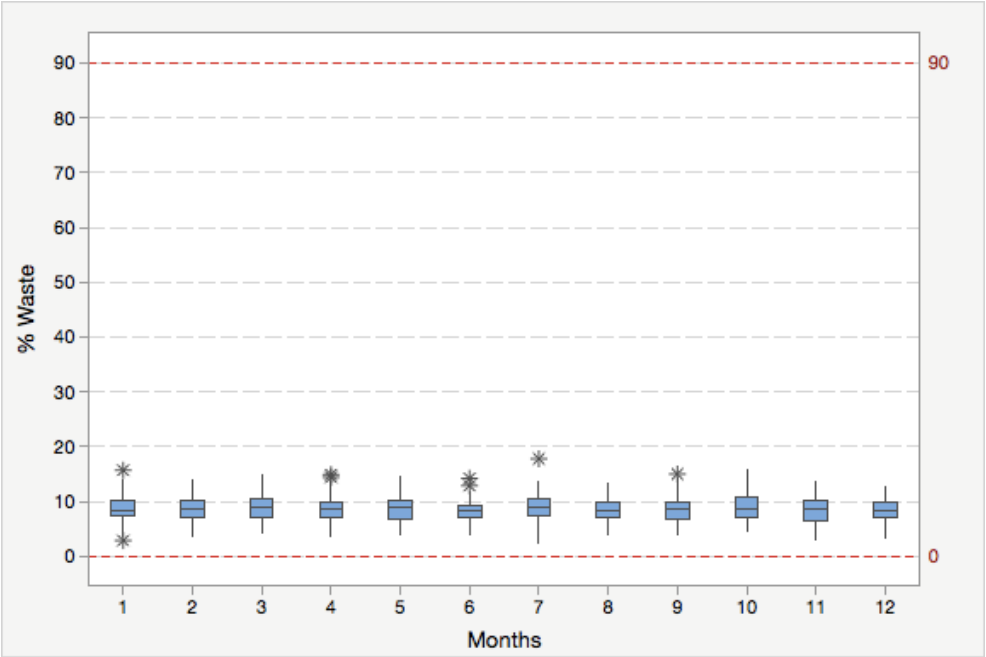


Figure 5-9 Waste (%) for collaboration under low variability

Figure 5-8 shows the percentage of food waste from the network when there is no collaboration. The median value for each month varies a little around 20%. That means 20% of the food supply gets wasted. Figure 5-9 shows the percentage of food waste from the network when the pantries collaborate with each other. The median value for each month varies around 8%. Which is a significant amount of decrease from 20%. Figure 5-10 shows incurred transshipment cost for each month. For each replication, the transshipment cost variability is extremely high. Although the median values are between $200 - $300, it can get as high as $6,000. This is partly a consequence of the modeling logic: it is assumed that offering pantries will send transshipments even if they have only one unit to offer or if receiving pantries have only one unit of demand, regardless of the transportation distance, which results in a greater number of high-cost outliers.

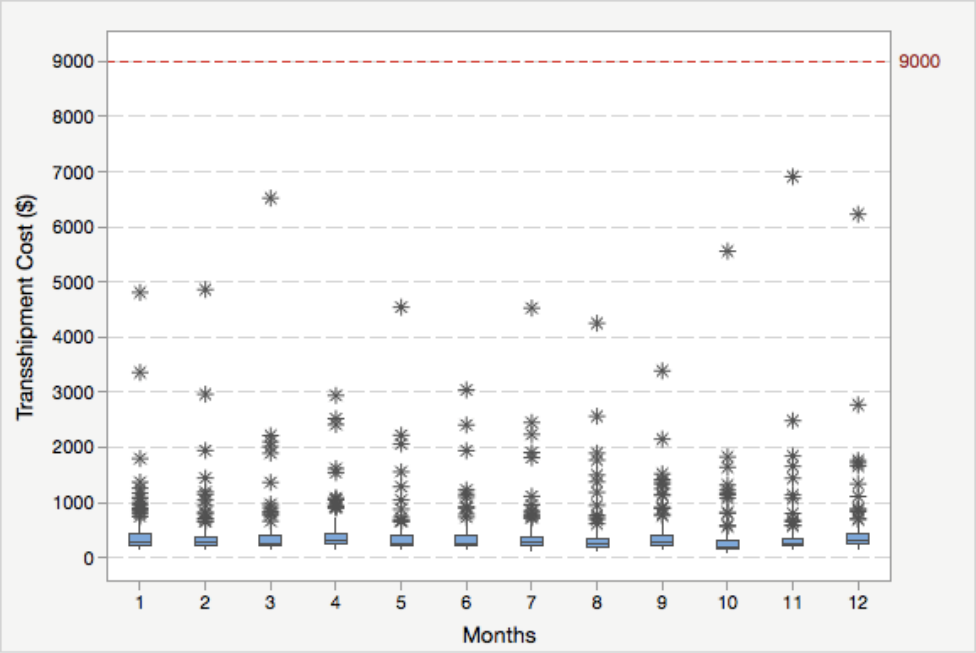


Figure 5-10 Transshipment cost for collaboration under low variability

Moderate Variability Scenario

Figure 5-11 shows the service level for the network when there is no collaboration. The median value for service level for each month varies from 60-63%. Figure 5-12 shows the service level for the network when pantries collaborate with each other. The median value for service level for each month varies between 70-72%.

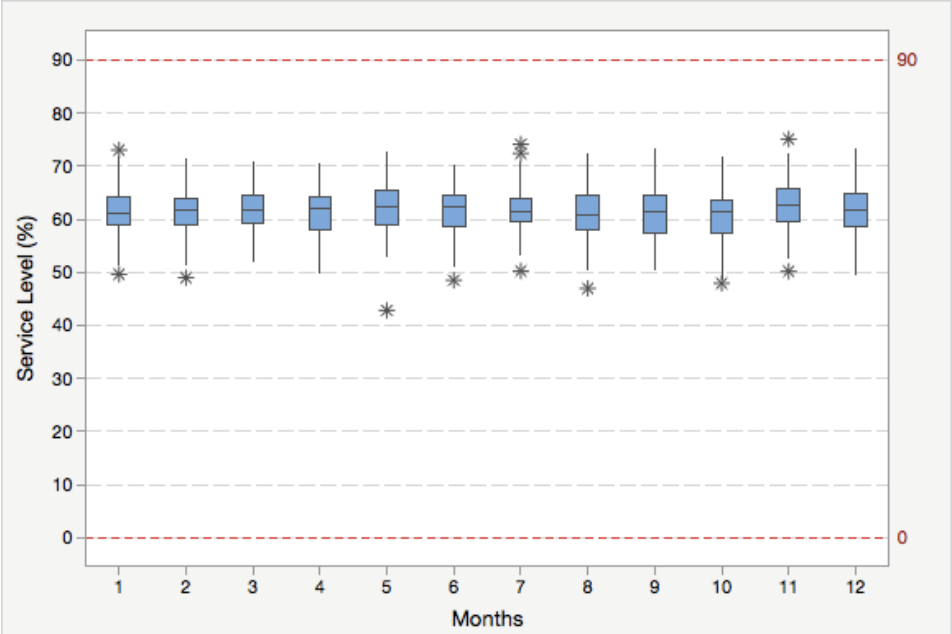


Figure 5-11 Service Level (%) for no collaboration under moderate variability

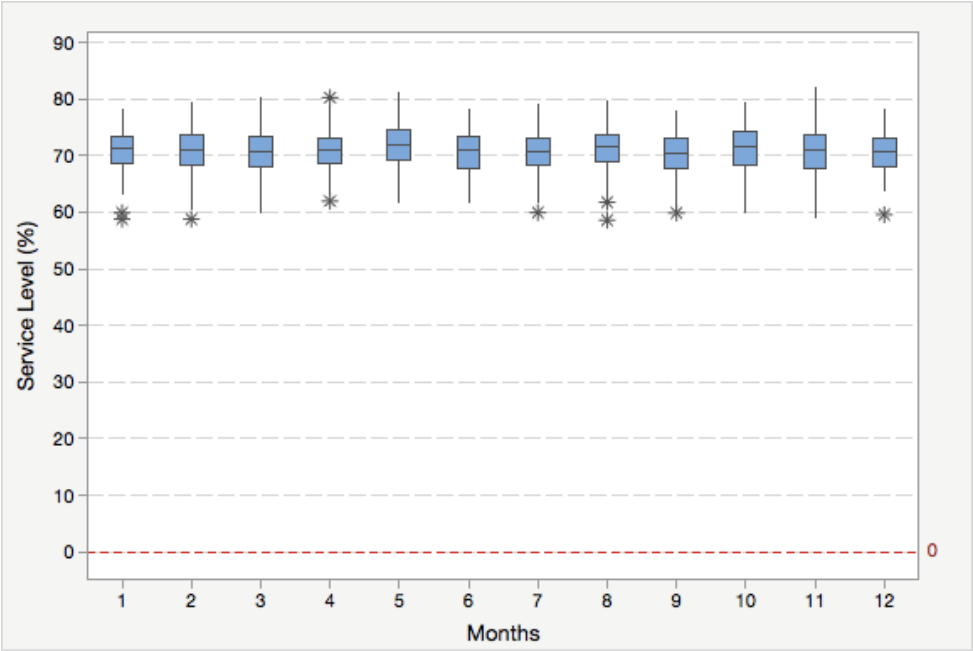


Figure 5-12 Service Level (%) for collaboration under moderate variability

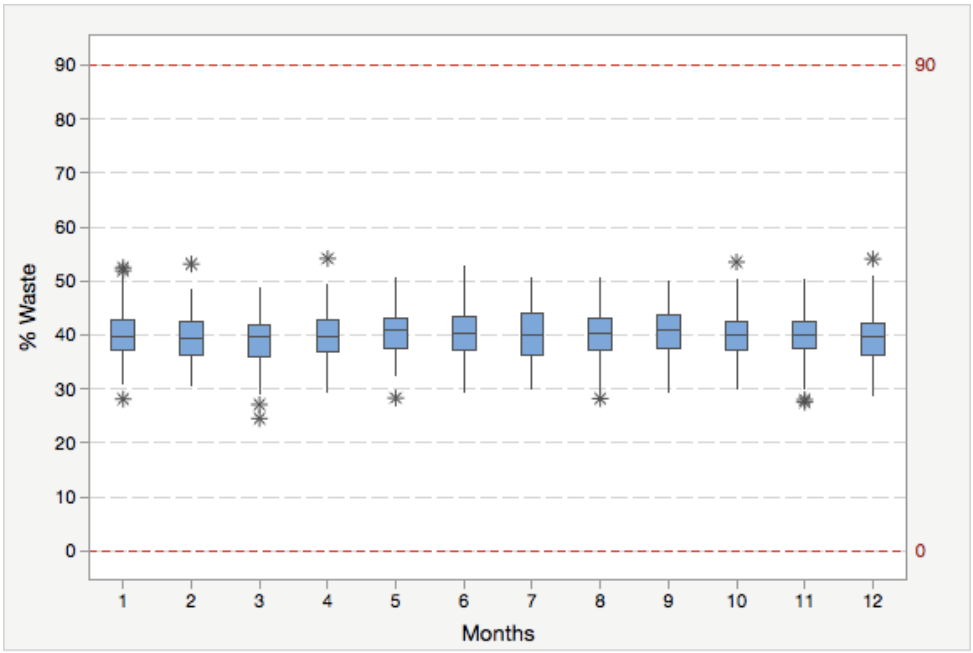


Figure 5-13 Waste (%) for no collaboration under moderate variability

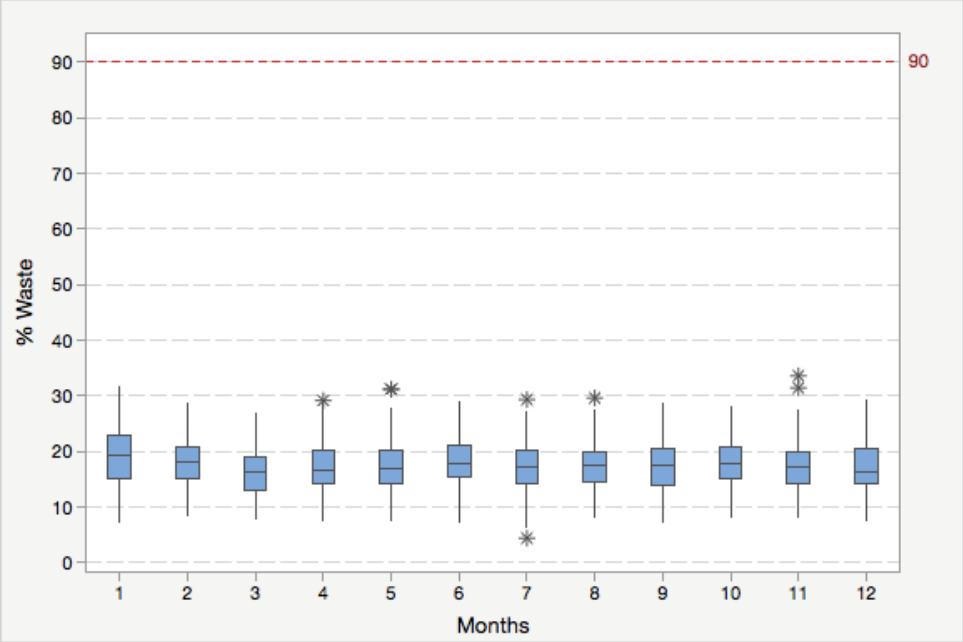


Figure 5-14 Waste (%) for collaboration under moderate variability

Figure 5-13 shows the percentage of food waste from the network when there is no collaboration. The median value for each month varies a between 39-41%. Figure 5-14 shows the percentage of food waste from the network when the pantries collaborate with each other. The median value for each month varies between 16-20%. Which is a significant amount of decrease from 39-41%. Figure 5-15 shows incurred transshipment cost for each month. For each replication, the transshipment cost variability is extremely high. Although the median values are between $200 - $300, it can get as high as higher, more than $8000, which is even higher than low variability scenario. This is partly a consequence of the modeling logic: it is assumed that offering pantries will send transshipments even if they have only one unit to offer or if receiving pantries have only one unit of demand, regardless of the transportation distance, which results in a greater number of high-cost outliers.

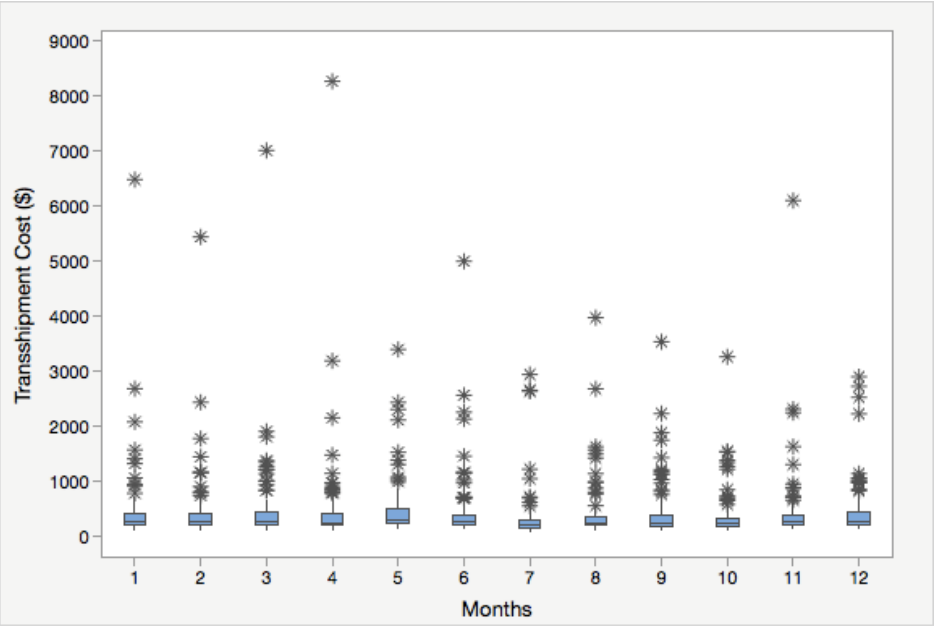


Figure 5-15 Transshipment cost for collaboration under moderate variability

High Variability Scenario

Figure 5-16 shows the service level for the network when there is no collaboration. The median value for service level for each month varies from 38-42%. Figure 5-17 shows the service level for the network when pantries collaborate with each other. The median value for service level for each month varies between 56-59%.

Figure 5-18 shows the percentage of food waste from the network when there is no collaboration. The median value for each month varies a between 58-61%. Figure 5-19 shows the percentage of food waste from the network when the pantries collaborate with each other. The median value for each month varies between 25-28%. Which is a significant amount of decrease from 39-41%. Figure 5-20 shows incurred transshipment cost for each month. For each replication, the transshipment cost variability is extremely high. Although the median values are between $200 - $300, it can get as high as higher, more than $8000, which is even higher than low variability scenario. This is partly a

consequence of the modeling logic: it is assumed that offering pantries will send transshipments even if they have only one unit to offer or if receiving pantries have only one unit of demand, regardless of the transportation distance, which results in a greater number of high-cost outliers.

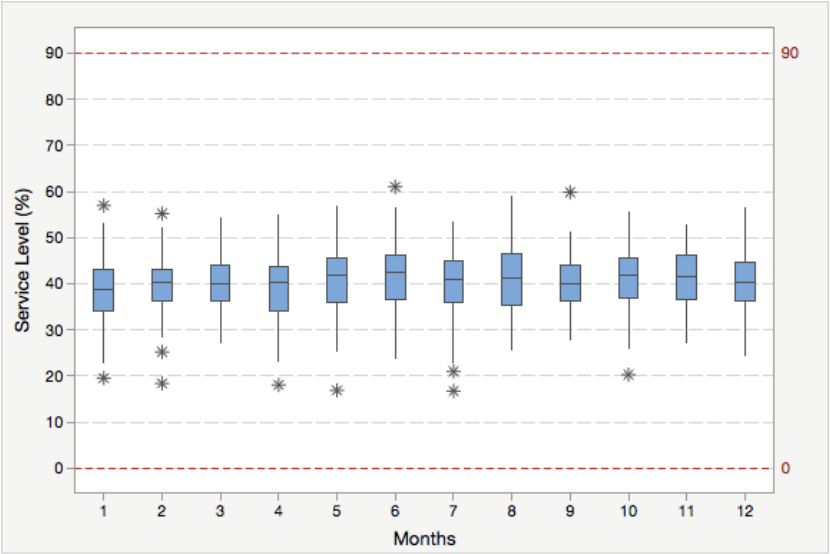


Figure 5-16 Service Level (%) for no collaboration under high variability

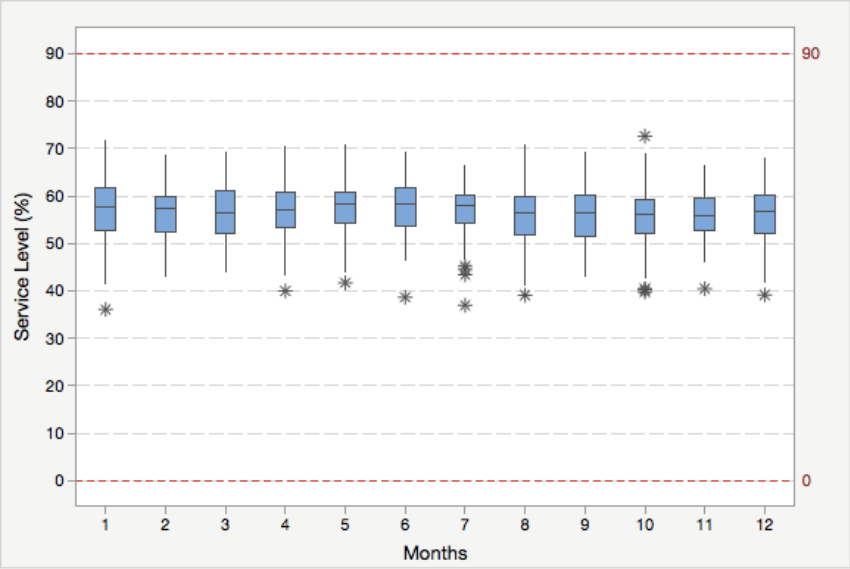


Figure 5-17 Service Level (%) for collaboration under high variability

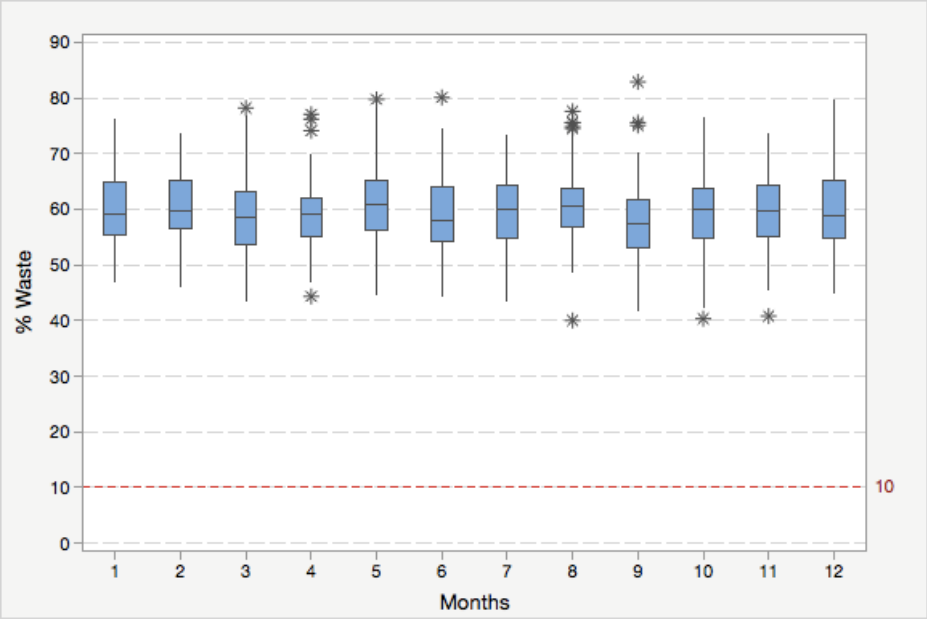


Figure 5-18 Waste (%) for no collaboration under high variability

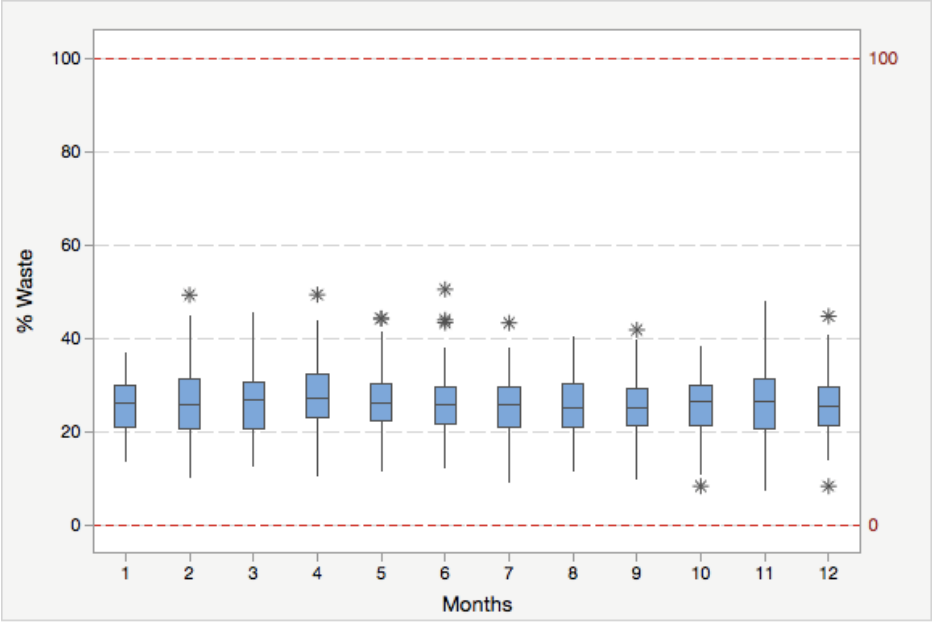


Figure 5-19 Waste (%) for collaboration under high variability

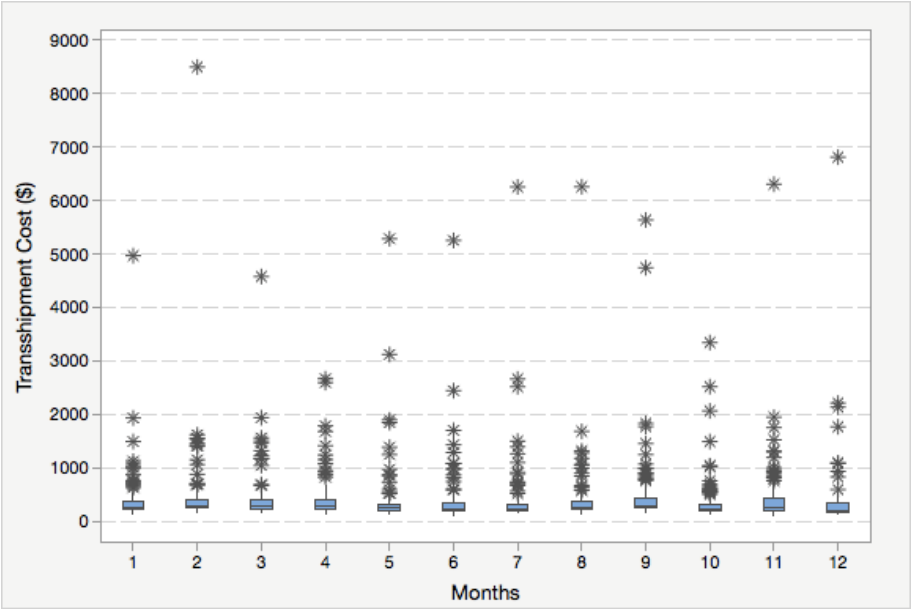


Figure 5-20 Transshipment cost for collaboration under high variability

Chapter 6

Discussion and Conclusion

The results of these preliminary experiments on the conceptual model suggest that collaboration in pairs (experimental scenario 2) yields improved service levels with relatively little transportation cost increase, compared with the scenario in which the pantries do not collaborate (experimental scenario 1). It also suggests that, as supply variability increases, collaboration can significantly increase service levels. Higher supply variability results in greater discrepancies between supply and demand, which results in lower service levels, higher transshipment costs, and many outliers.

The expanded was run under three variability level. With lower variability level, collaboration results in relatively lower increase in service level and lower reduction in food waste. With increasing variability in supply, the benefits of collaboration in terms of service level and waste reduction becomes more evident. Although, the cost of collaboration in terms of transshipment is extremely variable, even for lower variability in supply as this model includes 100 pantries, which is much higher than the 23 pantries in conceptual model.

The main goal of this study was to explore a potential solution to alleviate the severe problem of food insecurity. It demonstrates how ABM can be used to represent a problem by integrating both logistics and operation concerns with social aspects of the supply network.

There were three research objectives for this work and all three of them have been met as following:

Objective 1: To use empirical data collection and agent-based modeling to gain a better understanding of the conditions that facilitate food pantry collaboration.

- This study demonstrates how ABM can be used to represent a problem by integrating both logistics and operation concerns and social aspects of the supply network.
- The survey helped us to gain deeper insights of the network.
- It also helped us to validate many of our assumptions regarding benefits and barriers of collaboration.

Objective 2: To determine the degree to which collaboration can improve overall food assistance system efficiency and effectiveness.

- Conceptual and the extended model suggest that, as supply variability increases, collaboration can significantly increase service levels as well waste reduction.
- Higher supply variability results in greater discrepancies between supply and demand, which results in lower service levels, higher transshipment costs, and many outliers.

Objective 3: To assess which kinds of collaborative structures lead to the best outcomes.

- The results of the experiments on the conceptual model suggest that collaboration in pairs yields improved service levels with relatively little transportation cost increase.

ABM Results showed 5-20% increase in service level. That could result in feeding 16,192 – 64,768 more people. 10-40% waste reduction means 7.2 – 28.8 billion lbs. of waste reduction throughout the U.S.

Chapter 7

Future Work

7.1 Data Collection

Many pantries provided contact information in the conducted survey. It would be beneficial to contact them for formal interviews. Interviews are helpful for in depth answers, which helps to get better insights to the system and into relationships between the pantries and their suppliers. TAFB serves other counties in addition to Tarrant County. Collecting data from them and comparing them to Tarrant County will show a bigger picture for the food assistance network. All the collected data can be used for creating a structured database which can be used for further model extension and refinement.

7.2 ABM Development

Operational extensions

Suppliers

In real life, pantries get supply from the food bank as well as multiple food retailers. Incorporate multiple suppliers to the model will depict a model realistic picture.

Product variety

Multiple suppliers also bring more product variety. From our initial interviews and survey, we have learnt that some pantries have a shopping list, which is divided into separate food segments and in segment there are multiple options to choose from.

Number of pantries

There are more than 200 independent food pantries in Tarrant County. These pantries are divided into peer groups. Pantries in the same peer group are supposed to attend seasonal meetings and share their views and update each other on their

performances. Incorporating the all the pantries in model will give the whole picture of Tarrant County network.

Behavioral extensions

Pantry relationships

Pantry relationships are vital for their collaboration. Relationships depend on their communication and reciprocity. Incorporating how their relationship develops on how much their demand is being fulfilled and how often, would give a more realistic picture.

Resource availability

With donated food from multiple suppliers, supply comes with a very high variability. Resource availability is a potential concern for collaboration. Also, there should be enough transportation and communication resources to share the inventories for collaboration.

Frequency of collaboration

We would like to find the answer from the pantries that how often they are willing to collaborate and incorporate in the model.

Transshipment vs. cost

Transshipments lead to cost. It will be practical and efficient to find out when it is realistic to make a transshipment, in terms of quantity of inventory.

Appendix A

Survey Questions

Survey Questions

- What is your current position? Text box
- How many employees, staff members, and/or volunteers does your organization rely on to fulfill its mission?
- Do you have sufficient public/private support to fulfill your mission?
- Do you think you have sufficient space and equipment to serve the maximum amount of people you could with your existing staff/volunteers?
- What is the single largest barrier to providing more nutritious food to members of your community?
- How many TAFB agencies do you regularly communicate with?
- Which communication medium do you use?
- Which communication medium do you prefer?
- What kinds of information do you share with other TAFB agencies?
- Do you share your extra inventory with any other pantries?
- How often do you provide food to clients?
- Do you receive extra inventory from other pantries?
- In your opinion, what are the major benefits of collaboration (sharing inventory and other resources) with other pantries?
- In your opinion, what are the major barriers that discourage or prevent collaboration (sharing inventory and other resources) with other pantries?
- Which do you prefer: working in a collaborative environment, or working independently? Options: a. collaborative b. independent
- What is your agency's stance toward collaboration?
- Is your agency a member of a TAFB peer group?
    - If yes:

        - Please name the peer group
        - Does TAFB hold regular meetings for your peer group?
            - If yes, do you (or other members from your agency) attend those meetings?
        - Do you think these meetings are beneficial for building better relationships with other agency pantries?
        - Do you think these meetings are beneficial for building better relationships with TAFB?
    - What are your agency's operating hours?
    - Do you provide a shopping list to your clients?
    - How would you describe the variability of client demand for food at your pantry?
    - Is your pantry interested in expanding its capacity? Briefly describe.
    - From whom do you source your food? TAFB distribution center (%), TAFB directed pick up (%), other food banks (%), purchase from retailers/wholesalers (%), canned food drives (%), other sources (%) (please explain)
    - Do some of your food suppliers offer delivery services?
    - On average, how many pounds of wasted food (from spoilage and shrinkage) does your organization incur monthly?

Voluntary contact information:

- Are you are willing to be contacted by the UTA research team for follow-up and/or clarification on the responses you have provided?
    - If yes, please provide your contact information.

Appendix B

Presentation Slides

UNIVERSITY OF TEXAS ARLINGTON | COLLEGE OF ENGINEERING

Analyzing Collaboration in Food Assistance Networks Using Agent-Based Modeling

Joyita Mostafa
University of Texas at Arlington
August 1, 2019

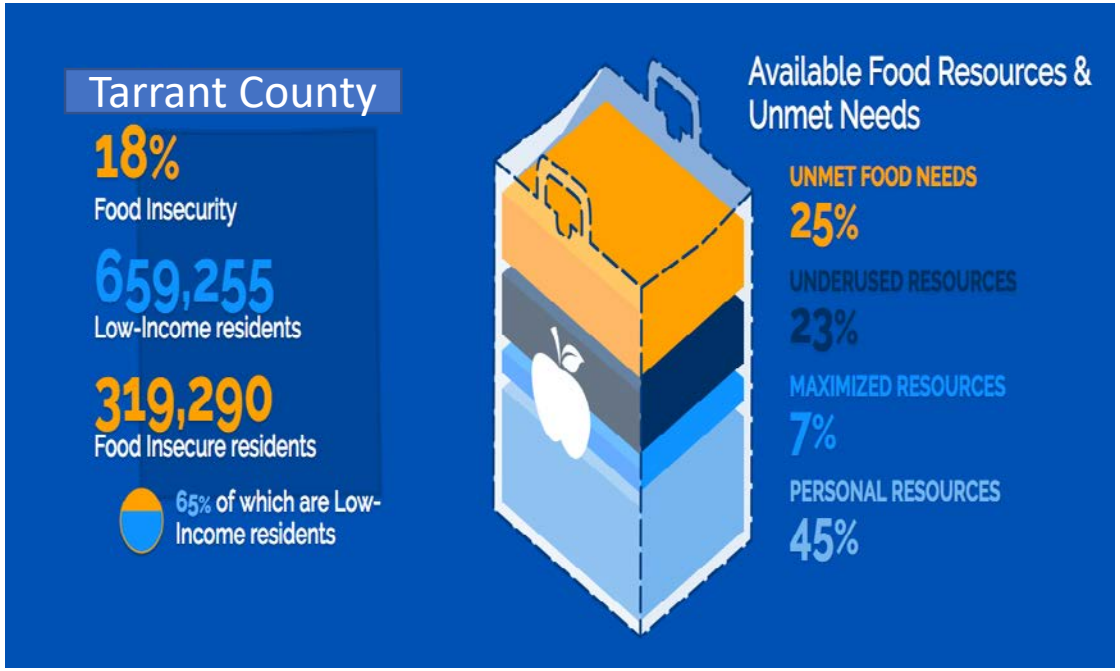
Committee: **Dr. Jamie Rogers (Committee chair)**
Dr. Caroline Krejci (Committee co-chair)
Dr. Yuan Zhou

Presentation Outline

- Research Motivation
- Research Objectives
- Background and Literature review
- Research Plan
- Research Contributions
- Recommendations

Food Insecurity, Hunger and Poverty

- Food insecurity is a lack of consistent access to nutritious food.
- 12.9% (41.2 millions individuals) of the U.S. population was food insecure. (USDA, 2016)



Source: Feeding America, 2016

Counties with the Highest Number of Food Insecure People

State	County (metro area)	Food Insecurity (#)	Food Insecurity (%)
NY	New York (five boroughs, collectively)	1,215,440	14.4%
CA	Los Angeles	1,147,010	11.4%
TX	Harris (Houston)	738,140	16.6%
IL	Cook (Chicago)	659,990	12.6%
AZ	Maricopa (Phoenix)	585,330	14.3%
TX	Dallas	442,920	17.6%
CA	San Diego	379,130	11.7%
MI	Wayne (Detroit)	366,690	20.7%
PA	Philadelphia County	327,320	21.0%
TX	Tarrant County (Fort Worth)	323,840	16.6%

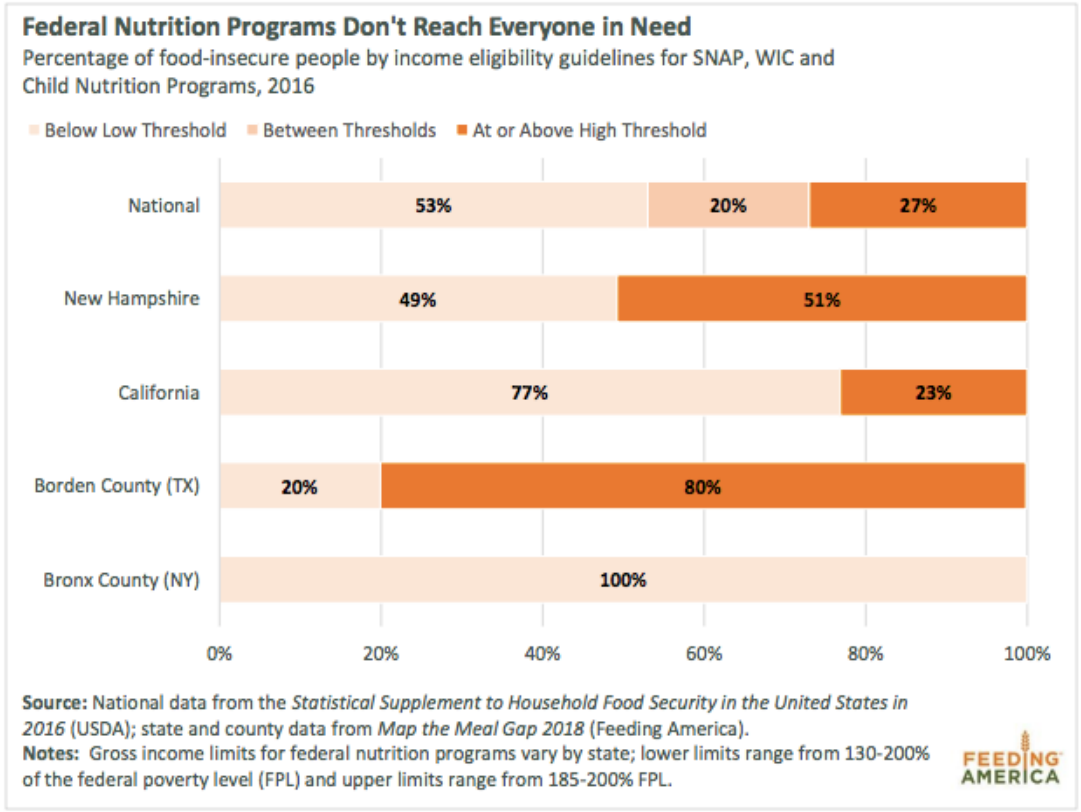
Source: Map the Meal Gap Project, Feeding America (2018)

Federal Nutrition Assistance Programs

- **Supplemental Nutrition Assistance Programs (SNAP)**
  - Largest program in domestic hunger safety net
  - Eligibility: The maximum gross income – 130% of the federal poverty level
  - For example 130% of the poverty line for a three-person family is $2,252 a month
- **Food Distribution Programs**
  - Commodity Supplemental Food Programs (CSFP)
  - The Emergency Food Assistance Program (TEFAP)
- **Child Nutrition Programs**
  - National School Lunch Program (NSLP)
  - School Breakfast Program (SBP)
- **Women, Infants, and Children (WIC)**

Federal Nutrition Assistance Programs

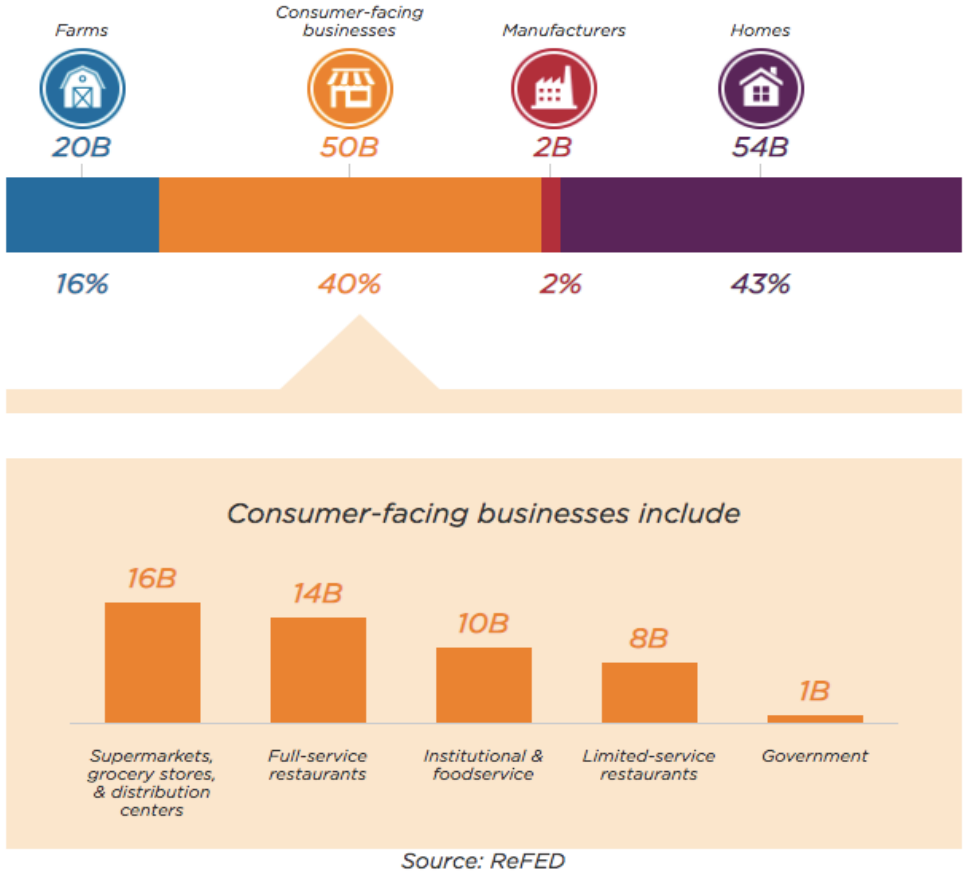
- 27% of the food insecure people weren't eligible for any kind of federal assistance.
- For example: In Borden County (TX), 80% of the food insecure individuals are not eligible for any federal food assistance.
- **In Tarrant County, Texas, 36% of the food insecure individuals may not be eligible for any federal food assistance program.**



Source: Map the Meal Gap Project, Feeding America (2018)

Food Waste in the U.S.

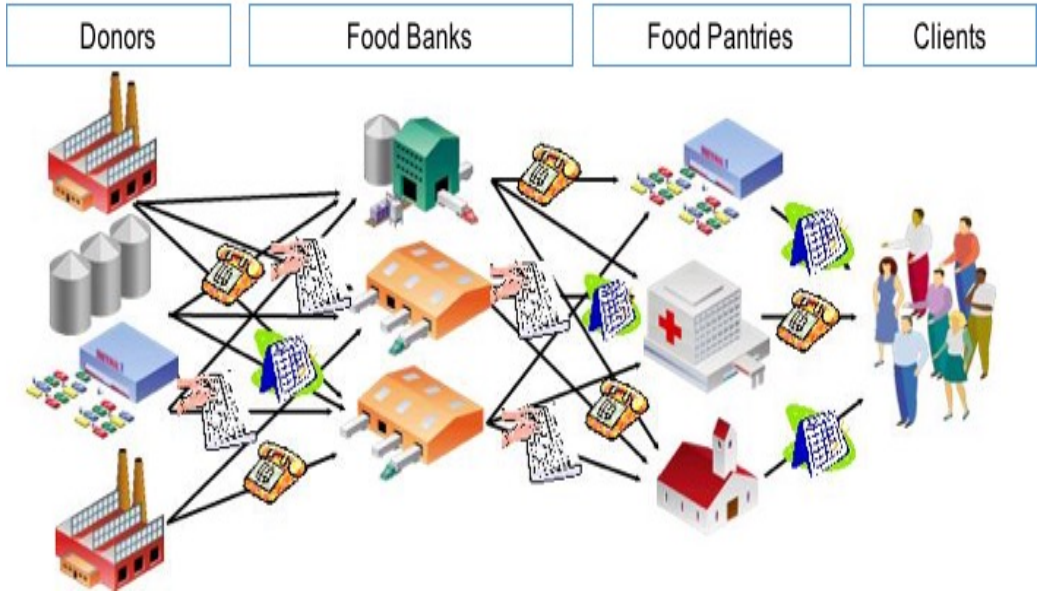
- $218 billion worth of food loss happens from different stages of food production and distribution.
- 72 billion pounds of food waste, are perfectly edible.
- Manufacturers, grocery stores and restaurants are responsible for 52 billion pounds of food waste.
- Rescuing and redistributing this food among the people in need can help a great deal to alleviate a giant problem like food insecurity.



Source: Map the Meal Gap Project, Feeding America (2018)

Feeding America Network

- A nationwide network, consisting of over 200 food banks.
- Each **food bank** has warehousing and transportation infrastructure for inventory pooling, sorting and distribution.
- Rescues donated surplus food from farms, manufacturers, and retailers to mitigate food insecurity.
- Each food bank distributes food to a large number of independent and small-scale food “partner agencies”, also known as **food pantries**, which the distribute the food to individual **clients** in need.



Research Motivation

- However, much demand goes unfilled
- Not entirely because of insufficient volume of supply
- Distribution inefficiencies – between supply and demand
  - Inefficient inventory management: No available forecast, No structured database.
  - Insufficient pantry capacity: Not enough cold storage available for certain perishables, Insufficient workforce, Insufficient service hours.
  - **Highly uncertain donor supply:** Unexpected large quantity of supply for unknown items, Unknown availability of supply.

Research Motivation

- **A potential solution to this problem is to connect the pantries and enable them to balance the supply and demand between themselves via transshipments**
- Some pantries are collaborating on an informal basis
  - Example: 4Saints Episcopal Food Pantry regularly shares excess food with Union Gospel Mission
- Other pantries report that they do not collaborate
  - Example: Eastside Ministries does not collaborate at present

Research Motivation

- Research hypothesis: Based on preliminary data collection, there are many possible barriers to pantry collaboration, including:
  - Feeding America discouraging collaboration
  - Inefficient communication between pantries
  - No structured platform and no real time inventory update
  - Transportation costs associated with transshipments
- Research aim is to determine:
  - Are these the most important barriers? Are there others?
  - How can these barriers be overcome? Would this improve the system?

Research Objectives

- The objectives of this research are:
  - **To use empirical data collection and agent-based modeling to gain a better understanding of the conditions that facilitate food pantry collaboration.**
  - **To determine the degree to which collaboration can improve overall food assistance system efficiency and effectiveness.**
  - **To assess which kinds of collaborative structures lead to the best outcomes.**

Existing Food Bank Studies

- Tarasuk et al. (2014) studied 517 different food donation agencies in five cities in Canada.
- Handforth et al. (2012) carried out a qualitative study on food banks in the Feeding America network to serve more nutritious food to their clients.
- Middleton et al. (2018) explored the socio-psychological impact of seeking and getting help from food banks.
- Depa et al. (2018) studied the population characteristics of food bank clients in Germany.

Food Bank Models

- Schneider et al. (2018) developed a multi-criteria vehicle routing model with multiple time windows in an effort to create a more efficient auditing schedule for the food bank.
- Davis et al. (2014) developed a set covering model that locates and assigns the agencies to specific food delivery points where they can receive food, subject to vehicle capacity and food spoilage
- Orgut et al. (2016) developed robust optimization model using historical data from a food bank: seeking to maximize the amount of distributed food.

Research Scope

- A food assistance network is composed of food banks, retailers, pantries, and clients.
- They have interrelationships that are continuously get reassessed.
- Leading to the dynamic formation of mutually beneficial alliances, as well as adversarial relationships.
- Agent-based modeling could be particularly useful for representing and analyzing such patterns of relationships among supply network actors.

Agent-Based Modeling

- Agent-based models are:
  - Computational models
  - Simulate and represent agent behaviors
  - Also, interactions between them and their environment.
- These agents are:
  - Autonomous individuals
  - Can be used to represent individual human actors or organizations
  - Agents can be programmed to make decisions and to adapt dynamically

Agent-Based Modeling

- Agent based modeling (ABM) can be useful for various situations but mostly for complex systems composed of many components.
- Emergence:
  - The appearance of complex patterns in the system.
  - ABM is very useful to display these patterns or emergence in a system and can bring out the possibilities of different occurrences.
- Randomness:
  - ABM can work with stochastic decisions.
  - In case of complex systems, it is very likely that we do not know the deterministic answer for most of the decisions, hence a deterministic model is not feasible.

Research Plan

- Data Collection
- ABM Development
  - Conceptual Model Development
  - Extended Model Development
- Experimentation
- Analysis and Result
- Recommendations

Preliminary Data Collection

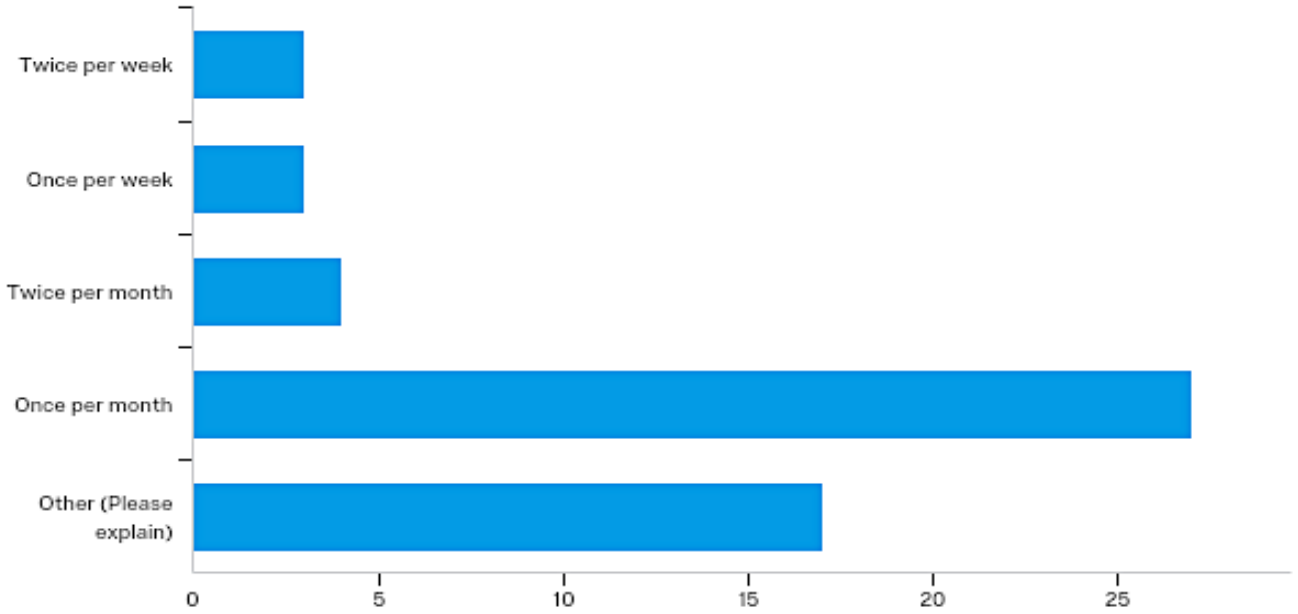
- **Informal Interviews**
  - 4 Saints Episcopal food pantry
  - Davis Memorial United Methodist Church
  - Eastside Ministries
- Operational data
- Attitude towards collaboration

Survey

- Reached out to 400 pantries under TAFB network
- 53 pantries have responded.
  - 30 small size pantries (staff members and volunteers < 35)
  - 23 medium-large size pantries (staff members and volunteers > 35)
- Collected data on-
  - Demand and supply
  - Food waste
  - Capacity and barriers
  - Current collaboration practice
  - Attitude towards collaboration

Survey Results

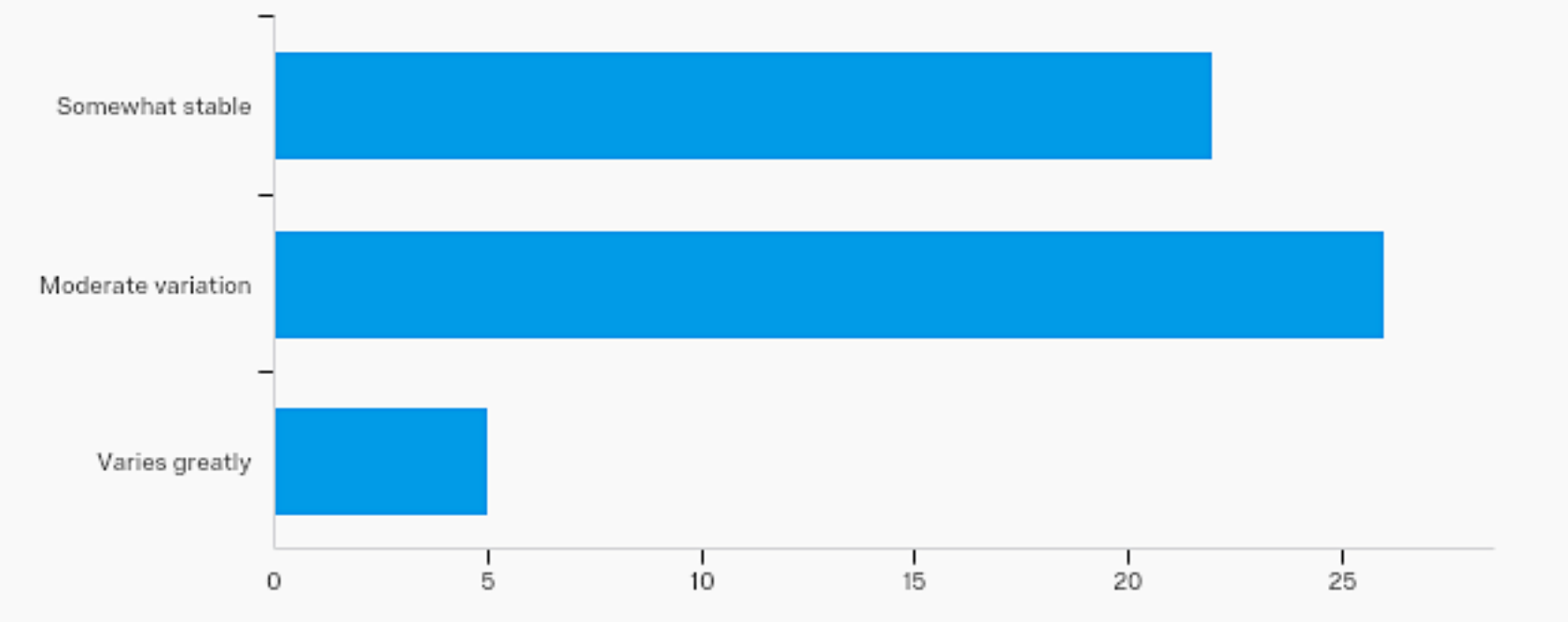
Frequency of Distribution



Frequency of distribution

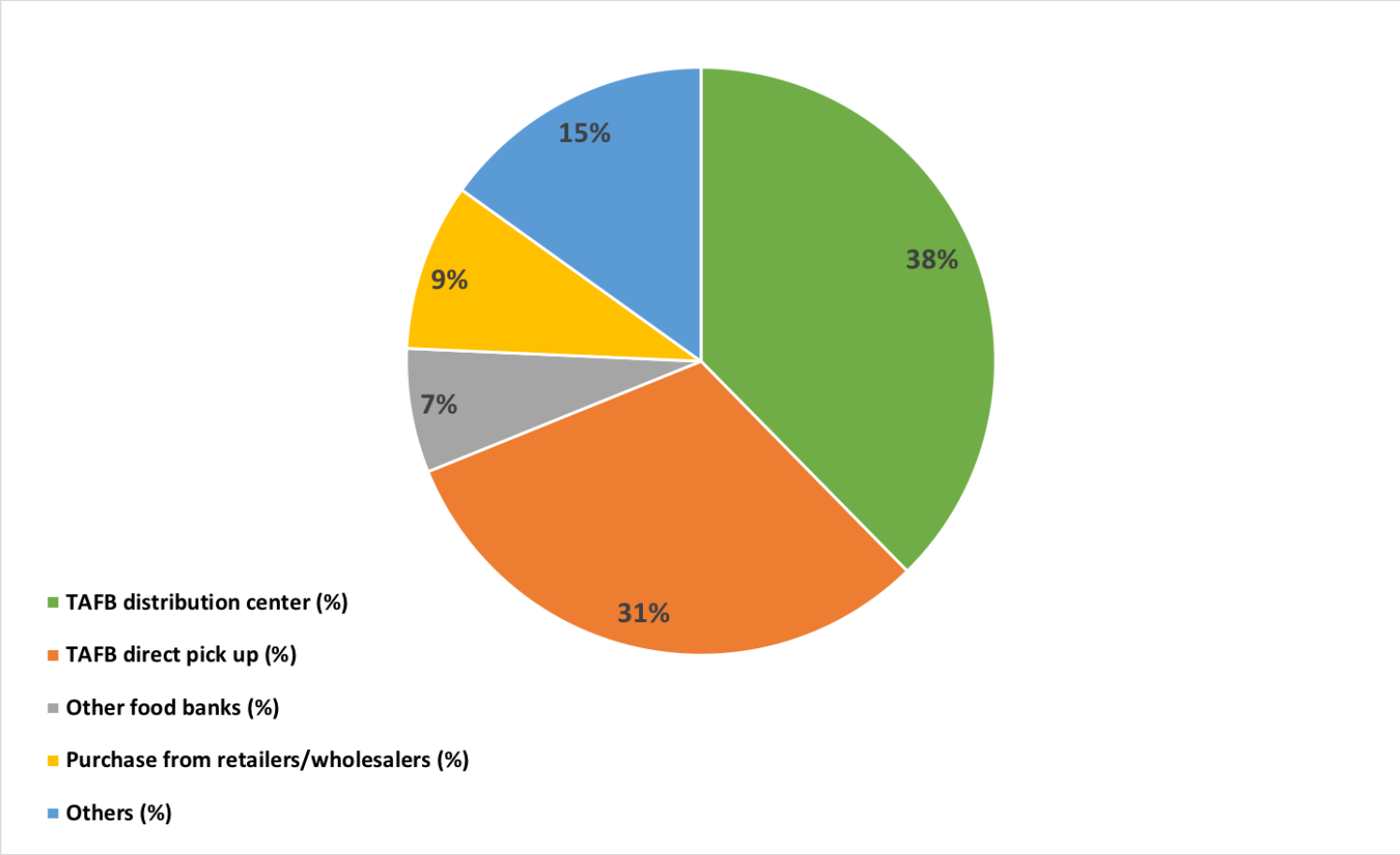
Other option includes: 3-5 times a week, emergency basis, 6 times a year

Demand Variability



Demand variability

Suppliers


15%
38%
9%
7%
31%
TAFB distribution center (%)
TAFB direct pick up (%)
Other food banks (%)
Purchase from retailers/wholesalers (%)
Others (%)

Food Waste

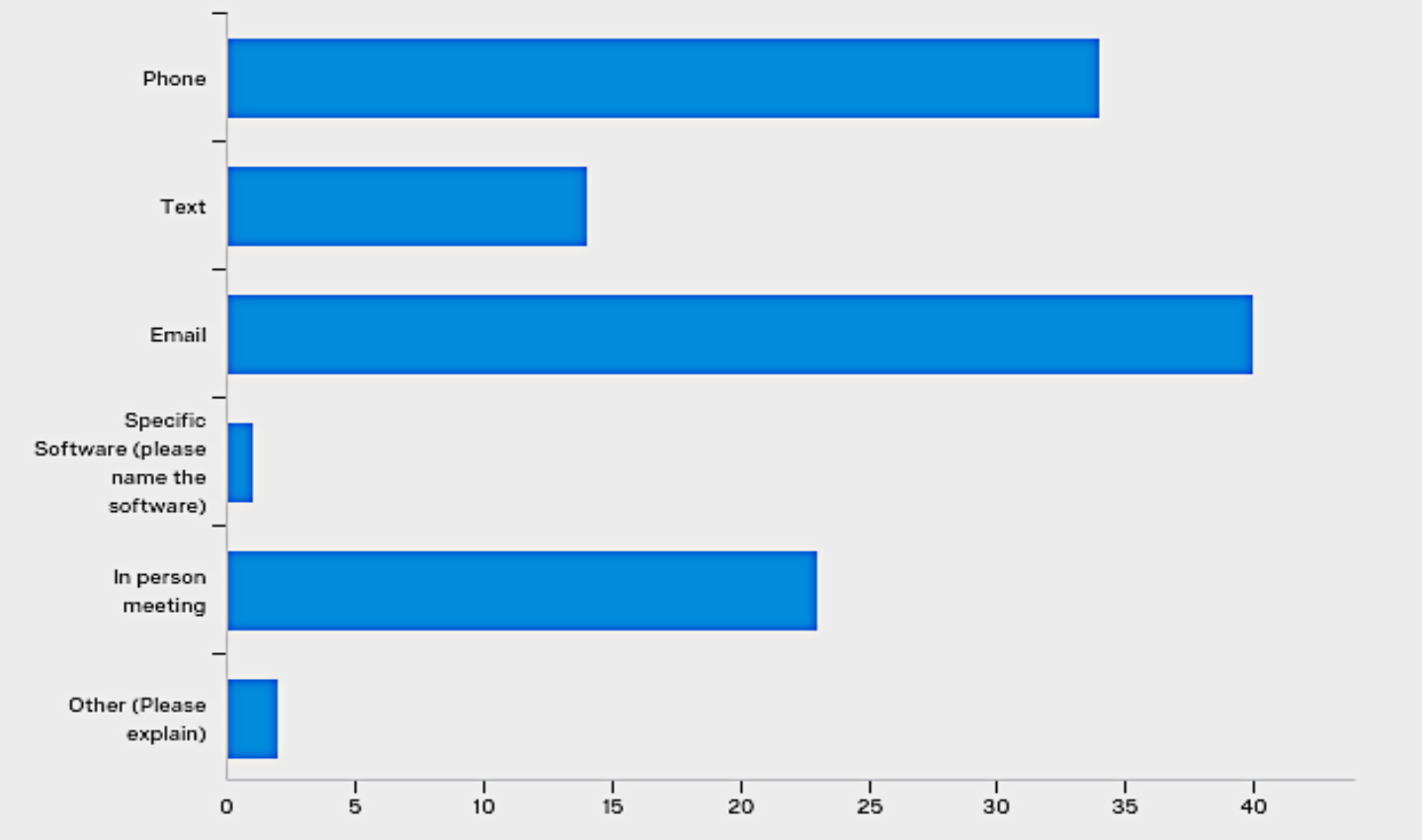
- 31 pantries have monthly food waste between 0-50 lbs. per month
- 17 pantries have more than 50 lbs. food waste per month.
- It goes as high as 1600 lbs.

Capacity and Barriers

- 75% of the pantries mentioned they have enough public/private support to run the pantries.
- 67% of the pantries said they have sufficient space and equipment.
- 55% pantries said they are interested in expanding their capacity.
- Barriers to providing more nutritious food
  - Lack of resources
  - Demand vs. supply mismatch
  - Transportation and communication

Current Collaboration Practice

- 42 pantries communicate with fewer than 5 pantries.
- 5 pantries communicate with 5- 10 pantries.
- 2 pantries communicate with more than 10 pantries.



Communication medium

Inventory Sharing

- 25 pantries share their extra inventory.
  - ➢14 pantries mentioned only with 1-2 pantries.
- 15 pantries receive inventory from other pantries.
  - ➢12 pantries mentioned from 1-2 pantries.
- They mostly share inventory on an ad-hoc basis.

Benefits of Collaboration: What the Pantries Say

- **Serve more people**
  - “Reach more families with better selection of inventory”
  - **“**Better and more consistent availability of food”
- **Less food waste**
  - “Network to alleviate food waste”
  - “Excess inventory does not go to waste”
- **Resource sharing**
  - **“When we have food left over, it would be nice to have a place to take it so that others can benefit"**
  - “It keeps us abreast of current challenges in the fight against hunger and, quite frankly, helps us feel less alone in the fight”
  - “Being able to accept donations that we do not have room for, a call to one or two other food banks to arrange pickup and storage”

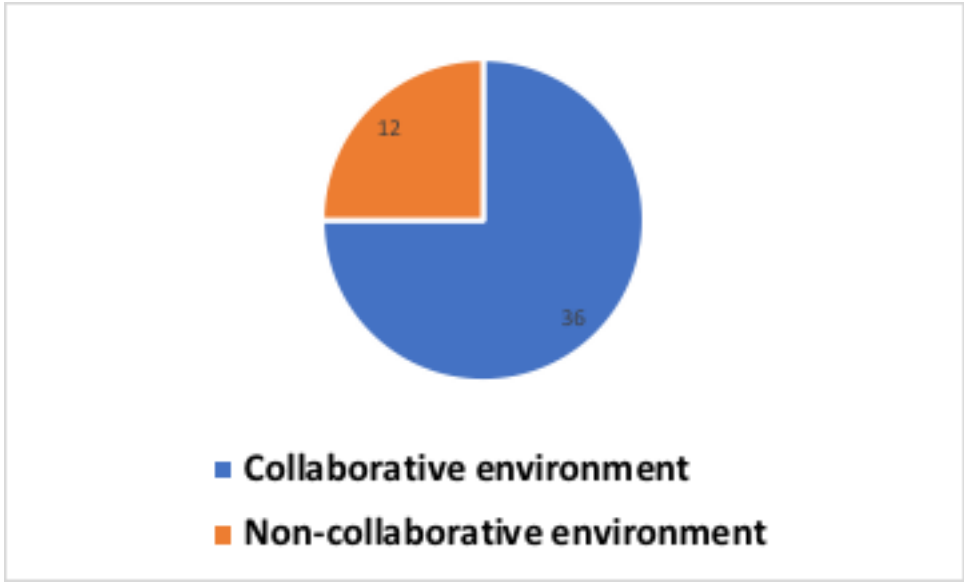
Major Barriers that Discourage Collaboration: What the Pantries Say

- **Lack of resources**
  - "Transportation, resources availability, time"
  - "The limited times that the mobile pantries operate and not being able to effectively share the inventory"
- **Behavioral issues**
  - "Time to time some pantries have a competitive spirit"
  - "Fear of losing donors"
- **Communication and coordination issues:**
  - "Not knowing where others are or the time of the month they distribute"
  - **"Shared online database; the need to take inventory of our own products"**

Collaborative vs Independent Environment

- 36 pantries responded, they would like to work in a collaborative environment

- 12 pantries responded that they prefer independent environment



Collaborative vs. Non-collaborative Environment

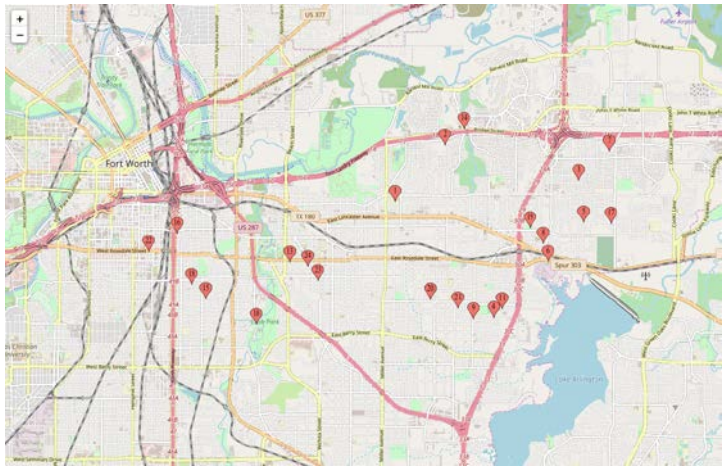
Conceptual ABM Development

- **To analyze the benefit of collaboration and determine an appropriate structure for food pantry collaboration, an agent-based model has been developed using NetLogo as a conceptual model.**
- A food assistance network located in Tarrant County, Texas, was used as a case study

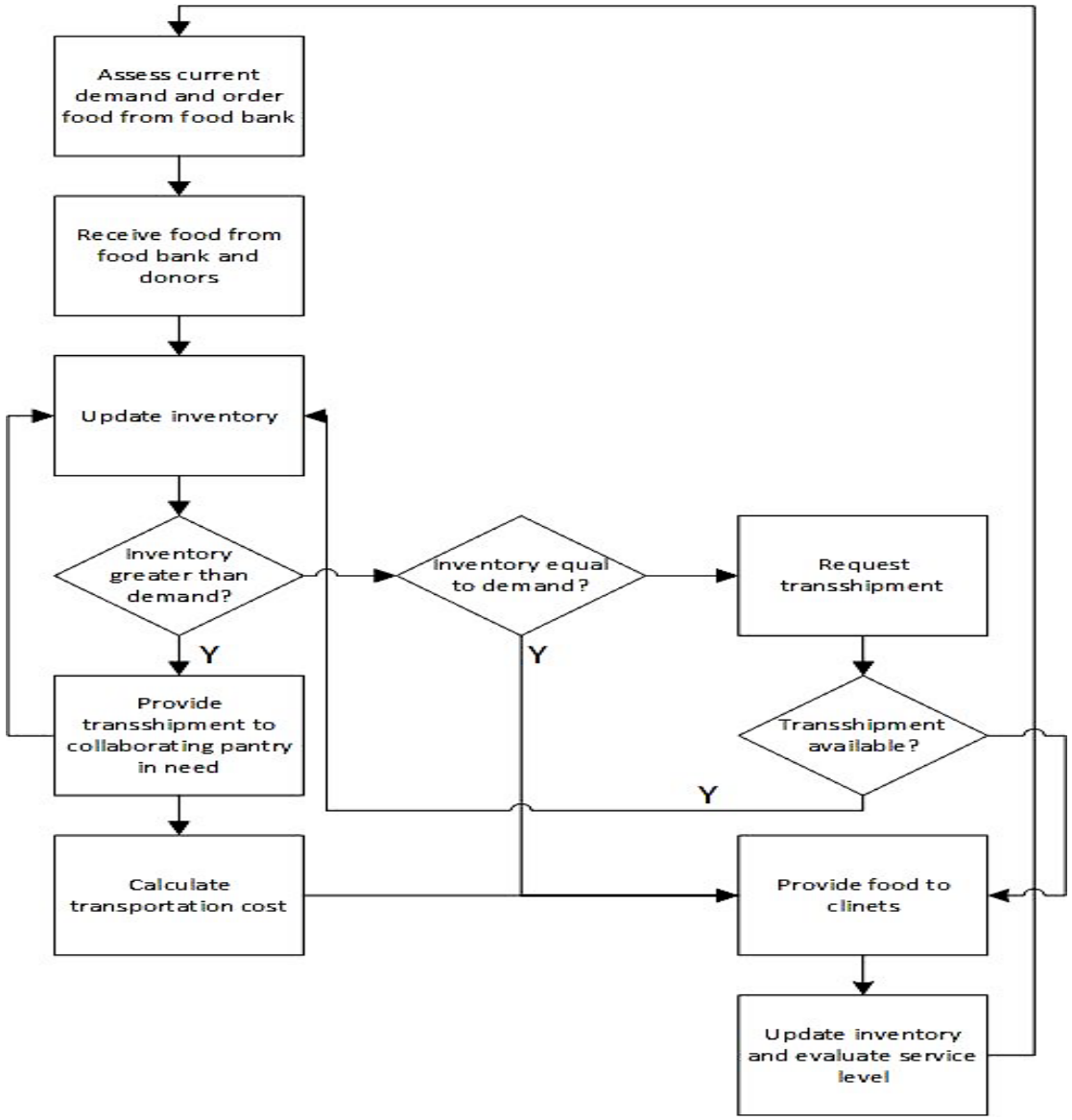
ABM Development

Base Model Description

- The 23 food pantry agents are assigned to specific geographic locations.
- An agent's demand for food in each weekly time-step is assumed to be constant, but the supply from the food bank is highly variable.
- The food is perishable; inventory cannot be carried from week to week
- The agents are able to make transshipments among other pantries to balance supply and demand.
- Each transshipment has an associated transportation cost.
- Key output metrics:
  - **Service level**: Percentage of demand fulfilled.
  - **Transportation cost**: Costs associated with transshipments.



Pantry locations on Google Maps



Flow chart for Agent's decision logic for each simulated week

Experimentation

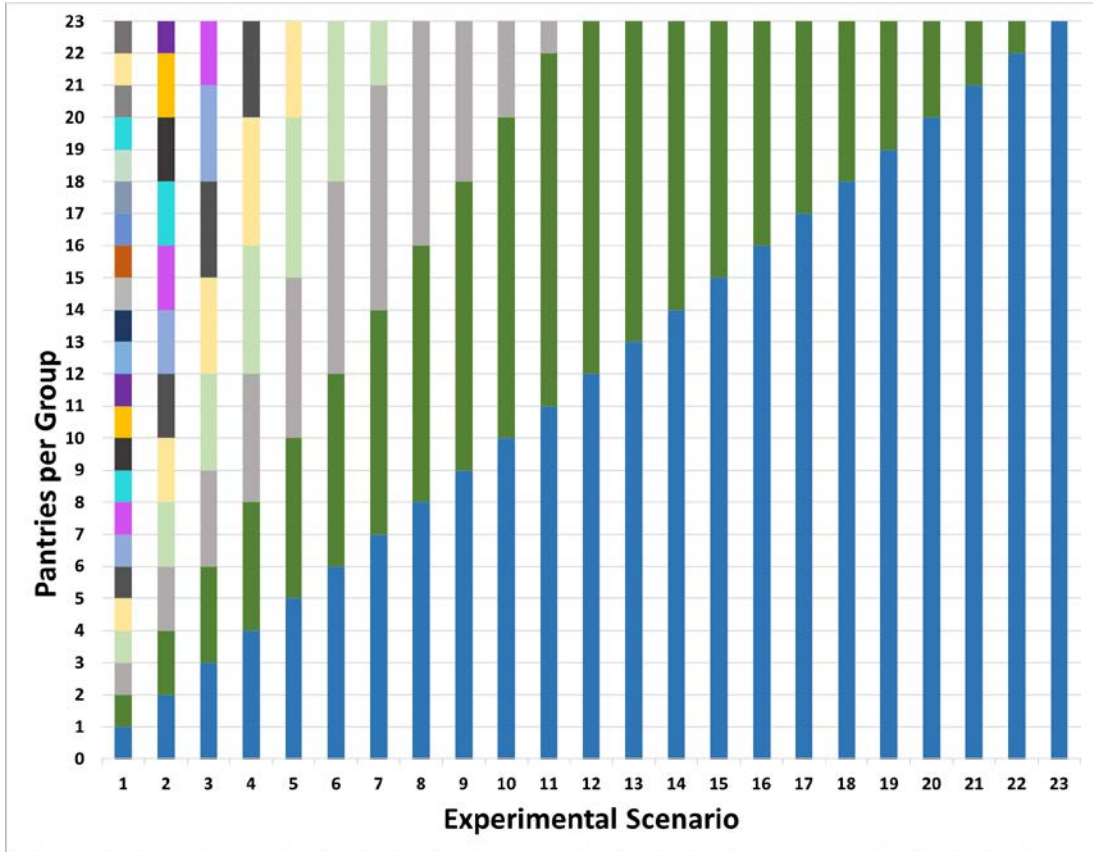
- 23 collaborative group structures.
- *Low variability scenario*:

  Product 1: N (1000, 500^2)

  Product 2: N (500, 250^2)
- *Moderate variability scenario*:

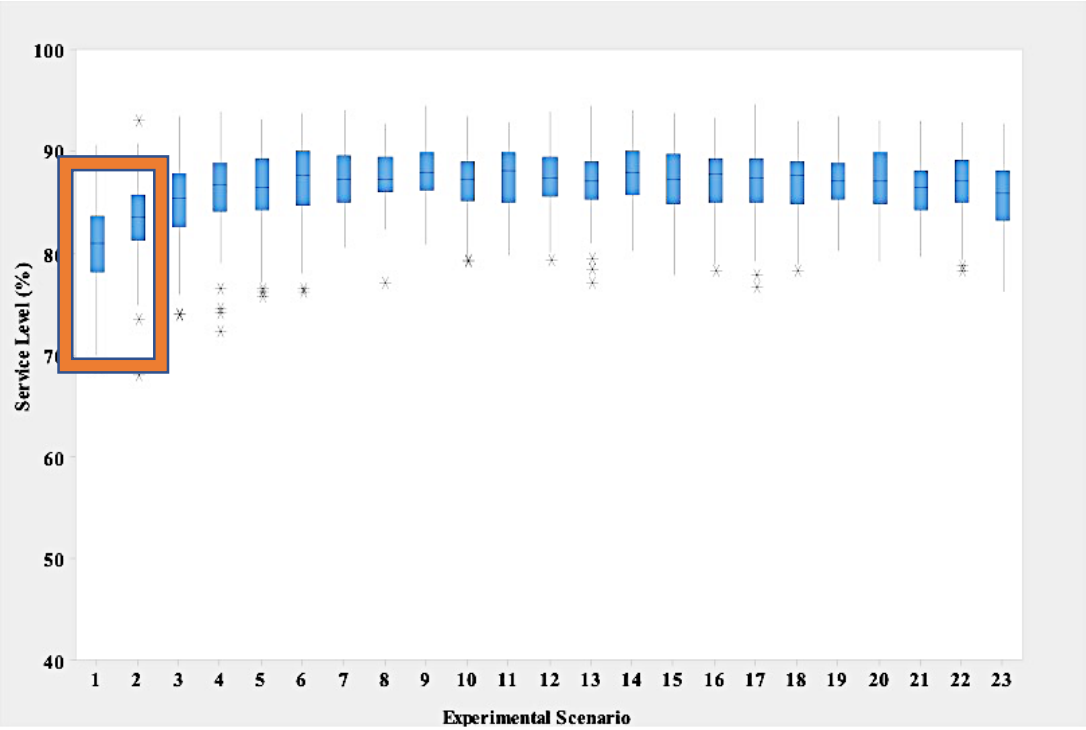
  Product 1: N (1000, 1000^2)

  Product 2: N (500, 500^2)
- 100 replications were run for each scenario.

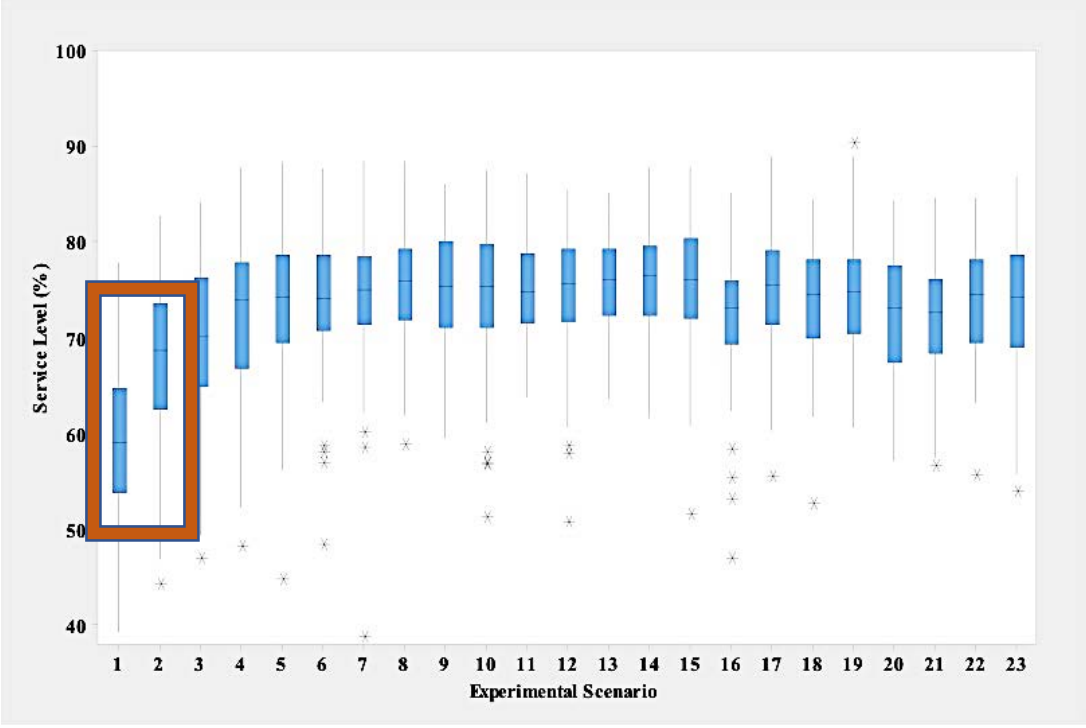


Group structures

Analysis and Result: Service Level

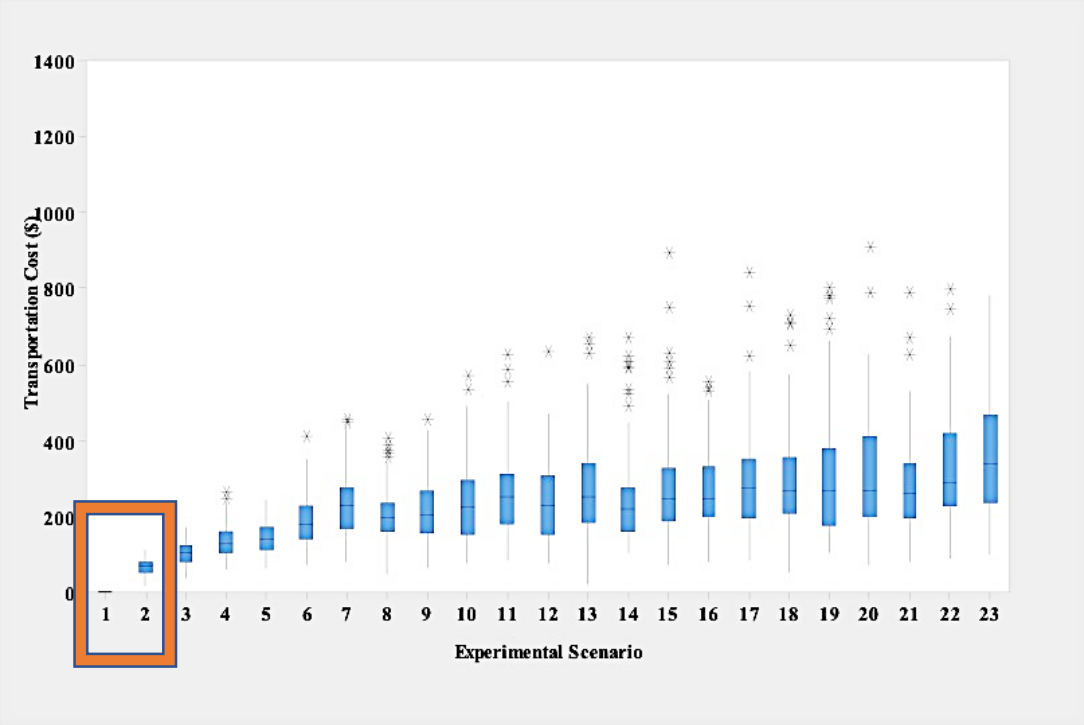


Service levels under low variability

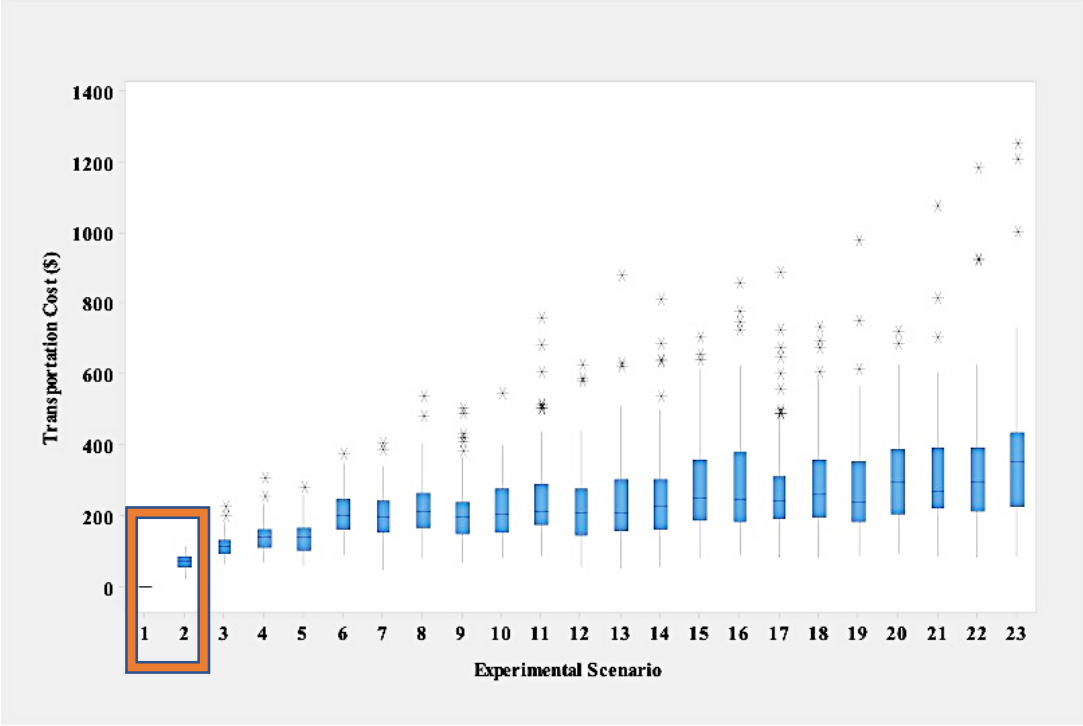


Service levels under moderate variability

Analysis and Result: Transshipment Cost



Transshipment costs under low variability

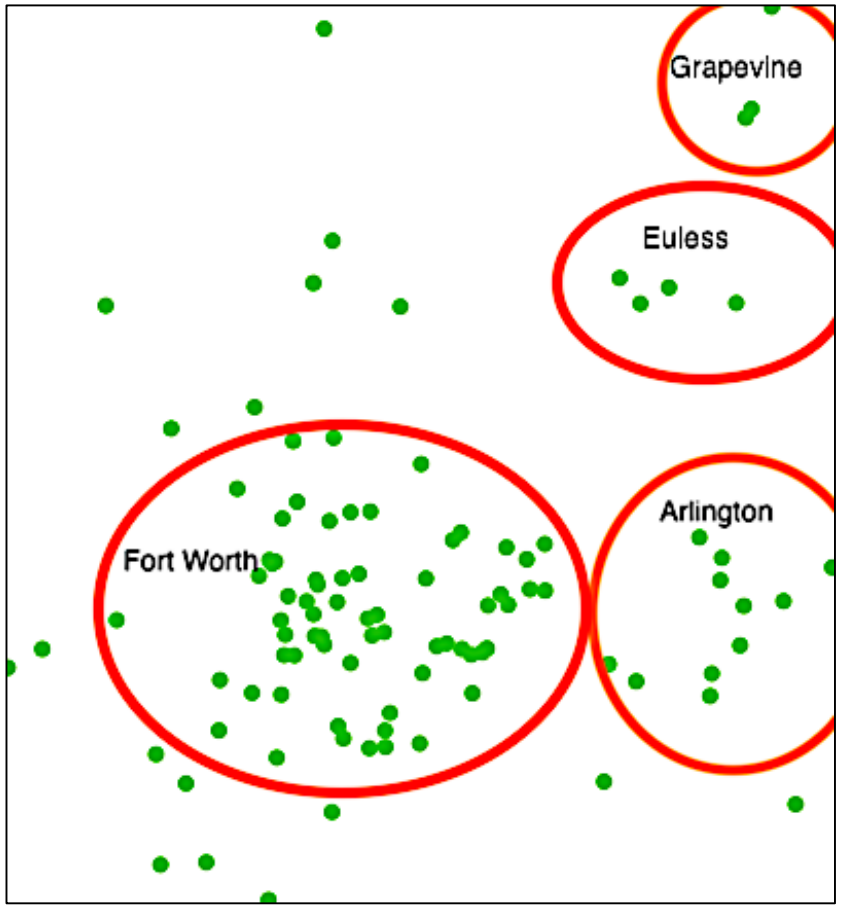


Transshipment costs under moderate variability

Model Extensions

- **GIS extension**
  - ➢Added 77 more pantries of Tarrant County.

Tarrant County on Google Maps



Pantry locations on NetLogo interface

Behavioral Extensions

- 18 of the pantry agents would choose to work in an independent environment.
- Each pantry agent will choose who do they want to collaborate with using a multi attribute utility function.
- Two attributes of this function is
  - Distance
  - Trust value
- The value of the function gets reassessed with every time step.

Utility Function

$$\mathbf{U_{Total(xy)} = (0.5 * U_{Distance(xy)}) + (0.5 * U_{Trust(xy)})}$$

$U_{Total(xy)}$ = Utility of pantry x for pantry y

$U_{Distance(xy)}$ = (Minimum distance between x and any other agents) / (Distance between x and y)

$U_{Trust(xy)}$ = (Trust value of x for y) / (Maximum trust value of x for other pantries)

Each pantry has a trust value for the other pantries, initially 1.

Satisfaction Threshold

- If, $\mathbf{U_{Total(xy)}}$ > **Satisfaction threshold**
- Pantry x will collaborate with pantry y
- Both of their trust value for each other gets update to + 0.1
- Satisfaction threshold is assumed to be 0.5 and constant

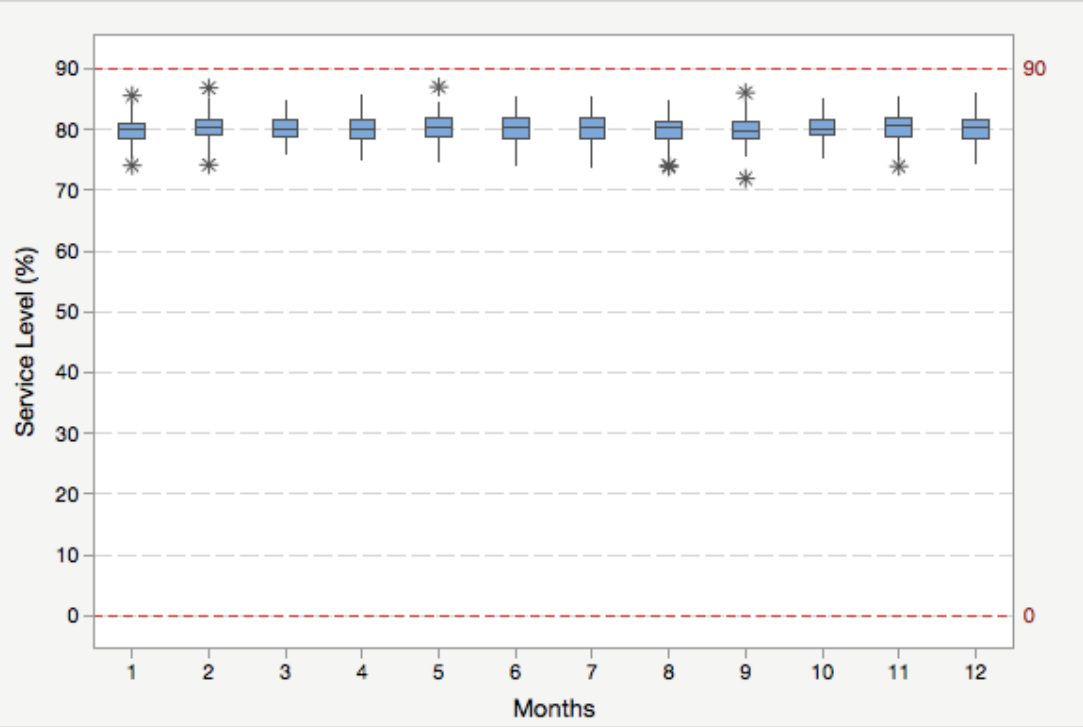
Key Output Metrics

- **Service level:** Percentage of demand fulfilled
- **Food waste:** % of food supply that is not distributed
- **Transshipment cost:** Costs associated with transshipments

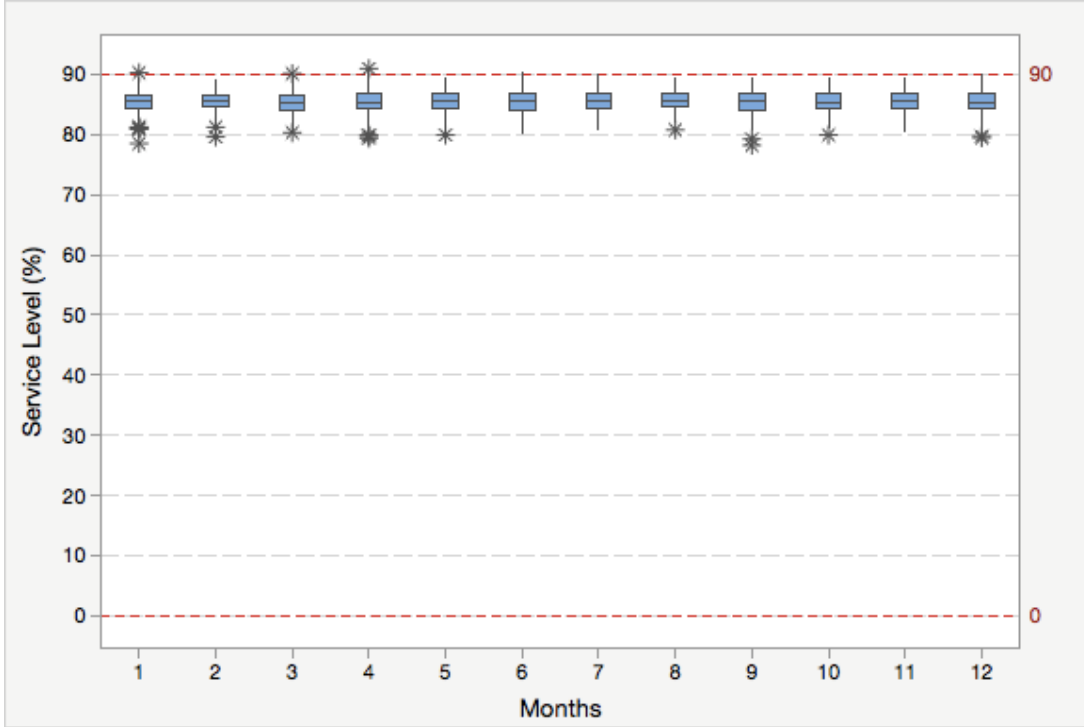
Experimentation

- *Low variability scenario*:
  Product 1: N (1000, 500^2)
  Product 2: N (500, 250^2)
- *Moderate variability scenario*:
  Product 1: N (1000, 1000^2)
  Product 2: N (500, 500^2)
- *High variability scenario*:
  Product 1: N (1000, 1200^2)
  Product 2: N (500, 750^2)
- Each scenario were ran for 52 time steps
- 100 replications were run for each scenario

Analysis and Result: Service Level

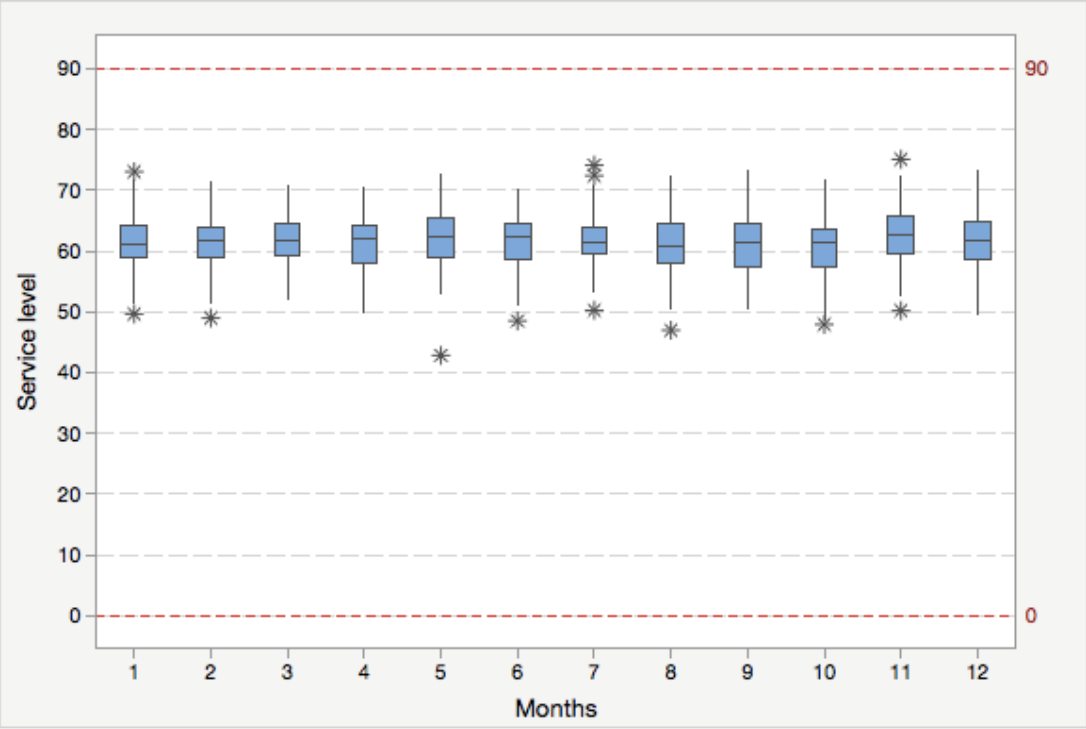


Service level for no collaboration under low variability

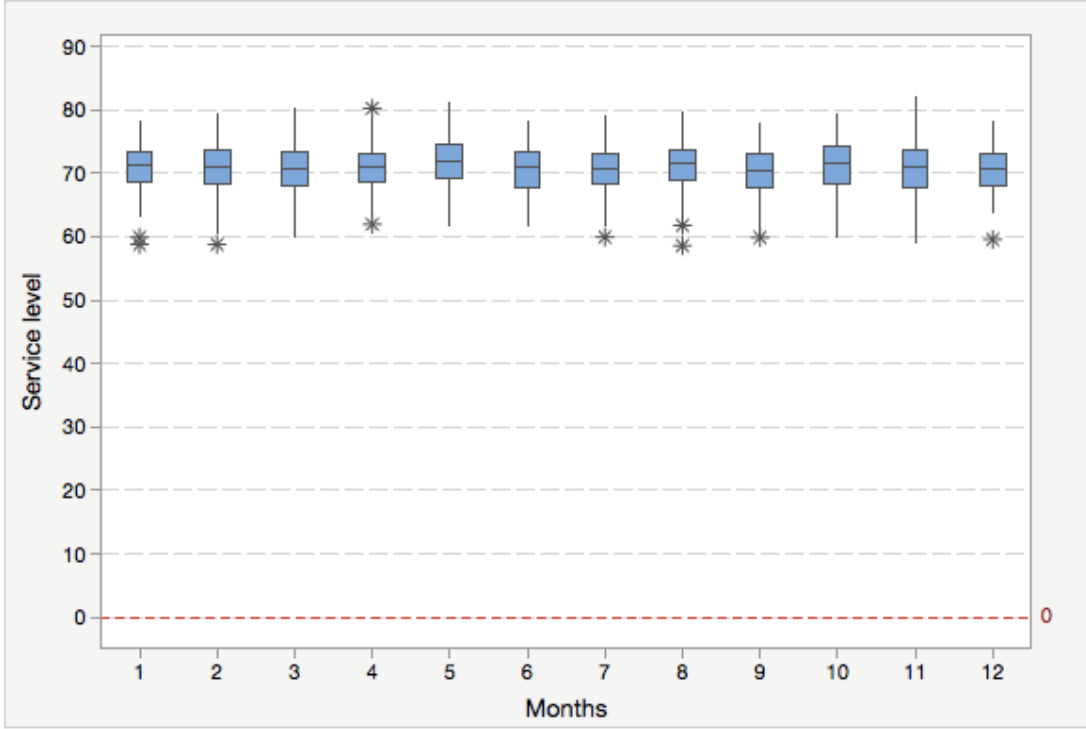


Service level for collaboration under low variability

Analysis and Result: Service Level

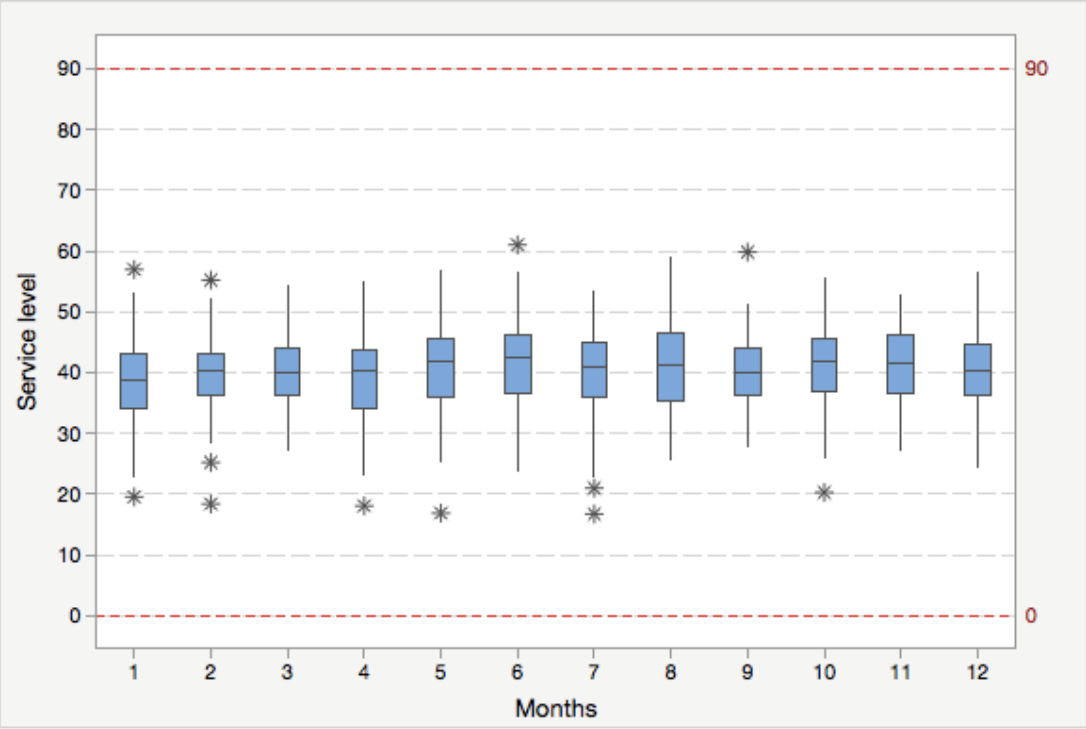


Service level for no collaboration under moderate variability

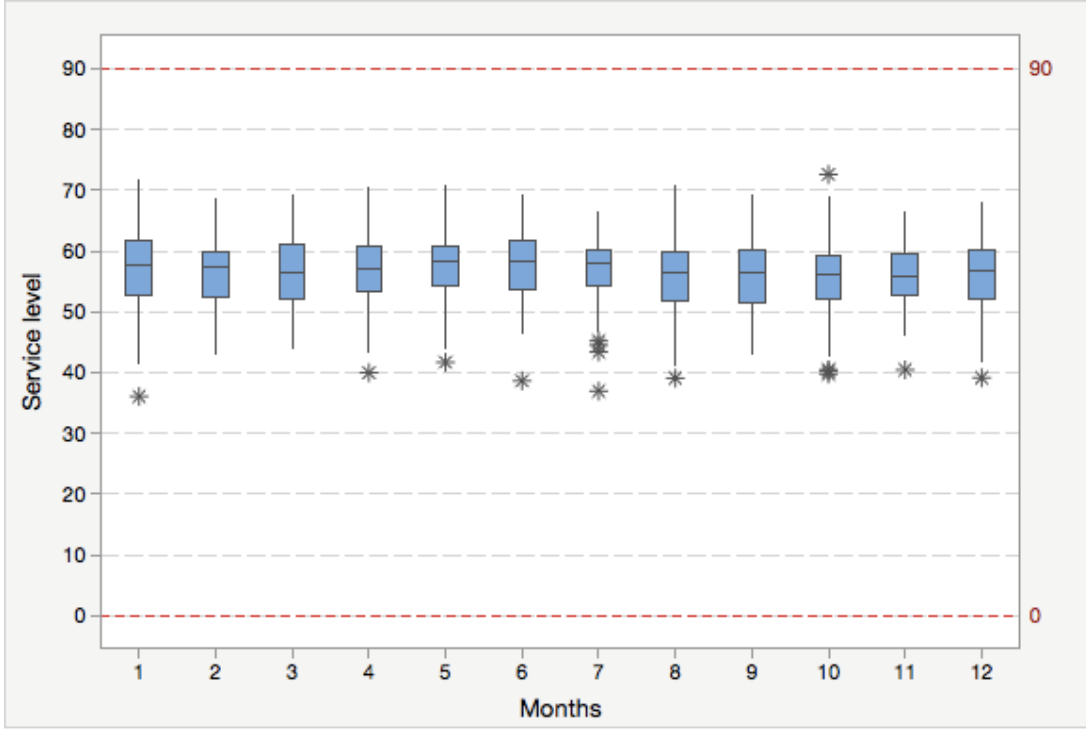


Service level for collaboration under moderate variability

Analysis and Result: Service Level

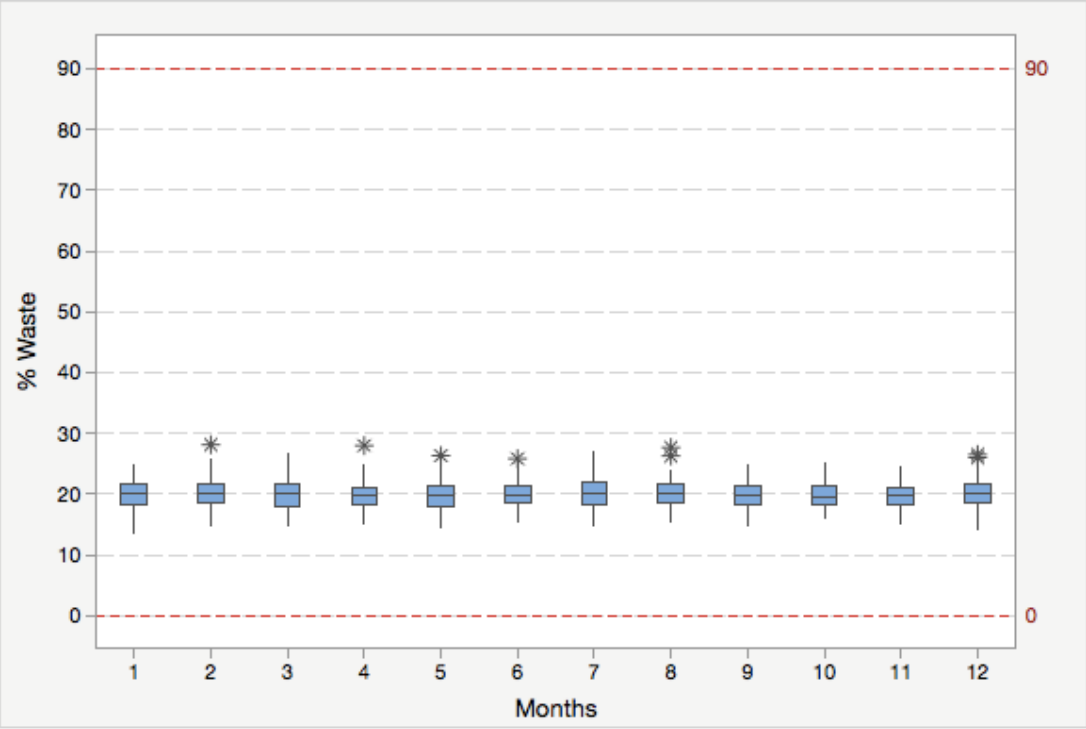


Service level for no collaboration under high variability

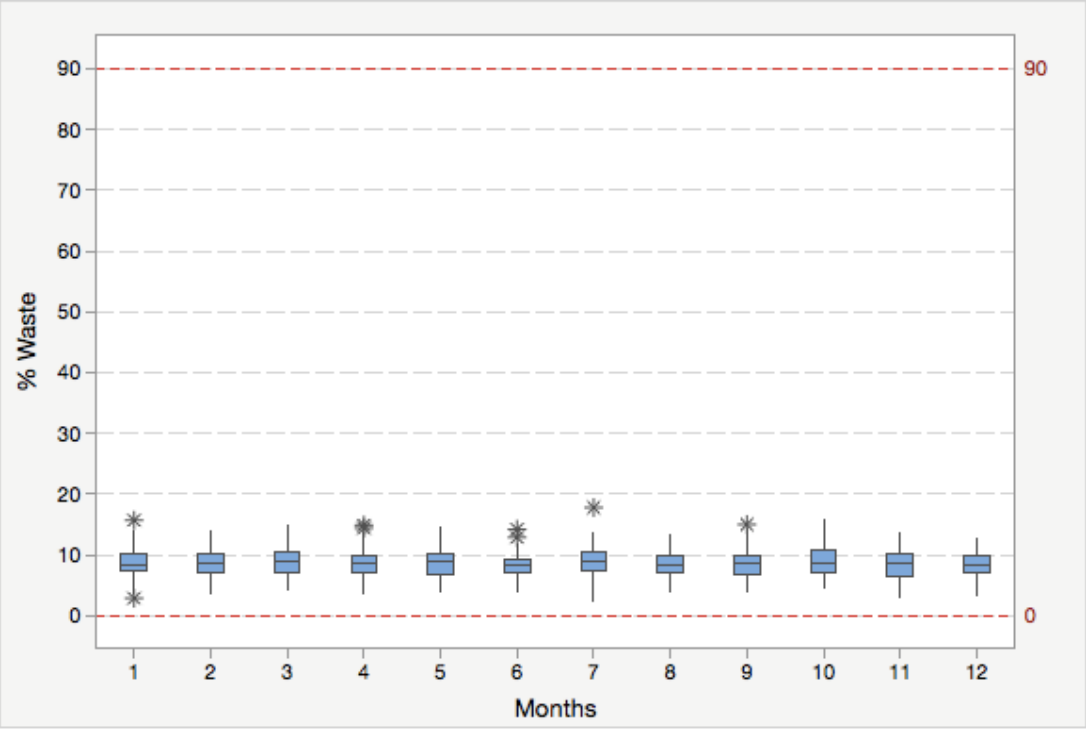


Service level for collaboration under high variability

Analysis and Result: Waste(%)

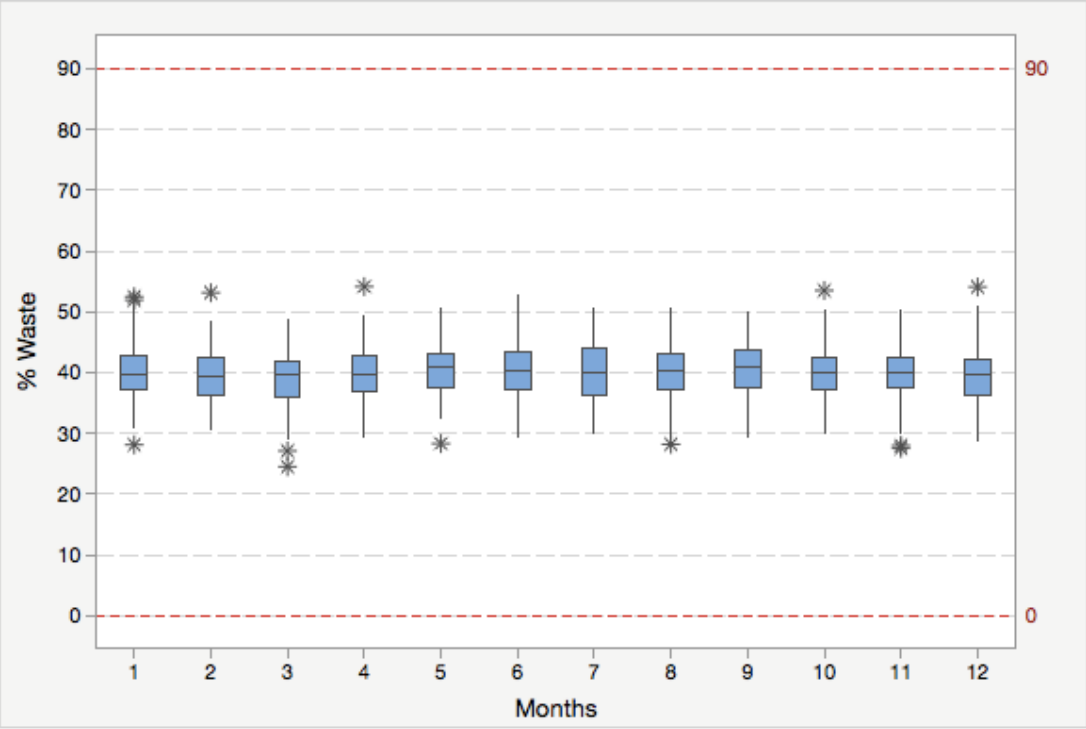


Waste(%) for no collaboration under low variability

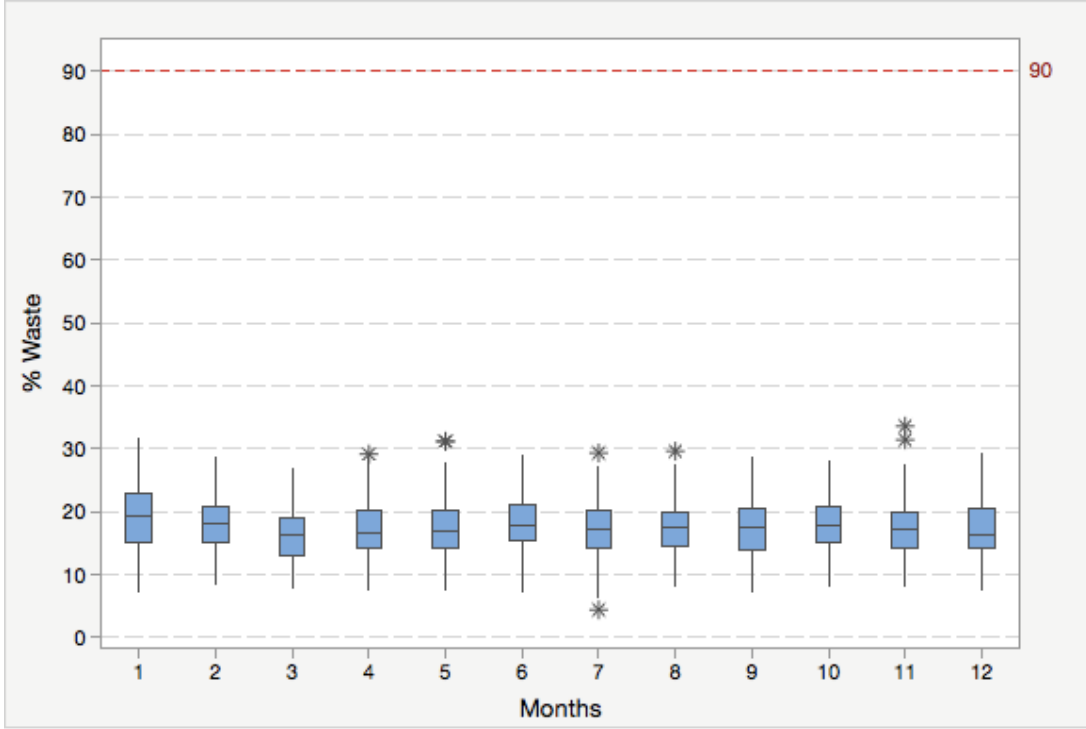


Waste(%) for collaboration under low variability

Analysis and Result: Waste(%)

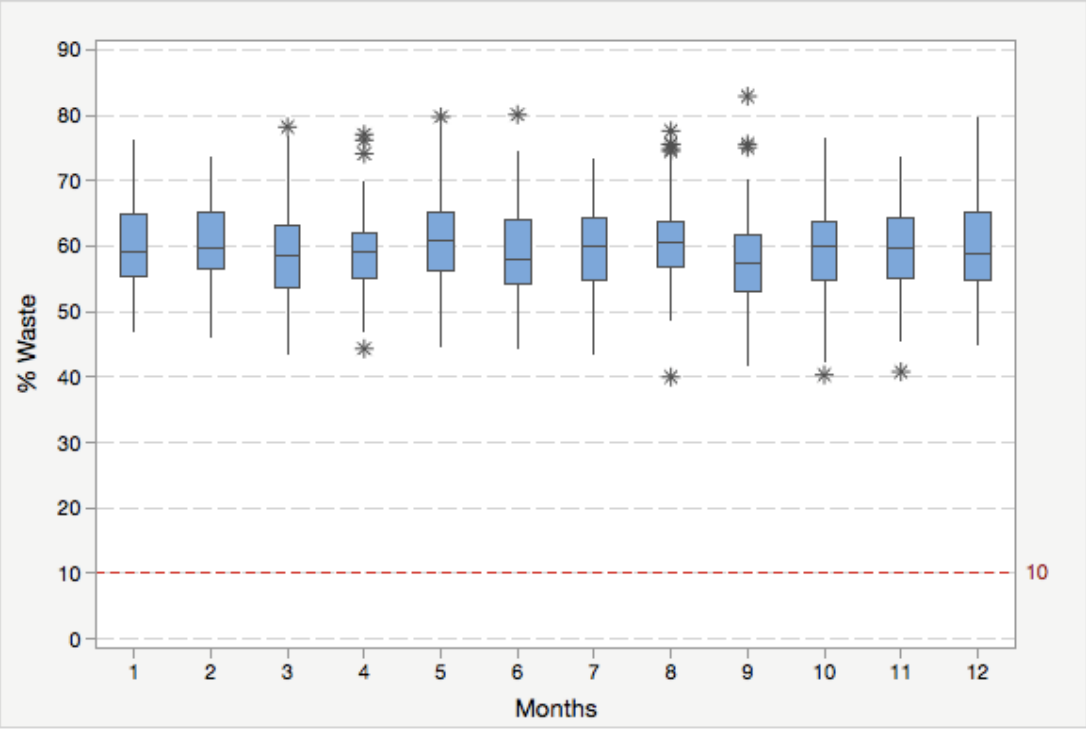


Waste(%) for no collaboration under moderate variability

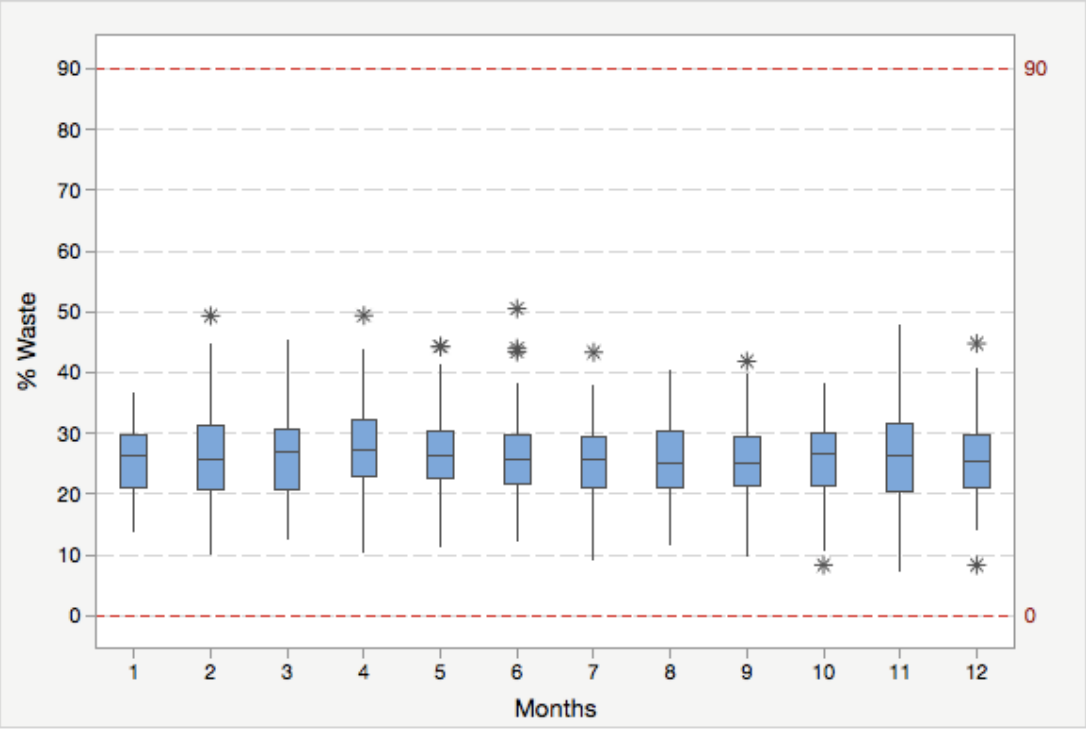


Waste(%) for collaboration under mdoerate variability

Analysis and Result Waste(%)



Waste(%) for no collaboration under high variability



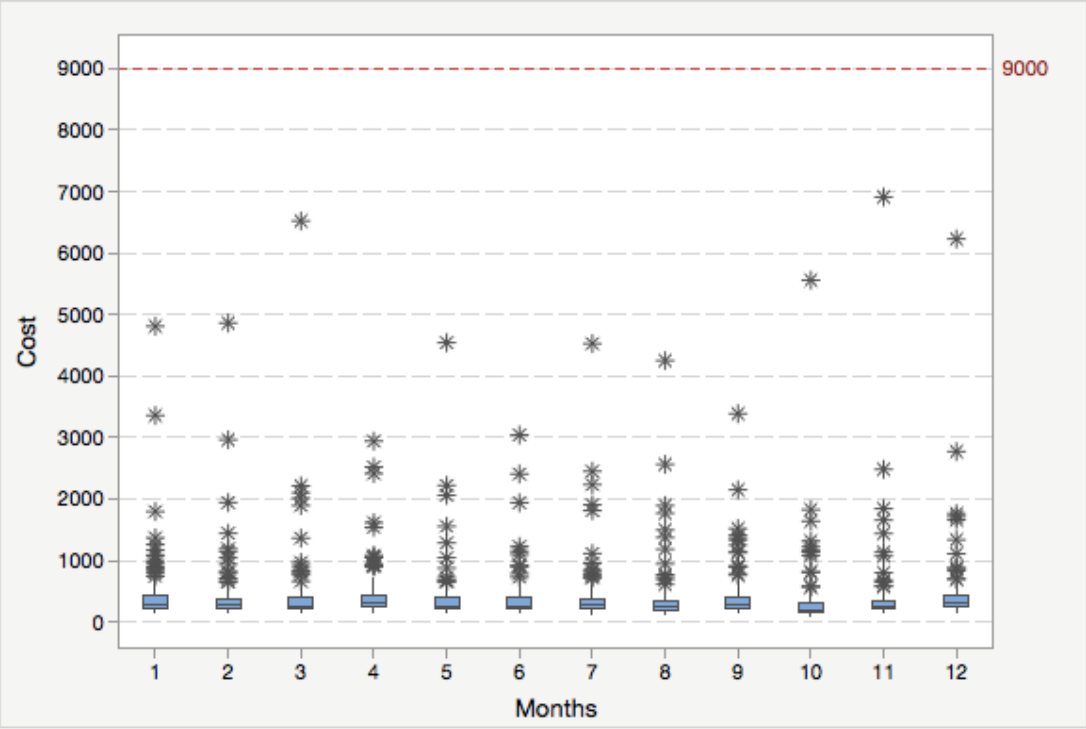
Waste(%) for collaboration under high variability

Analysis and Result

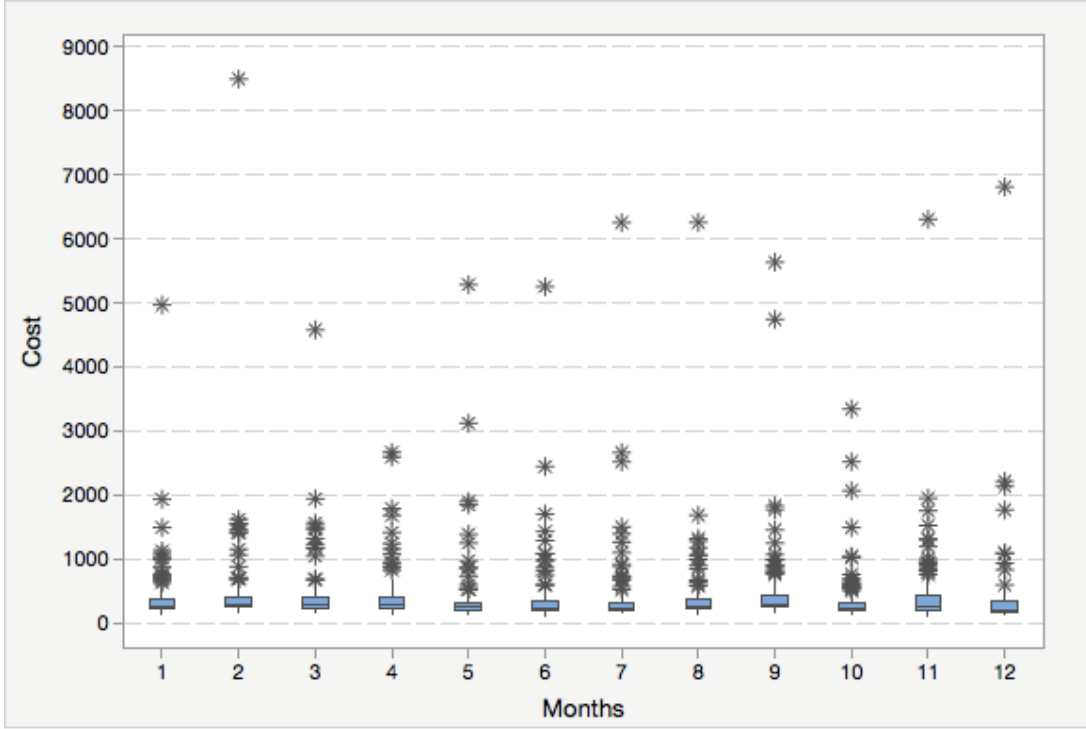
Summary for Service Level(%) and Waste (%) based on median values

Metric	Low Variability		Moderate Variability		High Variability	
	No Collaboration	Collaboration	No Collaboration	Collaboration	No Collaboration	Collaboration
Service Level (%)	80	85	60-63	70-72	38-42	56-59
Waste (%)	20	8	39-41	16-20	58-61	25-28

Analysis and Result: Cost



Transshipment cost under low variability



Transshipment cost under high variability

Research Objective-1

- **To use empirical data collection and agent-based modeling to gain a better understanding of the conditions that facilitate food pantry collaboration.**
- This study demonstrates how ABM can be used to represent a problem by integrating both logistics and operation concerns and social aspects of the supply network.
- The survey helped us to gain deeper insights of the network.
- It also helped us to validate many of our assumptions regarding benefits and barriers of collaboration.

Research Objective-2

- **To determine the degree to which collaboration can improve overall food assistance system efficiency and effectiveness.**
- Conceptual and the extended model suggest that, as supply variability increases, collaboration can significantly increase service levels as well waste reduction.
- Higher supply variability results in greater discrepancies between supply and demand, which results in lower service levels, higher transshipment costs, and many outliers.

Research Objective-3

- **To assess which kinds of collaborative structures lead to the best outcomes.**
- The results of the experiments on the conceptual model suggest that collaboration in pairs yields improved service levels with relatively little transportation cost increase.

Research Contributions

- Gathered and analyzed data on:
  - Food assistance network
    - Food pantry operations
    - Food pantry relationships/ communication
    - Collaborative tendencies among the food pantries
- Provide a better understanding of the conditions that facilitate food pantry collaboration.
- Determine the degree to which collaboration can improve overall food assistance system efficiency and effectiveness.
- Modeling contribution: Developed a novel preliminary collaboration model for non-profit supply chain.

Counties with the Highest Number of Food Insecure People

State	County (metro area)	Food Insecurity (#)	Food Insecurity (%)
NY	New York (five boroughs, collectively)	1,215,440	14.4%
CA	Los Angeles	1,147,010	11.4%
TX	Harris (Houston)	738,140	16.6%
IL	Cook (Chicago)	659,990	12.6%
AZ	Maricopa (Phoenix)	585,330	14.3%
TX	Dallas	442,920	17.6%
CA	San Diego	379,130	11.7%
MI	Wayne (Detroit)	366,690	20.7%
PA	Philadelphia County	327,320	21.0%
TX	Tarrant County (Fort Worth)	323,840	16.6%

Source: Map the Meal Gap Project, Feeding America (2018)

- **ABM Results showed 5-20% increase in service level**
- **That could result in feeding 16,192 – 64,768 more people.**
- **10-40% waste reduction means 7.2 – 28.8 billion lbs. of waste reduction through out the U.S.**

Recommendations to Food Assistance Network

- There are benefits of collaboration in terms of service level and waste reduction
- Food banks should be educated about the benefits of collaboration and explore ways to promote collaboration
- Food assistance network should consider a formal platform for collaboration using real time inventory update and shared capacity
- Ensure benefits of collaboration do not get outweighed by transshipment cost

Recommendations for Future Work

- Data Collection
  - Conducting interviews with those who have provided contact information in the survey to have a better understanding and in depth answers.
  - Collect data from other counties under TAFB.
- ABM Development
  - Suppliers
  - Product Variety
  - Transshipment Cost
  - Pantry Relationships

References

United States Department of Agriculture. Key Statistics & Graphics. Retrieved July 18, 2018 from https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/key-statistics-graphics/#foodsecure

Feeding America. Fighting Food Waste with Food Rescue. Retrieved July 18, 2018 from http://www.feedingamerica.org/our-work/our-approach/reduce-food-waste.html

"Map The Meal Gap". *Feeding America*, 2019, http://map.feedingamerica.org/county/2016/overall/texas/county/tarrant.

Tarasuk, Valerie, et al. "A Survey of Food Bank Operations in Five Canadian Cities." *BMC Public Health*, vol. 14, no. 1, 2014, doi:10.1186/1471-2458-14-1234.

Handforth, Becky, et al. "A Qualitative Study of Nutrition-Based Initiatives at Selected Food Banks in the Feeding America Network." *Journal of the Academy of Nutrition and Dietetics*, vol. 113, no. 3, Elsevier, 2013, pp. 411–15, doi:10.1016/j.jand.2012.11.001.

Middleton, Georgia, et al. "The Experiences and Perceptions of Food Banks amongst Users in High-Income Countries: An International Scoping Review." *Appetite*, vol. 120, Elsevier Ltd, 2018, pp. 698–708, doi:10.1016/j.appet.2017.10.029.

Depa, Julia, et al. "Prevalence of Food Insecurity among Food Bank Users in Germany and Its Association with Population Characteristics." *Preventive Medicine Reports*, vol. 9, no. January, Elsevier, 2018, pp. 96–101, doi:10.1016/j.pmedr.2018.01.005.

References

Schneider, Kellie, and Sarah G. Nurre. “A Multi-Criteria Vehicle Routing Approach to Improve the Compliance Audit Schedule for Food Banks.” *Omega (United Kingdom)*, vol. 84, Elsevier Ltd, 2019, pp. 127–40, doi:10.1016/j.omega.2018.05.002.

Davis, Lauren B., et al. “Scheduling Food Bank Collections and Deliveries to Ensure Food Safety and Improve Access.” *Socio-Economic Planning Sciences*, vol. 48, no. 3, Elsevier Ltd, 2014, pp. 175–88, doi:10.1016/j.seps.2014.04.001.

Sengul Orgut, Irem, et al. “Robust Optimization Approaches for the Equitable and Effective Distribution of Donated Food.” *European Journal of Operational Research*, vol. 269, no. 2, Elsevier B.V., 2018, pp. 516–31, doi:10.1016/j.ejor.2018.02.017.

Wilensky, Uri, and William Rand. *An Introduction to Agent-Based Modeling: Modeling Natural, Social, and Engineered Complex Systems with NetLogo*. The MIT Press, 2015.

References

1. United States Department of Agriculture. Key Statistics & Graphics. Retrieved July 18, 2018 from https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/key-statistics-graphics/#foodsecure

2. United States Department of Agriculture. OCE | U.S. Food Waste Challenge | FAQ's. Retrieved July 18, 2018 from https://www.usda.gov/oce/foodwaste/faqs.htm

3. Feeding Texas. What is Food Insecurity? Retrieved July 18, 2018 from https://www.feedingtexas.org/learn/food-insecurity/

4. Feeding America. Fighting Food Waste with Food Rescue. Retrieved July 18, 2018 from http://www.feedingamerica.org/our-work/our-approach/reduce-food-waste.html

5. Tarasuk, V., & Eakin, J. M. (2005). “Food assistance through “surplus” food: Insights from an ethnographic study of food bank work,” Agriculture and Human Values,22(2), 177-186. doi:10.1007/s10460-004-8277-x

6. Choi, T. Y., Dooley, K. J., & Rungtusanatham, M. (2001). “Supply networks and complex adaptive systems: Control versus emergence,” Journal of Operations Management,19(3), 351-366. doi:10.1016/s0272-6963(00)00068-1

7. Pathak, S. D., Day, J. M., Nair, A., Sawaya, W. J., & Kristal, M. M. (2007). “Complexity and Adaptivity in Supply Networks: Building Supply Network Theory Using a Complex Adaptive Systems Perspective*,” Decision Sciences,38(4), 547-580. doi:10.1111/j.1540-5915.2007.00170.x

8. "Map The Meal Gap Data | Feeding America". Feedingamerica.Org, 2019, https://www.feedingamerica.org/research/map-the-meal-gap/how-we-got-the-map-data.

9. "Map The Meal Gap". Feeding America, 2019, http://map.feedingamerica.org/county/2016/overall/texas/county/tarrant.

10. Gustavsson, J., et al. “Global Food Losses and Food Waste.” Food and Agriculture Organization of the United Nations, 2011, doi:10.1098/rstb.2010.0126.

11. Tarasuk, Valerie, et al. “A Survey of Food Bank Operations in Five Canadian Cities.” BMC Public Health, vol. 14, no. 1, 2014, doi:10.1186/1471-2458-14-1234.

12. Warshawsky, Daniel Novik. “New Power Relations Served Here: The Growth of Food Banking in Chicago.” Geoforum, vol. 41, no. 5, Elsevier Ltd, 2010, pp. 763–75, doi:10.1016/j.geoforum.2010.04.008.

13. Middleton, Georgia, et al. “The Experiences and Perceptions of Food Banks amongst Users in High-Income Countries: An International Scoping Review.” Appetite, vol. 120, Elsevier Ltd, 2018, pp. 698–708, doi:10.1016/j.appet.2017.10.029.

14. Depa, Julia, et al. “Prevalence of Food Insecurity among Food Bank Users in Germany and Its Association with Population Characteristics.” Preventive Medicine Reports, vol. 9, no. January, Elsevier, 2018, pp. 96–101, doi:10.1016/j.pmedr.2018.01.005.

15. Handforth, Becky, et al. “A Qualitative Study of Nutrition-Based Initiatives at Selected Food Banks in the Feeding America Network.” Journal of the Academy of Nutrition and Dietetics, vol. 113, no. 3, Elsevier, 2013, pp. 411–15, doi:10.1016/j.jand.2012.11.001.

16. Schneider, Kellie, and Sarah G. Nurre. “A Multi-Criteria Vehicle Routing Approach to Improve the Compliance Audit Schedule for Food Banks.” Omega (United Kingdom), vol. 84, Elsevier Ltd, 2019, pp. 127–40, doi:10.1016/j.omega.2018.05.002.

17. Davis, Lauren B., et al. “Scheduling Food Bank Collections and Deliveries to Ensure Food Safety and Improve Access.” Socio-Economic Planning Sciences, vol. 48, no. 3, Elsevier Ltd, 2014, pp. 175–88, doi:10.1016/j.seps.2014.04.001.

18. Sengul Orgut, Irem, et al. “Robust Optimization Approaches for the Equitable and Effective Distribution of Donated Food.” European Journal of Operational Research, vol. 269, no. 2, Elsevier B.V., 2018, pp. 516–31, doi:10.1016/j.ejor.2018.02.017.

19. Brock, Luther G., and Lauren B. Davis. “Estimating Available Supermarket Commodities for Food Bank Collection in the Absence of Information.” Expert Systems with Applications, vol. 42, no. 7, Elsevier Ltd, 2015, pp. 3450–61, doi:10.1016/j.eswa.2014.11.068.

20. Mohan, S., et al. “Improving the Efficiency of a Non-Profit Supply Chain for the Food Insecure.” International Journal of Production Economics, vol. 143, no. 2, Elsevier, 2013, pp. 248–55, doi:10.1016/j.ijpe.2011.05.019.

21. Heap, John. “ Supply Chain Management: Strategy, Planning and Operation (3rd Edition)20071Sunil Chopra and Peter Meindl. Supply Chain Management: Strategy, Planning and Operation (3rd Edition) . Upper Saddle River, NJ: Prentice-Hall 2006. 536 Pp., ISBN: 0131730428 RRP £38.99 .” International Journal of Productivity and Performance Management, 2014, doi:10.1108/ijppm.2007.56.4.369.1.

22. Audy, J. F., et al. “Cost Allocation in the Establishment of a Collaborative Transportation Agreement-an Application in the Furniture Industry.” Journal of the Operational Research Society, 2011, doi:10.1057/jors.2010.53.

23. Pérez-Bernabeu, Elena, et al. “Horizontal Cooperation in Road Transportation: A Case Illustrating Savings in Distances and Greenhouse Gas Emissions.” International Transactions in Operational Research, 2015, doi:10.1111/itor.12130.

24. Hezarkhani, Behzad, et al. “A Competitive Solution for Cooperative Truckload Delivery.” OR Spectrum, 2016, doi:10.1007/s00291-015-0394-y.

25. Furtado, P., and J. M. Frayret. “Impact of Resource Sharing of Freight Transportation.” Proceedings of 1st International Physical Internet Conference (IPIC 2014), 2014.

26. Krajewska, M. A., et al. “Horizontal Cooperation among Freight Carriers: Request Allocation and Profit Sharing.” Journal of the Operational Research Society, 2008, doi:10.1057/palgrave.jors.2602489.

27. Verdonck, Lotte, et al. “Collaborative Logistics from the Perspective of Road Transportation Companies.” Transport Reviews, 2013, doi:10.1080/01441647.2013.853706.

28. Hingley, Martin, et al. “Using Fourth-Party Logistics Management to Improve Horizontal Collaboration among Grocery Retailers.” Supply Chain Management, 2011, doi:10.1108/13598541111155839.

29. McAdam, Maura, et al. “Development of Small and Medium-Sized Enterprise Horizontal Innovation Networks: UK Agri-Food Sector Study.” International Small Business Journal: Researching Entrepreneurship, 2014, doi:10.1177/0266242613476079.

30. Bosona, T. G., and G. Gebresenbet. “Cluster Building and Logistics Network Integration of Local Food Supply Chain.” Biosystems Engineering, 2011, doi:10.1016/j.biosystemseng.2011.01.001.

31. , et al. LOGISTICS COLLABORATION SOLUTIONS TO IMPROVE SHORT FOOD SUPPLY CHAIN SOLUTION PERFORMANCE. 2017, doi:10.17501/wcosm.2017.2106.

32. Arvitrida, Niniet Indah, et al. “An Agent-Based Model of Competition and Collaboration in Supply Chains.” Loughborough School of Business and Economics (SBE) Doctoral Conference, 2016.

33. Liao, Shu Hsien, et al. “Assessing the Influence of Supply Chain Collaboration Value Innovation, Supply Chain Capability and Competitive Advantage in Taiwan’s Networking Communication Industry.” International Journal of Production Economics, 2017, doi:10.1016/j.ijpe.2017.06.001.

34. Morash, Edward A., and Steven R. Clinton. “The Role of Transportation Capabilities in International Supply Chain Management.” Transportation Journal, 1997.

35. Lynch, Daniel F., et al. “THE EFFECTS OF LOGISTICS CAPABILITIES AND STRATEGY ON FIRM PERFORMANCE.” Journal of Business Logistics, 2000.

36. Guo, Chao, and Muhittin Acar. “Understanding Collaboration among Nonprofit Organizations: Combining Resource Dependency, Institutional, and Network Perspectives.” Nonprofit and Voluntary Sector Quarterly, 2005, doi:10.1177/0899764005275411.

37. Benson, J. Kenneth, et al. “The External Control of Organizations.” Administrative Science Quarterly, 1978, doi:10.2307/2392573.

38. Williamson, Oliver E. “The Economics of Organization: The Transaction Cost Approach.” American Journal of Sociology, 1981, doi:10.1086/227496.

39. Galaskiewicz, Joseph, and Joseph Galaskiewicz. “3 – FROM SELF-INTEREST TO ENLIGHTENED SELF-INTEREST.” Social Organization of an Urban Grants Economy, 1985, doi:10.1016/B978-0-12-273860-9.50009-2.

40. Tsasis, Peter. “The Social Processes of Interorganizational Collaboration and Conflict in Nonprofit Organizations.” Nonprofit Management and Leadership, 2009, doi:10.1002/nml.238.

41. Snavely, Keith, and Martin B. Tracy. “Collaboration among Rural Nonprofit Organizations.” Nonprofit Management and Leadership, 2000, doi:10.1002/nml.11202.

42. Wilensky, Uri, and William Rand. An Introduction to Agent-Based Modeling: Modeling Natural, Social, and Engineered Complex Systems with NetLogo. The MIT Press, 2015.

43. Johnson, Paul E. “Rational Actors Versus Adaptive Agents: Social Science Implications.” Annual Meeting of the American Political Science Association, 1998.

44. Belew, Richard K., and Melanie (Computer scientist) Mitchell. “Adaptive Individuals in Evolving Populations : Models and Algorithms.” Adaptive Individuals in Evolving Populations, 1996.

45. Axelrod, R. “The Complexity of Cooperation.” Agentbased Models of Competition and Collaboration, 1997.

46. Arthur, W. Brian, et al. “Inductive Reasoning and Bounded Rationality.” The American Economic Review, 1994, doi:10.2307/2117868.

47. Schelling, Thomas C. “Dynamic Models of Segregation.” The Journal of Mathematical Sociology, 1971, doi:10.1080/0022250X.1971.9989794.

48. Nowak, Andrzej, et al. “From Private Attitude to Public Opinion: A Dynamic Theory of Social Impact.” Psychological Review, 1990, doi:10.1037/0033-295X.97.3.362.

49. Gotts, N. M., et al. “Agent-Based Simulation in the Study of Social Dilemmas.” Artificial Intelligence Review, 2003, doi:10.1023/A:1022120928602.

50. Macy, Michael W., and Robert Willer. “From Factors to Actors: Computational Sociology and Agent-Based Modeling.” Annual Review of Sociology, 2002, doi:10.1146/annurev.soc.28.110601.141117.

51. Axtell, Robert. “Why Agents? On the Varied Motivations for Agent Computing in the Social Sciences Agent. Working Paper.” Center on Social and Economics Dynamics - The Brookings Institution, 2000.

52. Smajgl, Alex, et al. “Empirical Characterisation of Agent Behaviours in Socio-Ecological Systems.” Environmental Modelling and Software, 2011, doi:10.1016/j.envsoft.2011.02.011.

53. Epstein, Joshua M. “Agent-Based Computational Models and Generative Social Science.” Complexity, 1999, doi:10.1002/(SICI)1099-0526(199905/06)4:5<41::AID-CPLX9>3.0.CO;2-F.