A systematic literature review of food banks' supply chain operations with a focus on optimization models

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Abstract

Purpose – Food banks play an increasingly important role in society by mitigating hunger and helping needy people; however, research aimed at improving food bank operations is limited.

Design/methodology/approach – This systematic review used Web of Science and Scopus as search engines, which are extensive databases in Operations Research and Management Science. Ninety-five articles regarding food bank operations were deeply analyzed to contribute to this literature review.

Findings – Through a systematic literature review, this paper identifies the challenges faced by food banks from an operations management perspective and positions the scientific contributions proposed to address these challenges.

Originality/value – This study makes three main contributions to the current literature. First, this study provides new researchers with an overview of the key features of food bank operations. Second, this study identifies and classifies the proposed optimization models to support food bank managers with decision-making. Finally, this study discusses the challenges of food bank operations and proposes promising future research avenues.

Keywords Food bank, Food pantries, Food distribution, Food insecurity, Supply chain, Operations, Nonprofit organizations, Optimization

Paper type Literature review

1. Introduction

Families worldwide struggle to collect enough food with basic nutrition for themselves and their children daily. Around 20% of the world's population survives with less than US$1.25 a day (Desai *et al.*, 2016), and more than 10% of the world's population does not have access to sufficient food. This leads to numerous problems worldwide; disease, poverty, hunger and malnutrition affect many lives (Reihaneh and Ghoniem, 2018).

Poverty and food insecurity have constantly increased worldwide. Food insecurity is a grave issue, particularly in developing nations, defined as "a socioeconomic inability to obtain appropriate quality food in sufficient amounts" (Trzaskowska *et al.*, 2020). Food insecurity arises when people have restricted access to proper food, hindering a vigorous life (Davis *et al.*, 2016).

Several nonprofit organizations have been established to reduce food insecurity, playing a progressive part in conveying essential services to defenseless and underserved individuals in society (Balcik *et al.*, 2014). Food banks are one type of nonprofit organization contributing the most to reducing food insecurity. Food banks are "humanitarian aid organizations that collect, organize and deliver food to nonprofit member agencies and to individuals to help alleviate society's hunger problem" (Ataseven *et al.*, 2018). Recently, the number of people suffering from malnourishment is estimated to be at its highest point, and food banks have been vital for the less fortunate (Tarasuk *et al.*, 2020).

Paradoxically, around 20%–30% of the food produced is wasted annually across the supply chain (Michelini *et al.*, 2018), leading to two concurrent social issues: food insecurity and food waste. Food banks play a key role in reducing wasted food problems by connecting the abundance in supply with the requests of needy people (Eisenhandler and Tzur, 2019a). We refer to Sengul Orgut *et al.* (2016a) for a discussion of food bank activities and Schneider (2013) for the political, legal, social and logistical barriers and incentives related to this topic.

Many authors emphasize the importance of the social problems facing food banks. Thompson *et al.* (2018) report on a qualitative study of the health and well-being challenges of

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food poverty and food banks. Puddephatt *et al.* (2020) prove that food insecurity creates health issues. Chen *et al.* (2018) encourage cash donations by helping people visualize the impact of their contributions. Finally, Waltz *et al.* (2018) explore barriers to equal food access and current approaches to overcoming social, economic and physical barriers.

In countries with good infrastructure, food banks assist people in need by gathering donations that they later redistribute appropriately and impartially (Sengul Orgut *et al.*, 2016a). Donations are not regular enough to satisfy demand; hence, food banks must deal with the conflict between being equitable (working so that each individual in need has the same likelihood of being served) and being effective (serving the maximum number of people in need). This is a typical problem for nonprofit organizations (Sengul Orgut *et al.*, 2016a; Solak *et al.*, 2014).

This paper has several aims:

- to provide essential knowledge for new researchers;
- to identify and classify the concrete decisions, pursued objectives and the major operations management problems faced by food banks;
- to describe the optimization approaches in the extant literature to address the identified problems; and
- to recognize emerging research directions in the field.

To this end, we conducted a systematic literature review on studies related to food bank operation, focusing on optimization models. Unlike Mahmoudi *et al.* (2022), who recently reviewed decision support models addressing food aid supply chains, our work differs in the research scope and framework used to classify and position the relevant studies. First, Mahmoudi *et al.* (2022) reviewed works related to food aid management with no restriction on the organizational structure managing the aid. However, our research focuses exclusively on food banks. By narrowing our research, we observed particularities and objectives in food banks, which are unobserved in food aid distribution networks and worth in-depth analysis. Furthermore, this narrower focus sheds light on how food bank operations differ from humanitarian aid distribution problems. Second, Mahmoudi *et al.* (2022) classified papers according to the methodology they proposed; those proposing optimization models were further classified into strategic, tactical and operational decision-making problems. In contrast, our analysis adopts a more comprehensive framework grounded on the operations handled by managers at the three stages of the food banks' supply chain (supply, food banks operations and demand). Given these differences, only 20 references are studied by the reviews. Given that this review contains more than 60 references, we believe that its content differs significantly and complements Mahmoudi *et al.* (2022).

The rest of this paper is organized as follows. Section 2 provides the research methodology and describes the criteria for selecting the articles used in this systematic literature review. Section 3 presents and analyses the results. Section 4 includes a discussion and presents directions for further research, whereas Section 5 concludes the paper.

2. Research methodology

This systematic review used the search engines Web of Science and Scopus, which are extensive databases in *Operations Research and Management Science* (OR/MS). This section describes the criteria used to select the articles, followed by an explanation of the article selection process and the steps to complete the data extraction.

2.1 Databases search

Databases were queried on June 1, 2022. Based on previous preliminary searches, we used "foodbank" and "food bank," which are both commonly used and are suitable to cover the extant literature. The following steps were followed for each database:

- Web of Science: The keywords "foodbank" OR "food bank" OR "food pantries" were searched, as shown.

The following filters were applied to exclude irrelevant articles relative to our interests:

1 the expression only appears in the article title, abstract or keywords;
2 only peer-reviewed articles (excluding book chapters, reviews, notes and editorials); and
3 regarding the subject area, the following were excluded:

- Public environmental, occupational health;
- Nutrition dietetics; and
- Agricultural economics policy.

A total of 304 articles were found in this database.

- Scopus: The keywords {foodbanks} OR {food banks} OR {food pantries} were searched, as shown.

The following filters were used to exclude articles that did not fit our search area:

1 the expression only appears in the article title, abstract or keywords;
2 only peer-reviewed articles (excluding book chapters, reviews, notes and editorials); and
3 in the subject area, the following were excluded:

- Medicine;
- Nursing;
- Agricultural and biological sciences;
- Environmental science; and
- Arts and humanities.

A total of 231 articles were found in this database.

We obtained 386 distinct articles from both databases to review. Table 1 summarizes the search criteria.

2.2 Final article selection

Included studies had to meet at least one of the following criteria:

- include a model or discussion on food bank operations, food banks supply chain or analytics applied to food banks;
- include information related to food bank operations;
- include information on donations; and
- include general information, such as nutritional needs, volunteering and food insecurity.

We also required the papers to be written in English.

A manual selection process was performed on the 386 articles, and we read the title and abstract of each article. If the article met the inclusion criteria above, the paper was downloaded, otherwise it was omitted. Two reviewers were

Table 1 Article search criteria in the databases

	Web of Science	Scopus
Search	"Foodbanks" OR "food banks" OR "food pantries"	{Foodbanks} OR {food banks} OR {food pantries}
Area	Article title, abstract, or keywords	Article title, abstract, or keywords
Type	Only peer-reviewed articles	Only peer-reviewed articles
Excluded subject areas	– Public environmental occupational health – Nutrition dietetics – Agricultural economics policy	– Medicine – Nursing – Agricultural and biological sciences – Environmental science – Arts and humanities
Articles found	304	231

consulted to determine a paper's relevance when we encountered any uncertainty.

After applying this filter, 86 research articles remained. We checked the content of these papers by reading them fully, keeping only those that fully met the inclusion criteria. This left a total of 52 articles.

The last procedure was to delve into the references cited by the most recent selected articles (we arbitrarily limited ourselves to those published in 2021) to find other articles that might contribute to this literature review.

A total of 9 additional articles were identified from the references, totaling 61 articles. Data retrieved from the databases were exported to Mendeley to continue the data extraction and synthesis.

2.3 Data extraction and analysis

We constructed a table to continue the data extraction, which included the following: title, authors, year of publication, keywords, abstract, summary, problem identification, the main topic and country. This helped us identify papers that included an optimization model contributing to Section 3.3. The rest of the papers were analyzed to contribute to other sections regarding important issues in food bank operations.

A second table was constructed with papers that included optimization models. A deeper analysis was performed for these papers to identify their goals and position the characteristics of the problems they studied concerning the analysis framework proposed in Section 3.3. A total of 18 articles that included optimization models were deeply analyzed.

3. Results and analysis

3.1 Statistics

We examined some facts to establish the importance attributed to food banks. Figure 1 illustrates the total number of articles per year in both databases. The number of related articles published annually is growing, indicating that the interest in this topic from researchers in the OR/MS area has increased. Nevertheless, the highest number of publications per year (19 articles published in 2021) is low compared to other research topics. For instance, one of the most recent systematic literature reviews that focused on mathematical models of humanitarian logistics (Hezam and Nayeem, 2021) reports a rise in published papers from around 100 in 2010 to 200 in 2019.

Figure 1 Articles published per year

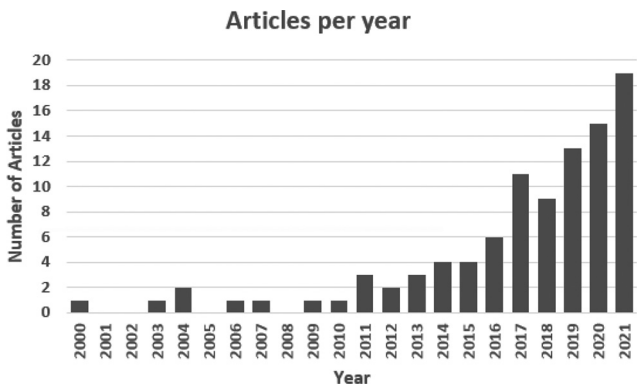


Figure 2 shows the countries each article addresses, providing an idea of which countries have more food bank related research. Of all publications, 64% were from the UK and the USA; thus, there is a gap in an opportunity to study other countries' operations to understand the most affected factors.

Finally, Tables 2 and 3 shed some light on where articles on food banks were published, providing complementary information on the publication data. On the one hand, Table 2 reports the journals that published more than three relevant papers, providing their categories according to Clarivate's Journal Citation Reports. Table 2 confirms that food banks received significant attention from journals in

Figure 2 Articles published by country

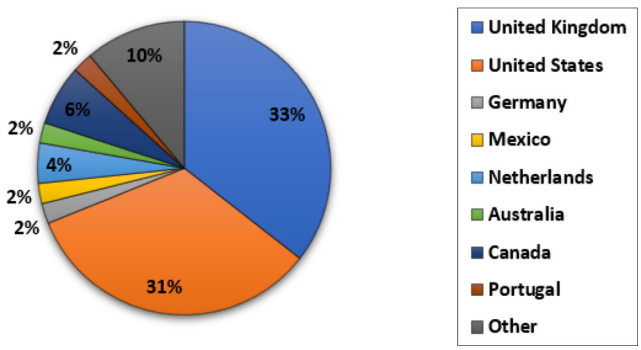


Table 2 Publications by journals

Journal	No. of articles	Category (JCR)
VOLUNTAS	7	Social Issues
Social Policy and Society	6	Social Work
Business Peace and Sustainable Development	5	–
European Journal of Operational Research	4	MS/OR
Journal of Poverty and Social Justice	4	Social Issues
Anthropology Today	3	Anthropology
Antipode	3	Geography
International Journal of Production Economics	3	MS/OR

Table 3 Articles on food banks published by journals in the OR/MS category

MS/OR journals	No. of articles
European Journal of Operational Research	4
Intern. Journal of Production Economics	3
Annals of Operations Research	2
IIE Transactions	2
Omega	2
Operations Research	2
Production and Operations Management	2
Socio-Economic Planning Sciences	2
Expert Systems With Applications	1
Interfaces	1
Journal of the Operational Research Society	1
OR Spectrum	1
TOP	1
Transportation Science	1

the social sciences, particularly journals in the social issues category.

On the other hand, Table 3 reports the journals in MS/OR that published relevant articles. Overall, articles published in OR/MS journals constitute 26.3% of the papers produced by the database search.

3.2 Food banks' supply chains and the differences with respect to commercial supply chains

This section introduces food banks' supply chain operations and discusses their main differences regarding commercial supply chains.

3.2.1 Food banks' supply chains

A food bank supply chain includes three main actors: donors, food banks and agencies. The term agency is used to describe entities (usually non-for-profit entities) that receive the food and distribute it to individuals.

The flows of food that food banks handle can be organized in various ways, as discussed in the following paragraphs. Figure 3 illustrates some common structures. Donors offer products to food banks on unknown dates and amounts (Fianu and Davis, 2018). In some cases, donations are performed directly at the food bank, the case for network *A* in Figure 3; however, in most cases, the food bank organizes the transportation of donations. In this case, visits to several donors are planned to reduce transport costs, as illustrated by network *B*. Food banks also receive financial donations that allow them to acquire more goods, particularly supplies that are not commonly donated.

At the depots, food banks verify the donations' quality, and depending on the agencies' profile and needs, they assign quantities to be delivered or prepare kits that, once delivered, help cover the needs of an individual or a family for a given period (e.g. a week). Because demand is usually higher than donations, food banks must evaluate methods for being as fair and equitable as possible, simultaneously maximizing the efficiency of the distribution operations.

As per the distribution, the food bank sometimes aids each agency directly (network *A*), but agencies are often grouped and visited in routes to maximize transport efficiency (network *B*). It is also possible to introduce food distribution points to share the distribution effort between the banks and the agencies (network *C*). Finally, it is also possible to organize mixed pickup and delivery routes, as discussed later, visiting donors and agencies (network *D*). Although mixed routes improve transport efficiency, they are more challenging to plan and manage.

Donations represent most of the food supplied by food banks. Because supply is generally lower than demand (Gómez-Pantoja *et al.*, 2020), hard choices must be made daily to decide who receives aid, the types of goods provided and the amount supplied. To this end, optimization models might help design effective food collection and delivery strategies (Davis *et al.*, 2014).

A large part of food banks' activities is based on the assistance of volunteers. As do Paço and Agostinho (2012) mention, volunteers are not paid and have highly valued opportunities competing for their time, attention and money; thus, agencies need to understand what motivates volunteers to donate their time to food banks. Furthermore, De Boeck *et al.* (2017) suggest that working with volunteers with inadequate training in food safety and other relevant knowledge on food logistics may generate bottlenecks and barriers during interactions with food donors and handling perishable food products. Why people volunteer has been studied but remains an unresolved question beyond this study's scope.

Kim (2015) explains that "one good governance model cannot always be applied to all countries because actors, networks and institutions embedded in unique contexts have their own endogenous properties." Therefore, structures differing from those described in the previous paragraphs can emerge to cope with specific regional peculiarities. For instance, the food banks in North Korea differ from those observed in occidental countries in several critical aspects, as reported in Table 4.

Figure 3 Different food banks supply chains reported in the literature

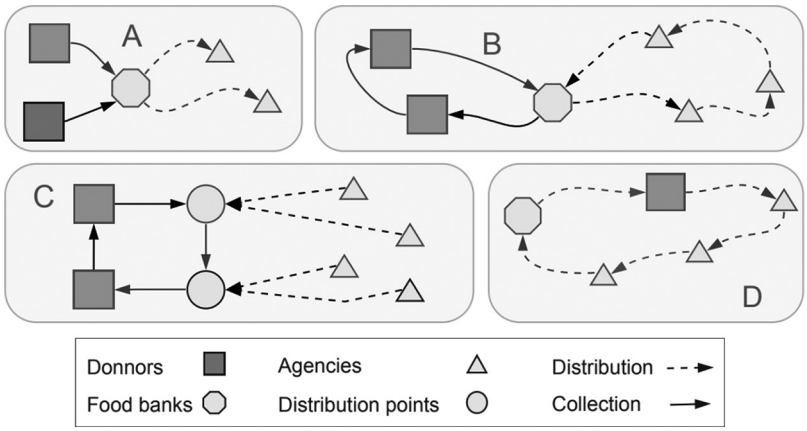


Table 4 Food bank logistic network model characteristics

Dimension	Occidental model	Korean model
Structural typology	Community-based nonprofit organizations voluntarily run food bank programs. The government has enacted laws to encourage donations	State-centered - the state takes the initiative in governing food banks. Asymmetrical relationships exist between the government and the food banks
Autonomy of actors	Food banks have significant autonomy; however, when donations are not enough, it is hard to satisfy the needs. They depend on donors to perform their activities	Food banks have little autonomy. Notwithstanding, when food banks do not have the capability and face weak public support for donations, the government sets the basis for developing the food bank
Results in terms of cooperation and diversity	Food banks have strong cooperative models in which various actors actively participate	Weak cooperation exists between participants: government, non-profit organizations, and individual donors. Large corporations rarely participate in food bank programs

Challenging situations usually lead to the emergence of new, better-adapted structures. For instance, Ogazon *et al.* (2022) discuss how food banks should adapt to cope with the consequences of a sudden event, such as a natural or human-made disaster. The recent COVID-19 pandemic exacerbated the food insecurity problem worldwide, so food banks multiplied their efforts to maintain service and adapt to the challenging situation. Blackmon *et al.* (2021) describe how, during the COVID-19 outbreak, the BOX program launched by the United States Department of Agriculture (USDA) aimed at purchasing fresh produce, dairy and meat directly from farmers and packaging them into boxes to be delivered directly to agencies and people in need. Thus, food banks became "virtual intermediaries" to coordinate supply and demand between suppliers and agencies.

Therefore, it can be concluded that the structure and governance of food banks are impacted by the region's social, economic and governmental characteristics. As discussed later, an emerging research stream examines food banks' growing role in facing extraordinary events, such as natural disasters or other disruptive situations (Roberts *et al.*, 2021; Ogazon *et al.*, 2022).

3.2.2 Differences between commercial and food bank supply chains

As explained, food bank supply chains can be divided into supply (donors), inventory and distribution management (food banks) and demand (agencies). Commercial supply chains include an additional area: the transformation or manufacturing process (production). Generally, food banks do not perform transformation or conservation of goods; they work as intermediaries to get donations to those in need. Furthermore, four essential aspects distance food banks from commercial supply chains at the distribution and demand levels. First, the uncertainty of incoming food necessitates appropriate levels of internal and external integration (Ataseven *et al.*, 2020). Second, food banks operate at a time-safe distance, indicating that the early expiration of donated goods limits a food bank's operating range. Third, dependency on the donated items restricts the choice concerning the types, quantity and nutritional composition of the products offered to beneficiaries, in sharp contrast with the almost unlimited choices offered by commercial supply chains. Finally, because food bank supply chains cannot consider meeting demand as an objective (as supply is continuously lower than demand), the main objective is to distribute donations as impartially as possible in proportion to demand.

Once they collect donations, the food banks aim to distribute food to agencies effectively and equitably. Fairness or equity is one of the distinct topics of decision-making in humanitarian operations and a key issue that impacts all food banks' operations. The notion of fairness in humanitarian aid distribution has been recently discussed (Holguín-Veras *et al.*,

2013; Anaya-Arenas *et al.*, 2014; Özdamar and Ertem, 2015; Gutjahr and Nolz, 2016). While there is no agreement on a definition or metric, Fernandes *et al.* (2016) proposed a structure as a basis for developing a performance measurement system for humanitarian logistics.

The uncertainty in donations and demand is one of the biggest challenges for food banks' operational decisions. In contrast, commercial supply chains are mainly concerned with managing time adequately; only the demand side harbors uncertainty, which can often be predictable (Hindle and Vidgen, 2018).

Finally, although both supply chains have a similar structure:

- most of the supplies are donations; and
- the workforce comprises mainly volunteers, meaning that food banks' cost structure and improvement opportunities are somewhat different from those in commercial supply chains.

3.3 Analysis of the contributions to food banks' supply chain operations

We describe the food bank's supply chain to propose a simple framework to classify and analyze the reviewed papers according to their contributions to the chain's three building blocks: supply, food banks and demand (see Figure 4). The following subsections present the topics contributed by the papers or the decisions discussed for each stage. Finally, we added a fourth stream of contributions that – rooting on the growing business analytics methods and tools – map supply and demand to emphasize the geographical/regional perspective of food assistance networks.

3.3.1 Supply

Uncertainty in the total available supply is one obstacle encountered in food bank operations. Food banks depend on donations, either in the form of goods or cash, made by individual donors, private sector organizations and governmental agencies. Food donations are uncertain in the frequency and the quantity provided, their prediction is challenging (Alkaabneh *et al.*, 2021), and management constitutes a daily challenge to satisfy the needy population's demand (Davis *et al.*, 2016). For instance, Brock and Davis (2015) report that collecting donations from supermarkets is planned without knowing if the food items are available and the quantity is sufficient. This is why initiatives to map the potential existing unused or wasted resources, such as those described in Bech-Larsen *et al.* (2019) and Hollander *et al.* (2020), are vital for maximizing food banks' supply.

Martins *et al.* (2019) suggested that donations from private organizations and individuals, key sources of supply for food banks, are more unpredictable than governmental and public funding and donations; they are stable and fundamental for steady operations.

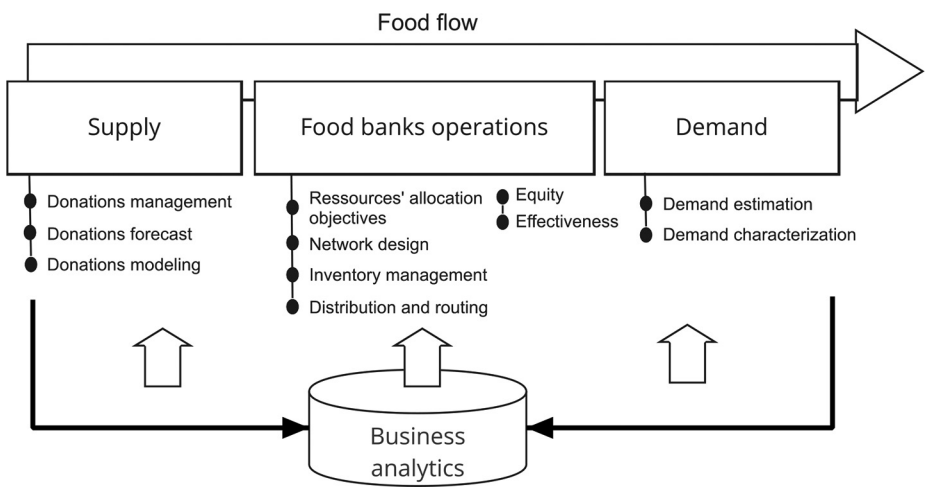
Some challenges derived from the uncertainty of supply extend from the capacity of donors to grant supplies, the diverse number of provisions given, and the reception of spontaneous and sometimes even undesirable donations (Martins *et al.*, 2019). For these reasons, methods of considering donations differ between authors. Some propose activities to increase donations (donations management), others try to predict the donations received and others consider donations a given parameter.

Donations management: Research into interventions designed to increase or affect contributions to food banks is limited. Farrimond and Leland (2006) confirmed that the location of signs and donation containers next to specific items in supermarkets increases donations of targeted products. Ahire and Pekgün (2018) explained that Harvest Hope Food Bank organizes promotional events and fundraising initiatives to increase food and dollar donations. They propose an integer programming optimization model to plan the optimal number of annual events of each kind to maximize the number of meals served using food and dollar donations.

González-Torre and Coque (2016) studied the potential partnership between marketplaces (significant generators of organic food waste because they sell fresh food) and food banks that might reuse food surpluses. They proposed guidelines to facilitate better management of the food surpluses and estimate the potential volume of organic waste generated by marketplaces that food banks might save.

Regarding individuals' donations, Bennett *et al.* (2021) examined the motivations and other factors that encourage

Figure 4 Proposed framework for the analysis of the reviewed papers' contributions



individuals (as opposed to businesses) to donate to food banks in the UK.

Donations forecast: Donators usually do not provide accurate information regarding available items or quantities. This can negatively impact inventory management capabilities and cause unnecessary transportation costs. Because of this uncertainty, some authors have proposed models to estimate donations.

Brock and Davis (2015) and Nair *et al.* (2017) evaluated approximation methods to estimate food availability from various food providers. Brock and Davis (2015) studied food surplus estimation at supermarkets, proposing an artificial intelligence approach based on a multiple layer perceptron artificial neural network (MLP-NN), multiple linear regression and two naive estimates to approximate the average collection amount. The four approximation methods are evaluated in terms of their ability to estimate collection amounts in the next planning period. Their results suggest that the MLP-NN model produces the best approximations. The methods proposed in Nair *et al.* (2017) can also be used to anticipate a potential donation from a new donor that may appear in the network.

Davis *et al.* (2016) performed a numerical study to quantify the extent of uncertainty regarding the donor, product and supply chain structure. Several predictive models were developed to estimate in-kind donations, including clustering, exponentially weighted moving average (EWMA) and autoregressive integrated moving average. Their results recommend EWMA as the most accurate forecasting method.

Paul and Davis (2021) proposed a method to identify the supply behavior of donors and cluster them based on the frequency, quantity and type of food donated. Results showed the necessary behavioral attributes to classify donors and the best way to cluster donor data to improve the prediction model, where exponential smoothing provides the best estimations.

Donations modeling: Finally, most papers assume that demand is given as a known parameter or a probabilistic function of known parameters.

Most reviewed models, like Gómez-Pantoja *et al.* (2020), consider the supply as a given parameter or known constant; however, neglecting uncertainty in donations may or may not be acceptable depending on the considered context. Balcik *et al.* (2014), Sengul Orgut *et al.* (2016b), Eisenhandler and Tzur (2019a) and Eisenhandler and Tzur (2019b) addressed food collection and distribution problems where donation and demand amounts are unknown before collection or delivery. They all proposed deterministic models that assumed that the quantity of available food is known. To validate their deterministic assumption, they perform sensibility analysis on their results. Sengul Orgut *et al.* (2016b) suggested that, because each agency must collect goods from the food bank, the supply is more related to the food bank's specific characteristics, such as the available budget, transportation availability and storage capacity, than to the donations themselves. They performed numerical experiments to assess how the variability in the food banks' receiving capacities affects the solution produced by the deterministic model. Similarly, Balcik *et al.* (2014) performed probabilistic sensitivity analyses to assess the effect on the models' deterministic solutions arising from supply uncertainty.

Marthak *et al.* (2021) studied the prepositioning of food before the strike of a natural disaster, so donations vary according to the severity of the anticipated event by a fixed adjustment factor estimated from historical data analysis.

Finally, other authors model supply as random variables to capture the donation uncertainty. Fianu and Davis (2018) dealt with a single product, so uncertainty only concerns the available quantities at each donor. Stauffer *et al.* (2022) considered a set of products, so the uncertainty affects the available quantity of each product. Alkaabneh *et al.* (2021) also considered several products, modeling their quantity and quality (i.e. their nutritional value) as random exogenous variables beyond the food bank's control.

In summary, food banks' supply has received limited attention from research; however, contrary to commercial supply chains where demand is the primary source of variability, donations are highly uncertain and constitute one of the biggest challenges to ensuring a fair distribution of food, as confirmed in the following sections.

3.3.2 Food bank operations

Melo *et al.* (2009) defined supply chain management to be "the process of planning, implementing and controlling the operations of the supply chain in an efficient way," whereas Hugos (2011) referred to logistics management as "a portion of SCM, that focuses on activities such as inventory management, distribution and procurement that are usually made on the boundaries of a single organization." Our analysis of the reviewed papers confirmed that most fit better within the latter definition. Furthermore, while distribution is the dominant topic among the reviewed papers, a few focus on inventory management or, in a broader perspective, resource allocation. Only six papers consider network design, defined as the decisions concerning facilities' location and capacity selection. From the six papers in network design, three study problems jointly decide the number and location of intermediate distribution sites and how they are fed. These joint decision problems are referred to as location-routing or location-transportation problems.

Finally, from the comparison with commercial supply chains, food banks' supply chains are strongly concerned with resource allocation or how supplies are assigned to agencies or individuals in need. Indeed, most reviewed papers deal implicitly or explicitly with resource allocation problems. Consequently, before discussing this section's main topics (network design, inventory management and distribution), the following paragraphs discuss the orientations and objectives guiding resource allocation in food banks' operations.

3.3.2.1 Objectives guiding food banks' resource allocation. Although operations efficiency always remains a significant concern, food bank managers are mainly guided by principles of equity and effectiveness. Several papers focus on the nutritional utility of the delivered food. We now discuss these four concepts and how they are addressed in the reviewed papers.

Efficiency: According to Davis *et al.* (2014), "while profit is not their objective, food banks, like other nonprofit organizations, must efficiently use their existing resources to best serve their communities." To this end, operational costs must be minimized or, in other contexts, kept under budget

constraints. Martins *et al.* (2019) included the fixed cost for supporting agencies and the cost for operating storage areas and handling products at food banks in their economic objective function. Islam and Ivy (2021) and Hasnain *et al.* (2021) included as operational costs the total cost of food bank operation and the cost of receiving and distributing food, computed using the quantity of distributed food, the distance covered and the per-mile cost. Operational costs may include different expenses depending on the context. For instance, Stauffer *et al.* (2022) included mobile pantries for food distribution. Their objective function includes their fixed cost of allocation and operating cost; however, most authors focus exclusively on transportation costs. Moreover, the total distance is usually considered a proxy for the transport costs. Works proposing location-transportation problems (Solak *et al.*, 2014; Davis *et al.*, 2014; Reihaneh and Ghoniem, 2018) aim to minimize the number of facilities to distribute food. Then they seek to balance the distance traveled by the food bank's vehicles to bring the food to drop sites and the distance charity agencies travel to grab the food at those drop points. Marthak *et al.* (2021) consider the cost related to prepositioning and distribution of food on the arrival of a natural event. These costs depend on the traveled distance and the transported quantity.

Finally, although some authors do not target cost or efficiency metrics as objectives, they either restrict the consumption of resources (e.g. by setting a bound on the length of routes) or impose budget constraints. For instance, Eisenhandler and Tzur (2019a, 2019b) do not include the vehicle's travel cost in their models; however, they limit the available budget for transportation. Furthermore, Gómez-Pantoja *et al.* (2020) impose a limit on the available budget to buy food products.

Equity: Most selected papers intend equity in food distribution as their primary goal. Equity is referred to as distributing goods in proportion to the needs, often estimated as the population living in poverty in an area. Still, reaching an equal distribution of food is challenging because of limited vehicle capacities or the time before the items spoil; hard decisions must be made in these cases. Different methods are used in the literature to address equity, including minimizing the difference between the maximum and minimum values, the variance, the coefficient of variation, the sum of absolute deviations, the maximum deviation or the mean absolute deviation (Fianu and Davis, 2018). Minimizing these objectives can maximize equity, although they usually lead to different solutions. Fianu and Davis (2018) present a model that can assist food banks in distributing uncertain supplies equitably; they measure equity as a function of the pounds distributed per person in poverty (PPIP). They also use a benchmark proposed by their food bank partner, setting the target PPIP to 75 per year. Sengul Orgut *et al.* (2016b) and Islam and Ivy (2021) incorporate equity in their models by imposing a user-specified upper bound on the absolute deviation of each agency from perfectly equitable distribution. Perfectly equitable distribution means that food donations are distributed to the agencies so that the total donated food allocated to an agency equals the fraction of the total poverty population assigned to that agency.

Effectiveness: Regarding effectiveness, food banks seek to distribute the greatest quantity of goods while wasting as little as possible. Effectiveness is also essential because waste provokes bad publicity and reduces future donations. Sengul Orgut *et al.* (2016b) qualified distribution as effective if the amount of undistributed supply is minimized. This is easy to express in words, but all the issues surrounding food bank operations make this objective difficult to satisfy. Many factors affect food bank operations and considering all of them in one model is impossible. Stauffer *et al.* (2022) penalized the amount of undistributed food in their objective function. Sengul Orgut *et al.* (2016b) minimized the amount of wasted food by ensuring timely delivery of healthy, usable food to the beneficiaries. Sengul *et al.* (2018) aimed to maximize total food distribution while enforcing a user-specified level of robustness in a context where the amount of donated food that agencies could effectively receive and distribute is uncertain.

Nutritional utility: Food banks play a growing role in food safety, distributing billions of pounds of free food and beverages (Tarasuk *et al.*, 2020). Ross *et al.* (2013) investigated the types of food moving through six California food banks to assess the nutritional quality of these foods. They concluded that, although the six participant food banks were moving toward more healthful food than previously, still, further attention and action would be required to continue this trend. Therefore, it is understandable that the research concern works on the quality rather than the quantity of the delivery food. Ortuño and Padilla (2017) aimed to maximize the quantity of energy content (in Kcal) sent daily to the families, subject to volume and weight constraints so that the families feel they receive an equal amount of products. Gómez-Pantoja *et al.* (2020) proposed a similar approach, separating the needs of each individual into categories. If the set of products assigned to an individual reaches a given minimal quantity for a given category, the individual is satisfied. The problem's objective is to maximize the total number of satisfied categories. Ogazon *et al.* (2022) did not consider nutritional utility as an objective; they proposed a set of constraints ensuring that the mix of products delivered to each agency (e.g. sugary drinks) respects proportions that the food bank managers set. Units of food that do not meet these proportions may not be delivered.

Most of the papers consider more than one dimension. Balcik *et al.* (2014) formulated two objectives under agencies' demand uncertainty: maximizing equity and minimizing waste. They empirically demonstrated that solving the problem for the waste-minimizing objective achieves near-minimal waste while providing equitable food allocation. Islam and Ivy (2021) studied trade-offs between operation costs (the total cost of branch operation and the cost of receiving and distributing food), effectiveness (the cost of undistributed food) and fairness (maintaining a maximum deviation from perfect equity). Eisenhandler and Tzur (2019a, 2019b) included an objective function that balances equity and effectiveness adequately. The function multiplies the measure of effectiveness – the total allocation supplied to all agencies by an equity measure – which is one minus the Gini coefficient of the food allocation vector. Alkaabneh *et al.* (2021) considered measures of the effectiveness of the resource allocation problem faced by food banks. They implicitly considered an equity performance measure, developing a dynamic programming

model in which the primary decision is how much of each product to allocate/distribute to each agency.

Hasnain *et al.* (2021) explored solutions that prioritize effectiveness and equity (besides efficiency), developing a single period, weighted multicriteria optimization model that provides flexibility for decision-makers to capture their preferences over the three criteria of equity, effectiveness and efficiency.

Finally, Martins *et al.* (2019) proposed a network design model that accounts for all dimensions of sustainability (economic, social and environmental) through three objective functions. They investigated the trade-offs under the three conflicting objectives and suggested strategies to improve the sustainable performance of a food bank network in Portugal.

This analysis demonstrates an interesting evolution in how models' objectives are formulated and extend away from those proposed in humanitarian logistics. Recent models are more concerned with the utility of the distributed food (i.e. the nutritional value) than the actual quantity. Interestingly, deprivation, a metric receiving significant attention in humanitarian logistics, is not mentioned in any reviewed papers.

The following subsections present the four topics on which food bank operations have been segmented: network design, inventory management and distribution. The analysis is completed with the contributions of analytic models to the field

3.3.2.2 Network design. Network design concerns the structure of the network and usually encompasses decisions related to the choice and location of facilities and the election of their capacity. We identified only a few papers that addressed network design problems in the context of food banks.

Martins *et al.* (2019) considered strategic decisions, including opening new food banks and selecting their storage and transport capacities from discrete sizes over a multiperiod planning horizon. In addition, existing food banks may be closed or have their capacities expanded. Islam and Ivy (2021) presented a mixed-integer programming model to identify the efficient assignment of demand zones to banks and the equitable allocation of donated food from the food banks to the demand zones. They empirically studied the interaction between the cost of shipping donations and the cost of undistributed food and proposed a more flexible supply chain structure where food from local and national sources might be shipped directly to the agencies.

Stauffer *et al.* (2022) also examined the structure of the food bank supply chain, focusing on how the use of mobile pantries for food distribution (i.e. integrating the last link of their food aid supply chain), additional food bank storage capacity and improved partner agency capacity can improve food banks' performance. They proposed a stochastic two-stage mixed-integer formulation to perform extensive sensitivity analysis on how these factors impact total costs, equity in distribution and minimized disposal, providing managerial insights and guides on the design of food banks networks. Ogazon *et al.* (2022) dealt with reconfiguring food bank operations on the verge of a sudden event, such as natural disasters, which provoke sudden variations in the demand and the supply, forcing food banks to adjust their operations to satisfy the needs of the affected people. They proposed several reconfiguration strategies and compared their performance empirically to elaborate guidelines on how the food banks should reorganize their responsibilities concerning the day-to-day model.

The rest of the papers on this topic discussed food distribution problems where the network structure is modified by inserting food distribution points so that agencies travel a reasonable distance to collect the food they ordered from these distribution points, aiming to share the distribution effort between the bank and the agencies. To this end, the number and the location of distribution points must be jointly decided with the routes for delivering the food from the bank's depots. Davis *et al.* (2014) studied a one warehouse multiperiod problem where routes mixing collections and deliveries at distribution points must be planned so that a given number of collections must be performed and each distribution point is visited once. This single visit must deliver enough food to satisfy the needs of the covered agencies for the planning period. Routes are limited by the drivers' allowed working time and vehicle capacity. Davis *et al.* (2014) proposed a two-step approach to tackle this challenging problem. First, they solve a capacitated set covering problem to determine the location of the food distribution points and the agencies' assignment. Then, a periodic vehicle routing problem with backhauls determines the collection and delivery schedule. Solak *et al.* (2014) referred to this problem as the vehicle routing with demand allocation problem, proposing a formulation for the problem and two Benders decomposition-based solution procedures. Reihaneh and Ghoniem (2018) proposed a multistart optimization-based heuristic to tackle larger instances.

Table 5 summarizes the main characteristics of the reviewed papers on network design. Column *Main problem* formalizes the paper's aim. Columns *Supply* and *Demand* report how problems are modeled in the paper (D = deterministic, S = random), whereas column *Objective* indicates the nature of the problem's goal (F = equity, E = efficiency/cost, U = utility, W = waste) and column *Horizon* reports if the problem spans one (single) or several (multi) periods. Columns *Modeling* and *Solving* describe the proposed modeling and solving approaches, respectively. Finally, column *Application* details if the paper addresses a real or a theoretical context and if the numerical experiments were executed on real or randomly generated instances.

Table 5 confirms that our search led to only two papers dealing with "classic" network design (i.e. deciding facilities' opening and closing and their capacities), whereas three more papers proposed location-routing problems to reduce transportation costs for food banks. Unsurprisingly, all the papers assumed deterministic contexts that sought to maximize efficiency (or minimize costs) and proposed MILPs to formulate their models and approximated (heuristic) methods to solve them efficiently; however, as mentioned in the previous section, Martins *et al.* (2019) sought to improve the sustainability of the solutions simultaneously.

3.3.2.3 Inventory management. Although food banks do not perform transformations or long-term food conservation, some papers address short-term inventory management or restrictions related to inventory capacity. The latter can be observed in Sengul Orgut *et al.* (2016b), which considered the distribution of donations over one month as a single period problem. Donations received and food distributed during the

Table 5 Characteristics of reviewed papers on network design

Reference	Main problem	Supply	Demand	Objective	Horizon	Modeling approach	Solving approach	Application (context/ instances)
Davis *et al.* (2014)	Location routing	D	D	E	Multi	MILP	Two-step method	Real/Real
Solak *et al.* (2014)		D	D	E	Single	MILP	Benders + two-step method	Real/Random
Reihaneh and Ghoniem (2018)		D	D	E	Single	–	Multistart heuristic	Theo./Random
Martins *et al.* (2019)	Network design	D	D	Sus	Multi	MILP	Commercial solver	Real/Real
Islam and Ivy (2021)		D	D	F, E	Single	MILP	Commercial solver	Real/Real

Notes: D = deterministic; S = random; F = equity; E = efficiency/cost; U = utility and W = waste

period were aggregated and restricted by flow conservation equations that set each bank's total (inventory) capacity. Sengul Orgut *et al.* (2018) extended the previous problem to incorporate variability in the agencies' capacities. They produce feasible and near-optimal solutions using robust optimization if agencies' capacity varies within specified limits. They also introduce a stochastic formulation that treats the equity limit as an uncertain parameter, providing a feasible solution in the presence of small deviations from perfectly equitable distribution.

Conversely, Gómez-Pantoja *et al.* (2020) and Alkaabneh *et al.* (2021) addressed multiperiod contexts where inventory levels and policies must be handled explicitly. Gómez-Pantoja *et al.* (2020) introduced a resource allocation model that considers inventory management and product purchases. The model also considers product-beneficiary compatibility, balanced nutrition and the priority of beneficiaries to decide who is served, what kind of products and how many will be supplied. Alkaabneh *et al.* (2021) developed a framework for optimizing resource allocation by food banks among the agencies they serve, maximizing the expected utility of agencies over a finite horizon. Contrary to Gómez-Pantoja *et al.* (2020), which assumed that supplies are known in advance, Alkaabneh *et al.* (2021) considered uncertainty in supply. To handle the uncertainty of future supplies, they proposed an approximate dynamic programming approach that uses the Monte Carlo simulation to estimate the expected utility value of an assignment policy at each horizon period on which a decision is made. Numerical experiments executed on actual instances demonstrated significant improvement in the allocation process over static policies.

Finally, Marthak *et al.* (2021) proposed a stochastic programming model that considers prepositioning strategies among food bank facilities in high-risk areas for hurricanes. Some researchers outlined the central work of food banks to build community resilience before, during and after disasters (Roberts *et al.*, 2021). The model considers the uncertainty associated with a hurricane's impact on each facility regarding the available supplies, donations received and the expected demand for the facility's service region.

Table 6 summarizes the reviewed papers' main characteristics related to inventory management. Compared to Table 6, papers on inventory management are driven by fairness and utility objectives, which align with their tactical rather than strategic decisional scope.

3.3.2.4 Distribution. Although most analyzed papers report direct food transport from banks to agencies, others propose alternative approaches, including distribution routes or mixed collection and distribution routes.

Lien *et al.* (2014) and Balcik *et al.* (2014) addressed similar versions of a sequential resource allocation problem (SRA-e), which considers equity in its objective while obtaining an effective allocation of scarce resources to reduce waste. The problem seeks to create food collection and distribution routes. Food is collected at the first stops and delivered at subsequent stops in the route (the agencies). Because agencies' demand is not known in advance, the driver must determine the food to deliver at each stop to meet the agency's demand and reserve food for the remaining agencies on the route. Assuming that the demand follows continuous probability distributions, Lien *et al.* (2014) propose a dynamic programming framework that allows them to characterize the optimal allocation policy structure for a given customer sequence. The optimal structure is used to develop a heuristic allocation policy for instances with discrete demand distribution. Balcik *et al.* (2014) extended the SRA-e to a multiroute setting and incorporated travel time restrictions that limit the length of the potential routes. Given the problem's computational complexity, they proposed a decomposition-based heuristic encompassing three phases to solve the problem: clustering, sequencing and allocation. The heuristic drastically reduced the computational time producing high-quality solutions.

Eisenhandler and Tzur (2019a, 2019b) present a similar problem: the food bank must determine which agencies to visit, in what sequence and how much to pick up or deliver to each donor or agency. In this version, the food bank determines how much food should be picked up (delivered) from (to) each supplier (agency), considering the limited capacity of the vehicle. Based on this information, the food bank determines a plan for a single day of activity using a single vehicle to collect and distribute the food to the agencies. This setting requires simultaneous vehicle routing and resource allocation decisions to balance two possibly colliding goals: maximizing the total amount distributed and achieving equity in the allocation. Eisenhandler and Tzur (2019b) contribute a different formulation for the same problem and a matheuristic solution. Table 7 reports the main characteristics of the reviewed papers related to distribution.

In summary, the extant literature's contributions to food bank operations cover an extensive range of problems that are,

Table 6 Characteristics of reviewed papers on inventory management

Reference	Supply	Demand	Objective	Horizon	Modeling approach	Restrictions	Application (context/instances)
Orgut *et al.* (2016)	D	D	F + W	Single	MILP	Banks cap	Real/Real
Singul *et al.* (2018)	D	D	F + W + R	Single	MILP	Charities cap	Real/Real
Gómez-Pantoja *et al.* (2020)	D	D	U	Multi	MILP	Compatibility product individ	Real/Random
Alkaabneh *et al.* (2021)	S	D	F + E	Multi	Dyn. prog		Real/Real
Marthak *et al.* (2021)	S	S	E + U	Single	Stoch. prog		Real/Real

Notes: D = Deterministic, S = random, F = equity, E = efficiency/cost, U = utility, W = waste

Table 7 Characteristics of reviewed papers on distribution

Reference	Supply	Demand	Objective	Horizon	Modeling approach	Solving approach	Restrictions	Application (context/instances)
Lien *et al.* (2014)	D	S	F + W	Single	Dyn. Prog.	Decomp. heu	Vehicle cap	Real/Real
Balcik *et al.* (2014)	D	S	F + W	Single	MILP	Decomp. heu	Vehicle cap., multiple routes	Real/Random
Eisenhandler and Tzur (2019a)	D	D	F + E	Single	MILP	Large neigh. heu	Vehicle cap., travel time	Inspired/Random
Eisenhandler and Tzur (2019b)	D	D	F + E	Single	MILP	Matheuristic	Vehicle cap., travel time	Real/Real

Notes: D = Deterministic, S = random, F = equity, E = efficiency/cost, U = utility, W = waste

in most if not all the cases, related to real applications. These contributions address various situations regarding geographic scope, managerial objectives, the time horizon covered or the aggregation of needs to be satisfied. Network design problems address situations covering large regions and where the effectiveness drives decisions in food transportation. Inventory-related problems concern food allocation, so food transportation is not considered or is a less relevant element in those models. Fairness and the food quality distributed to beneficiaries influence allocation decisions. Finally, distribution models focus on collecting and distributing food over small or local regions. These problems address supply and demand uncertainty and explicitly capture the real-life limitations affecting transportation decisions, such as truck capacity or driving time restrictions. As explained in the following paragraphs, each family of problems addresses and models the beneficiaries' needs and the demand in different manners.

3.3.3 Demand

Demand points encompass agencies that include shelters, food pantries and soup kitchens that help deliver goods to needy people. Adequate and equitable distribution is vital for hunger-relief organizations, and because supply is almost always lower than demand (Balcik *et al.*, 2014), it is of the utmost importance to identify and characterize demand. Other than equity in satisfying needs, several considerations must be addressed. For instance, food banks must ensure the quantity and quality of the supplied food, which is difficult because of the limited control of the supply (Gómez-Pantoja *et al.*, 2020), or minimize spoilage when distributing food to the furthest agencies (Solak *et al.*, 2014). Additionally, recent research has shifted focus toward a better, more accurate identification of individuals' needs and the customization of the food they are provided (Ortuño and Padilla, 2017).

Demand estimation: In most cases, demand is a known deterministic parameter. In some cases, agencies estimate and inform the banks about demand. For instance, Gómez-Pantoja *et al.* (2020) assumed that the beneficiaries to support and their needs are known. Other authors (Fianu and Davis, 2018; Sengul *et al.*, 2018) used socioeconomic data related to poverty to estimate food needs in a given area. In particular, Sengul Orgut *et al.* (2018) estimated demand from poverty data, as referred to in the US Census Bureau (2016).

Estimating demand is critical to avoid or minimize waste in SRA-e (Balcik *et al.*, 2014), where each truck collects food and then delivers it to the remaining agencies along its route. Because demand at each agency is not known in advance, the volunteer driver must decide the amount of food it delivers at each stop, considering the potential needs of the remaining agencies.

Some authors proposed analytic methods to model and estimate demand. Black and Seto (2020) analyzed an administrative dataset of food bank member usage to provide a descriptive profile of patterns of food bank usage. They applied cluster and regression analyses to identify predictors of the frequency and duration of service usage. They concluded that while many users engaged with food bank services for a short duration with a limited frequency of visits, most visits were made by a small subset of deeply engaged longer-term members, raising important questions concerning the role of food banks and how they can better meet people's needs.

The volume of food donations is regularly insufficient to meet all demands. Martins *et al.* (2019) considered the case

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where an agency applying for first-time food assistance joined a group of agencies waiting to be served. Demand for individual food items may not be fully satisfied, but a certain minimum level of assistance must be guaranteed to all agencies served by a food bank, considering predictable variations.

Demand characterization: Demand satisfaction is not just a matter of delivered quantity but nutritional content. Recent studies focused on the nutritional needs of individuals to define demand or measure their food distribution performance. For instance, Alkaabneh *et al.* (2021) measured resource allocation plans' effectiveness based on the nutritional value of the allocation decisions; however, not all families have the same nutritional needs. Thompson *et al.* (2018) suggested that to estimate the ideal demand of a family, the daily energy necessities, the members that make up the family and the characteristics of each person, such as age, gender, body size and composition, must be considered. Gómez-Pantoja *et al.* (2020) highlighted the importance of the compatibility between the products and the beneficiaries. They indicated that compatibility involves nutritional aspects (e.g. baby milk will be wasted if it is donated to a family without babies), cultural aspects (e.g. some religions prohibit certain animal products) and logistical aspects (e.g. a product requiring refrigeration will be wasted if it is given to a family with refrigerator).

Another practical issue concerns grouping the available products into packages for distribution. One of food banks' key and challenging tasks is that receiving heterogeneous supplies must be allocated to personalized kits for beneficiaries. Garthwaite *et al.* (2015) concluded that considering the profile of each family and their particular needs while creating the personalized kits brings several benefits and enables food banks to have a more significant impact.

Determining how to measure the nutritional value of the food delivered was addressed by Ortuño and Padilla (2017) and Gómez-Pantoja *et al.* (2020). In their work, Ortuño and Padilla (2017) classified goods according to their nutritional group (vegetables, fruits, grains, dairy, meats, oils) and their energy input (measured in Kcal), depending on the type of food. The minimum energy requirements of each family were determined according to the number of members and their characteristics (age, sex, physical activity, weight and height). Gómez-Pantoja *et al.* (2020) and Ogazon *et al.* (2022) also considered several categories of nutrients or products, determining that each individual must receive a minimal amount of each to be considered satisfied. The problem aims to determine the individuals to be served and the mix of products assigned to each of them to maximize the total number of satisfied categories while guaranteeing a minimum diversity in the assignment of products, balanced nutrition and compatibility between products and beneficiaries.

3.3.4 Business analytics: opportunities for improving food banks' supply chain

The emergent field of business analytics is progressively contributing to all possible activities, including food banks' supply chains. We identified three papers with research contributions that might contribute to improving food banks' supply chains. From a strategic perspective, Hindle and Vidgen (2018) developed a business analytics methodology and applied it to an agency organization in the UK. The authors developed a logical model that identified the main activities undertaken by the organization. This model was used to identify leverage points and opportunities for business analytics tools, that is, value areas where analytics can be applied, to create value with relative ease. They recognized that combining geospatial analysis and visualization with open data on poverty provided the greatest opportunity because of its potential to predict where food bank aid would be most needed. Sucharitha and Lee (2020) also attempted to answer if food agencies serve their intended recipients sufficiently or sparsely and if the food agencies provide the optimum coverage of donated foods. They combined data from the Greater Cleveland Food Bank and demographic data provided by the USDA. They then used a probabilistic model as a clustering approach to analyze the whole database to identify regions within each cluster that lack food agencies near families in dire need and vice versa. Similarly, Brinkley (2017) sought to understand the geographic patterns of local food supply chains in an attempt to relocalize food systems by identifying gaps or "structural holes" in the local food network.

4. Discussion and suggested future research directions

Despite the variety of specific research or the practical questions they raise, the analysis of the papers confirms that the research on food banks is proliferating and gaining momentum. In doing so, the research progressively diverges from the general literature in humanitarian logistics. In our opinion, this can be partially explained by the long-term mission of food banks, which contrasts with the event-driven, often urgent nature of most studies in humanitarian logistics. A recent literature review on humanitarian logistics (Hezam and Nayeem, 2021) focuses on disruptive situations, such as disasters and crises, whereas food banks deal with steady situations. Nonetheless, resilience is a new topic in food banks' supply chains, as pointed out by Blessley and Mudambi (2022). They performed qualitative analyses on how disruptive events (the 2018 US–China trade war and the 2020 COVID-19 pandemic) affected food banks' supply chain resilience. The authors explained that food banks responded mainly by adapting storage policies, learning quickly to increase or decrease deliveries according to the food supply, collaborating with external partners, leveraging social capital along the supply chain and encouraging the distribution and consumption of low-demand products.

Black and Seto (2020) indicated that food banks feed a growing part of society, and their impact on public health is being increasingly recognized (Iafrati, 2018). This raises questions on the potential extension of the products and services they might offer to specific populations. From a strategic standpoint, food banks' impact goes beyond efficiency and, to some extent, equity and should be measured in terms of sustainability; however, among the reviewed papers, only Martins *et al.* (2019) and Iafrati (2018) addressed the three pillars of sustainability.

Blackmon *et al.* (2020) demonstrated that the added value of food banks exceeds their actual physical resources (trucks, facilities) when proximity and access to communities matter. This key role and the engagement of food banks in long-term

population health explains the development of new and richer objective functions aiming to personalize the specific needs of beneficiaries. Although fairness is still a central issue for food banks, new metrics are being proposed around the idea of "nutritional utility" (Ortuño and Padilla, 2017; Gómez-Pantoja *et al.*, 2020) in contrast with "deprivation," an emergent metric in the field of humanitarian logistics (Holguín-Veras *et al.*, 2013; Gutjahr and Nolz, 2016).

Additional research should be dedicated to strategic questions concerning the design of the overall distribution network. Only three reviewed papers address classical network design decisions (e.g. decisions concerning facility locations and their capacity or the network's structure), and the remaining studies assume all the facilities and their capacities are given. In all the reviewed papers, demand is aggregated at agencies abstracting crucial problems, such as individuals' access to services, that might be formulated as location or coverage problems. In this sense, Stauffer *et al.* (2022) suggested that food banks can maximize distribution and equity by integrating distribution to individuals through mobile pantries or sharing distribution operations with partner agencies. New models are required to study the more complex resulting logistic networks. Moreover, combining these new models with the power of emerging analytics tools constitutes a promising research direction that, to our knowledge, has been unexplored in the context of food banks.

Concerning resource management, surprisingly, only one of the reviewed papers (Blackmon *et al.*, 2021) envisaged using a decision support system to assign volunteers to handle different operations. As pointed out by do Paço and Agostinho (2012), volunteers are crucial for banks and agencies. Therefore, food banks should aim to maximize their comfort and satisfaction, which adequate work schedules and duty rosters can achieve.

Our last comment is dedicated to supply. Most of the reviewed papers agreed on the importance of supply for food banks, but only a few aim to develop knowledge on managing donations. Only Bech-Larsen *et al.* (2019) and González-Torre and Coque (2016) examined new potential sources that might redirect food surpluses as donations to food banks. More quantitative studies, such as Brock and Davis (2015), Davis *et al.* (2016) and Paul and Davis (2021), developed models to estimate or forecast donations which, in turn, might help improve demand fulfillment while reducing waste. From a more operational perspective, the reviewed papers said little about purchasing and its leverage for local development. Moshtari *et al.* (2021) reviewed 51 scholarly articles on procurement in humanitarian operations. Although the differences between humanitarian and food bank operations were established, they raised questions concerning procurement organization, objectives and policies, processes and lack of collaboration among stakeholders that also concern food banks. Similarly, Anaya-Arenas *et al.* (2018) emphasized how humanitarian organizations, such as Oxfam México, purchase as much aid and supplies as possible from the closest available sources to promote local markets and reactivate commercial activities in the served region. According to the authors, this local sourcing policy may imply higher costs and supply risks; however, it aligns with the sustainable objective of humanitarian organizations. We believe that the same sustainability goals should be emphasized in the context of food banks.

As per the suggested directions for future research, most reviewed papers propose extensions to their formulations or the development of approximated yet efficient methods to solve them. They often suggest extending the proposed experiments to better understand their models' behavior or perform sensitivity analyses; however, some suggest more general lines of research that might eventually lead to unexplored topics.

Davis *et al.* (2014) suggested investigating approaches to estimate food availability from donors with different characteristics and generate strategies for inventory management that complement the food bank's operations. Being able to estimate donations accurately would significantly improve operations.

Gómez-Pantoja *et al.* (2020) proposed to differentiate and prioritize products according to perishability, which is an essential issue because it leads to the unnecessary waste of food. With this prioritization approach, food banks would improve their operations by having less spoilage and thus be able to deliver more food to people in need.

Solak *et al.* (2014) recommended exploring methods that allow flexibility when considering food bank operations in different countries. This is easy to say but difficult to implement because of the earlier-addressed limitations; however, most food banks must include some general characteristics in their operations. Therefore, a general model might be elaborated as a base and modified to satisfy each region's necessities.

Parker *et al.* (2020) advised exploring other types of collaborations between the banks, including how agencies' expectations may change over time. Usually, collaborations are not considered because of distance and time restrictions leading to food waste; however, achieving adequate collaboration between agencies can significantly improve food banks' operations.

In summary, this systematic literature review demonstrated a growing scientific interest in food bank operations, which has inspired various problems and scientific challenges. Moreover, we are convinced that this rising interest will accelerate in the future. Indeed, the crucial role of food banks during the COVID-19 pandemic (Blackmon *et al.*, 2020) should lead to a significant increase in scientific publications on food banks' activities and contributions.

5. Conclusions

This study presents a systematic literature review of scholarly articles on food bank operations. The study results show that, from an operations perspective, food banks deal with an extensive range of problems that, although related to issues observed in commercial operations, require the formulation of distinct optimization models. Moreover, some emerging features specific to food banks, such as a significant concern for the delivered food's nutritional utility and its long-term impact on the populations' health, seem to differentiate food bank literature from the broader humanitarian logistics literature.

This study makes several contributions to the current literature. First, it provides new researchers with an overview of the food bank supply chain's features and the challenges faced by food bank operations managers. Additionally, assembling,

classifying and comparing the optimization models in this research area helps identify the most relevant characteristics involved in food bank operations, hopefully aiding future works to improve these operations.

Based on this review, we make several recommendations for future research. Work addressing the potential extension of food banks' role and the set of products and services they offer to specific populations would be valuable additions to the literature and the practice. Furthermore, future models can support the coordination and integration of these services with other programs and services. Individuals' accessibility to agencies' services is a crucial matter for food banks, and, in this vein, the merging of optimization models with analytics tools represents a promising research direction. Finally, technology advancements and new business models have brought several opportunities for new potential partnerships of food bank supply chains with their commercial counterparts (i.e. web-based food markets) at various levels or stages of their chains. Also, the proper use of technology can provide tools to avoid waste. In some countries, food retailers and supermarkets use programs that lower expiring products' prices, thereby reducing waste. The extent to which these technologies can impact the potential amount available for donations is unclear and requires exploration.

This research has limitations. As an emergent and not yet fully established research stream, we observed variability in the scientific terms identifying the topic and its related features. Authors inconsistently use the term "food bank" or related variants (i.e. foodbank) as a keyword or tag to identify their research. For instance, a scoping review on "Moving food Assistance into the Digital Age" (Martin *et al.*, 2022) does not contain "food bank" in the title, abstract or keywords; however, the paper's content is enormously relevant for food banks. While the omission of some potential papers does not necessarily undermine the value of this review, it may temper some of our conclusions.

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