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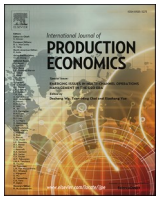

Dealing with donations: Supply chain management challenges for food banks

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ABSTRACT

Food banks redistribute food donations that would otherwise be lost for consumption by humans to people in need. As such, food banks play an important role both in addressing food insecurity for people at risk of poverty or social exclusion and in the prevention of food waste and its related environmental impacts. The efficient and effective management of food bank supply chains is a key part of reaching these important societal goals. In practice, however, the typical characteristics of food bank supply chains provide many challenges for supply chain management. In this paper, we present an overview of the key supply chain challenges in food bank supply chains based on experiences from various actors in these supply chains. Also, we review what the operations and supply chain management literature has contributed so far to addressing these challenges. Based on these challenges and the literature review, we will discuss the implications for future research. We found that important challenges related to dealing with voluntary labour, managing highly perishable products, and limited IT infrastructures have not received much attention in the literature. Furthermore, interdependencies between challenges related to supply, demand, and the matching of supply and demand require more interaction with different research disciplines.

1. Introduction

Across the world, food banks have been set up to support people in need, often combined with ambitions to prevent food waste. The term food bank here refers to initiatives providing (emergency) food for people to take away, prepare, and eat (Dowler and Lambie-Mumford, 2014). With the combined goal of addressing food waste and alleviating food insecurity, food banks help address several of the Sustainable Development Goals (SDGs) formulated by the United Nations: no poverty (SDG 1), zero hunger (SDG 2), good health and well-being (SDG 3), responsible consumption and production (SDG 12), climate action (SDG 13).

In many places in the world, the number of people dependent on charitable food assistance to alleviate food insecurity is growing (Davis et al., 2014). Crises like the COVID-19 pandemic and high inflation rates only increase these needs (e.g., Capodistrias et al., 2022). In 2021, 95.4 million people, or 21.7% of the population in the European Union (EU) is at risk of poverty or social exclusion (Eurostat, 2021a). This means that they were in at least one of the following three circumstances: at risk of poverty after social transfers (income poverty), severely materially deprived, or living in households with low work intensity (Eisenhardt, 2021). About 7.5% of the population cannot afford a healthy and nutritious meal (including meat, vegetables or equivalent) (Eurostat, 2021b). Similarly, in the United States, in 2020, 10.5% of the households were food insecure at least part of the year (Coleman-Jensen et al., 2021). Food banks aim to support these people with donated food. In 2020, food banks associated with FEBA, the European Food Banks Federation, repurposed around 860,000 tons of food, helping about 12.8 million people in need through large (decentralized) networks of food banks and related charitable organizations, such as soup kitchens and homeless shelters, building largely on volunteers (FEBA, 2021).

However, providing these services comes with challenges. For example, research shows that food banks are limited in their capacity to improve overall food security due to the limited provision of foods with high nutritional value (e.g., Bazerghi et al., 2016; Neter et al., 2016). This is related to, amongst others, the fact that the food products

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available to food banks include a wide variety in nutritional value and food groups in many countries (Jessri et al., 2014), which is pointing towards challenges in making demand and supply meet. Furthermore, the uncertain nature of the donation-driven supply of food products makes it difficult to provide a stable food source for food bank beneficiaries (Davis et al., 2016).

An important and valuable source of supply for food banks consists of surplus food from industrial processing and retail sales activities. As such, food banks also provide a significant contribution to preventing food waste (González-Torre and Coque, 2016). By repurposing food that is not suitable for selling (e.g., due to packaging problems) or cannot be sold within its limited shelf life, people in need can be supported and the significant environmental impacts of food waste can be reduced. Redistribution for human consumption is normally considered the best way to deal with food waste from the perspective of reducing environmental impacts (e.g., Eriksson and Spångberg, 2017; Albizzati et al., 2019), prioritized above, for instance, the use as animal feed and energy production in many different hierarchical frameworks focused on food waste reduction and reuse.

Unfortunately, there has been little attention for a comprehensive and system-wide examination of food bank supply chains (Sengul Orgut et al., 2016). More specifically, dealing with the uncertainties in supply when matching demand and supply is an under-researched core challenge (Midgley, 2014), especially when this matching must consider the different product mixes and product qualities (Rong et al., 2011). Thus, there is a need for food bank-focused research on aspects related to supply chain management, including the handling of the specific supply and demand uncertainties found in this context and on the trade-offs between equity, efficiency, and effectiveness, as also emphasized by Sengul Orgut et al. (2016).

This paper aims to (i) provide an overview of the supply chain challenges that food banks deal with based on food banking practices from selected countries, (ii) review the operations and supply chain management literature regarding food bank supply chains, and (iii) discuss the extent to which the practical challenges have been addressed in the literature and outline the main challenges that should be addressed in future research.

The remainder of this paper is structured as follows. In Section 2, we first discuss our research approach in more detail. In Section 3, we introduce the general structure of food bank supply chains illustrated with examples from three European countries. Section 4, subsequently, presents an overview of supply chain challenges based on experiences from various actors in food bank supply chains. In Section 5, we present and structure the literature on food banks available in the operations and supply chain management domain. The challenges and the literature are contrasted in Section 6, followed by our conclusions in Section 7.

2. Research approach

The main objective of this paper is to present an overview of supply chain challenges in the context of food banks (in Section 4) and discuss to what extent these challenges are addressed in the operations and supply chain management literature (in Sections 5 and 6).

The overview of supply chain challenges is grounded in a wide variety of interactions with food banks in different countries. More specifically, we interviewed and surveyed different actors in food bank supply chains, supervised many student projects addressing specific challenges at food banks, and organized several workshops. This work included food bank supply chain actors from the Netherlands, Germany, and the United Kingdom.

Given our exploratory aim, we decided to employ an exploratory multiple case study design, similar to Capodistrias et al. (2022). We collected descriptive quantitative data (e.g., via student projects), which we combined with qualitative information from interviews and workshops related to both local and national food bank initiatives in the three countries mentioned above. Using multiple cases about the same phenomenon, each in a slightly different setting, is a well-accepted approach in case research (the *common process* design, see Eisenhardt (2021)). The resulting challenges found are based both on a combination of publicly available information and on past and present research activities involving one or more of the authors. Following Yin (2018), we ensured multiple evidence sources and aimed to identify a chain of evidence. For each of the research activities (included in Table 3 in the appendix), at least one of the authors played a role as researcher or research supervisor and was actively involved in the work. As we directed our empirical focus largely on countries from which we could draw on direct experience with food banks, we verified our findings with the European Food Bank Association (FEBA) to identify how our findings may be viewed from a more general perspective. In an online meeting with the Secretary General of FEBA, we discussed in detail the list of challenges that we produced based on our research in the three focus countries. For every challenge, the main validation question for FEBA was if it also holds true for the majority of the European countries. The feedback led to the exclusion of a small number of identified challenges because they were mostly considered relevant to only a limited number of countries based on the local organization of their food bank systems. An example of such a local challenge is the optimal composition of food parcels for pickup at food banks (see Section 3) since this is practice used in only a few European countries. FEBA acknowledged that the remaining challenges were relevant for food banks throughout Europe.

In the literature review in Section 5, we focus on peer-reviewed journal contributions from the operations and supply chain management literature and do not aim to cover research on, e.g., sociological or nutritional aspects of food bank support. This was operationalized by searching for food bank-related keywords (food bank(s), food pantry (pantries), soup kitchen, food donation) in the relevant Operations Research & Management Science and Industrial Engineering categories of the Web of Science database. An additional validation was performed by a similar search within the Decision Sciences category in the SCOPUS database.

Finally, we combined our inventory of supply chain challenges with the literature review by mapping the challenges against the streams of literature we identified. This mapping provides a basis for our discussion as it shows how the current state-of-the-art operations and supply chain literature on food banks addresses the identified challenges. Conversely, it also clearly shows which challenges have not been addressed.

3. Food bank supply chains

The supply chains behind food banks and other charitable food organizations are not typical food supply chains. Nor are they the same as the humanitarian supply chains used in relation to disaster relief (e.g., Day et al., 2012; Holguín-Veras et al., 2012). Even though food bank supply chains share many specific characteristics, there are also differences between how they operate in specific countries. To illustrate this variety, but also the similarities, we first introduce the operations of food bank supply chains in the three countries mentioned in Section 2 (the Netherlands, Germany, and the United Kingdom). Subsequently, we describe a general structure of food bank supply chains.

3.1. The Netherlands

Food banks are a relatively recent phenomenon in the Netherlands compared to many other countries. The first food bank was opened in 2002 in Rotterdam as a private initiative to battle poverty and provide a solution to food that would otherwise go to waste. Only in 2013, a national member association of food banks was set up to support the local food banks.

In the Netherlands, the number of households calling upon food banks for support has increased year after year. In 2020, food assistance recipients in the Netherlands relied on an infrastructure of 172 food

banks (with in total 528 distribution points) and 10 regional food bank distribution centres, delivering food to close to 160,500 people with the help of about 13,000 volunteers (Voedselbanken Nederland, 2020).

The regional distribution centres are independent organizations taking care of food collection in the region and from national sources, assembly of parcels and distribution of these parcels to the recipients. They keep a registration of goods received, in stock, and handed out (which is often not the case at the local level). The status in 2020 is that information systems are being developed to support operational processes in distribution centres. Since they are part of the Dutch national association, they agree to specific rules and regulations specified by the national society. In the Netherlands, about 30% of the total flow of goods to recipients comes through the network of regional distribution centres, and 70% is sourced locally by the local food banks and distribution centres.

The objective of food assistance in the Netherlands is not to provide a complete meal for recipients every day but to provide food parcels on a weekly basis that supplement a normal diet for 2–3 days per week (Neter et al., 2016). Recipients are eligible for food assistance for a period of a maximum of three years. Typically, the parcels are handed out by the food banks every week on a fixed day of the week. Increasingly, the social supermarket model is used instead of prepared parcels. Social supermarkets are currently used by almost 40% of the food banks in the Netherlands (Polman, 2021). The food banks are entirely dependent on volunteers (even at the level of the national association) and for most of the local food banks, it is an explicit objective neither to buy food nor to sell to beneficiaries.

3.2. Germany

In Germany, food banks have existed since 1993, and they have been organized in the Tafel Deutschland umbrella organization since 1995. Tafel Deutschland consists of 956 local organizations running more than 2000 sites (Tafel Deutschland, 2021a). Many local Tafel initiatives (60%) are run by local branches of large welfare organization (Caritas, Diakonie, German Red Cross, etc.), and the remaining locations are individual legal entities. Across all the local initiatives covered by Tafel Deutschland, around 60,000 volunteers are involved, and up to 1.65 million beneficiaries are supported (of which 70% are adults and 30% are children). Some independent Tafel initiatives also choose not to be a member of Tafel Deutschland.

Each Tafel location has its own characteristics and way of operating. Some locations only hand out food parcels once a week or every two weeks, and some operate social supermarkets on a more regular basis. Where possible, Tafel locations also offer services beyond food donations. For instance, some food banks offer cooking courses, and in many cases, they help beneficiaries find other relevant resources (e.g., additional counselling, debt counselling). The economic strength of regions is often a main driver behind the type and extent of support a local food bank offers (Tafel Deutschland, 2021a), meaning that this can vary significantly across regions. Normally, Tafel locations do not act as soup kitchens, but many Tafel locations deliver food to social institutions that prepare meals (e.g., homeless shelters, youth clubs in socially deprived areas). Furthermore, independent of the Tafel locations, local church congregations sometimes run soup kitchens.

Typically, most collection and distribution activities are carried out at the local level. Donations picked up at local supermarkets, bakeries, butchers, etc. Are the main supply for the food banks. For the food banks within Tafel Deutschland, this makes up 82% of the supply (Tafel Deutschland, 2021a). The remaining supply mostly comes from dedicated donation campaigns (8%) and state- or nation-wide redistributions (8%). Some food banks also work with larger donations from food companies or retailers and additional products that are bought to supplement donations (even though the buying of food is normally not done at food banks associated with Tafel Deutschland).

For food traceability reasons, most donations that are picked up at local donors (e.g., supermarkets and bakeries) are directly delivered to the distribution points. If available (in larger cities), trucks might also drive past a central warehouse to complement the donations with additional products that were underrepresented in the donations to be able to provide a certain variety at the distribution points.

The local food banks pay a small membership fee to be part of the national organization. Other financial flows might come from individuals or companies, supporting the organization in funding a variety of activities. The beneficiaries of the food bank typically also pay a fee for every time they receive a parcel (per parcel or per person). The food banks provide donors with a receipt for the goods they donated. This can be used for tax benefits. Besides this, hardly anything gets registered at the local level.

3.3. United Kingdom

The food bank supply chain in the United Kingdom consists of multiple actors. The two main national (overlapping) organizations are FareShare and the Trussel Trust food bank. Starting in 1994 with a single warehouse in the London region, FareShare now has 28 centres across the United Kingdom (FareShare, 2021), serving over 900.000 people per week through various member organizations. One of the largest members of FareShare is the Trussel Trust food bank, also a national organization. The first Trussel Trust food bank was founded in 1997, and by now, they support over 1200 locations (The Trussel Trust, 2021).

Food donations stem from multiple sources. The larger volumes, for example, from food manufacturers, are often donated to FareShare, which then distributes it to its members. Many supermarkets donate food to FareShare as well but also to the other charitable organizations nearby. The third stream of donated food comes from individuals, who either donate directly to the local charitable organizations or participate in larger collections organized by supermarkets or churches. The donated goods are usually picked up by FareShare or the charitable organization itself. The goods distributed by FareShare are always transported by FareShare itself.

FareShare has an online ordering system in which all the available food is listed. Each member of FareShare can order a certain amount of food each week with this system.

Most food is provided to beneficiaries either as a food parcel or as a prepared meal. For example, the food parcels of the Trussel Trust food banks are standardised and should provide food for three days. Some charitable organizations apply the concept of a social supermarket, and sometimes also charge a small payment to the beneficiaries.

The United Kingdom has a strict and elaborate policy on food donations. All incoming goods need to be recorded, and, depending on whether the good has a use-by or a best-before date, goods need to be consumed within 24 h or up to 3 months beyond this date.

All FareShare member organizations pay a yearly fee, which covers (part of) the operational expenses, including the delivery of goods. Food banks that are a member of Trussel Trust also pay a membership fee. Other financial means are donated, either by individuals or companies, to the charitable organizations.

3.4. General characteristics of food bank supply chains

Fig. 1 shows a general overview of the structure of food bank supply chains. Starting from donors, (regional or even national) networks consisting of regional distribution centres (DCs), and distribution points

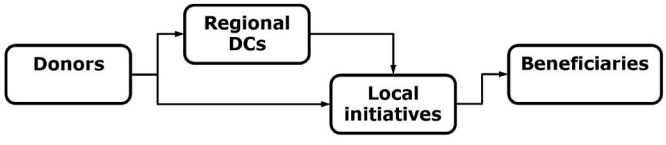

Fig. 1. General structure of food bank supply chains.

are used to distribute donated food to eligible citizens, which are normally referred to as beneficiaries in this context.

In these donation-driven food bank supply chains, donors can come from the primary food production sector, the food-processing industry, the retail sector, the food service sector, and can also be individual citizens. Many of the donations are the result of disturbances or inefficiencies in food supply chains (e.g., oversupply of products, products close to best-before dates) and, as such, also directly contribute to food waste reduction for the donor. In fact, food donation is also included in the national food waste prevention strategies of most European counties (EU Platform on Food Losses and Food Waste, 2019). In addition, donations can also be purely driven by charitable considerations of the donor (which is often the case for donations by individual citizens).

Donation supply chains typically consist of an agglomerate of local, regional, and national food bank initiatives and other charitable organizations. Locally, a variety of organizations provide food distribution to beneficiaries (e.g., churches, charities, private initiatives, or branches of food banks). Often, some form of regional or national collaborative initiative on a larger geographical scale supports these local initiatives with food, amongst other things. This collaboration is typically facilitated by organizations that operate distribution centres covering larger geographical areas (with local initiatives often being members of these overarching organizations). Such regional distribution centres can also be co-located with local initiatives. In many countries (e.g., in the United States and in a large part of Europe), food banks deal with the regional or national redistribution of donations to local charitable organization and, in this way, do not directly provide food to beneficiaries. In some countries, however, this final stage in the food bank supply chain is also covered by the food bank organization itself. In the EU, this for instance holds for Estonia, Germany, and the Netherlands (FEBA, 2022a). Donations feed into this agglomerate of national, regional, and local initiatives at all levels, but eventually all end up at the local level through which food is provided to the beneficiaries. The extent of coordination between local initiatives and national or regional DCs differs between countries, as also identified by Capodistrias et al. (2022).

At the end of the supply chain, beneficiaries are normally citizens that experience some form of income poverty and/or food insecurity. Distribution to beneficiaries is typically done in one out of two ways: through offering food parcels with a prepared selection of products or by providing food to social supermarkets in which beneficiaries can select products in a store-like setting. Some of the local charitable organization also provide the food in the form of meals.

4. Challenges in the food bank supply chain

In this section, we provide an overview of supply chain challenges based on food banking practices from three different countries. This overview provides a basis for the inventory of current literature in the next section and the subsequent discussion of further research challenges.

Table 1 presents an overview of the main challenges we identified, organized in supply-side challenges, demand-side challenges, and challenges related to matching supply and demand. An explicit connection between these challenges and the context in which we identified them is included in Table 4 in the appendix. In that table, we for instance see that each of the challenges was identified in at least two of the countries we studied, and they were all confirmed to be relevant beyond that by the European Food Bank Association (FEBA). In the remainder of this section, we further describe these challenges.

4.1. Supply-side challenges

The major issue at the supply side of the food bank is the reliance on uncertain donations, in terms of obtaining sufficient donations, and donations of the right type (in terms of product categories and nutritional goals). Supermarkets and other donors usually donate food that they cannot sell anymore. They might have predicted the demand wrongly and, therefore, had too much of a certain type of food, or a certain product is taken out of the assortment and, therefore needs, to be removed from the shelf. In the first case, the quantity of the surplus food can vary substantially. Sometimes, hardly any food is left over at stores, distribution centres, or processing plants whilst on other days there are enormous quantities available. The second case might happen less frequently (for instance after promotional activities for which the sales volumes were overestimated), but the quantities can be much larger, leaving the food bank with a lot of the same products at once.

Sometimes, larger food donations are given by food manufacturers, for example, when a production batch received the wrong labels. This can be a useful source of non-perishable products but can also leave the food bank with enormous quantities of the same item.

Depending on the relationship between the donor and the food bank, there might be a reasonably stable basic inflow of goods in general. However, even the basic inflow might be irregular and vary in terms of quantity. Another inflow of products arises from special initiatives such as Christmas donation campaigns. Such initiatives commonly lead to large volumes of donated food making it possible for the food bank to ask for specific products. The downside of these actions is the storage capacity needed after the initiative.

In some cases, food banks also experienced declining donations from supermarkets, which is a third issue. This may be due to improved forecasting and inventory management at retailers or due to more aggressive discounting by retailers. Both developments aim to reduce

Table 1
Overview of the main supply chain challenges in food bank supply chains.

Supply-side challenges	Demand-side challenges
Obtaining sufficient food donations	Difficulty in reaching the potential beneficiary
Irregularity in donation offers	Heterogeneity in dietary requirements of beneficiaries
Waste reduction strategies of donors reduce food available for donations	Beneficiaries do not always use all donated products
Competing uses for surplus food	Adverse effects of global developments and shocks
Perceived donor risk in donating	
Supply-demand matching challenges	
Perishability and food safety	*Information technology (IT)*
Short remaining shelf life of donations	Often limited IT infrastructure
Need to comply with traceability requirements	Easy solutions required for volunteers
Health and food safety	*Transportation and logistics*
Difficult to match actual donations with nutritional goals	Lack of coordination of transport activities
Difficult to incentivize healthier products	Increased transportation cost
Voluntary labour	*Supply chain coordination*
Limited availability of voluntary labour	Lacking transparency in supply chain
Diverse and uncertain skillset among volunteers	Many unconnected initiatives
	Complexity in achieving equitable food support

food waste at supermarkets, but this also reduces the number of products available for donation. Many European food banks also acknowledge that food waste reduction efforts are a main driver behind decreases in donations (FEBA, 2022b).

Furthermore, an increasing number of other uses of surplus food are more profitable for food manufacturers or retailers. Manufacturers can, for instance, sell their surplus food to energy recovery sites. Retailers often have opportunities to sell surplus perishables to companies processing this into, e.g., soups or to food waste reduction platforms such as Too Good To Go. Retailers also increasingly sell perishable products in their stores at a (sometimes steep) discount when these are close to the best-before date. The increasing attention for food waste reduction initiatives leads to less availability of food for the food banks even though some of the initiatives might serve a purpose similar to, or complimentary to, that of food banks.

Finally, donors may experience barriers to donation due to unintended use of donated items. Especially for larger donations, donors sometimes fear that food will be sold by the food bank beneficiaries, which will negatively affect the donor. Third, companies are hesitant to donate when they might be legally responsible in cases where food safety becomes an issue.

4.2. Demand-side challenges

Following their mission, food banks want to help as many people in need as possible. However, reaching out to their potential beneficiaries is sometimes complex, which is a first challenge. In many countries, a voucher (or some registration) is needed to enter a food bank, and to obtain these vouchers, beneficiaries must prove they need the assistance of the food bank. Acknowledging the need for assistance and going through an intake process can be (emotionally) very complicated for beneficiaries and can involve feelings of shame. Moreover, not all people in need are reached by the food banks. Many potential beneficiaries might be unaware of the possibility to obtain assistance from a food bank.

Another challenge regarding the demand is understanding and matching the specific needs of the beneficiaries. They might have special dietary constraints due to health or religious reasons. Moreover, the diet of families with children usually differs from an elderly, single-household beneficiary. Some food banks tend to consider all dietary wishes, for example, by separating parcels with pork from those with beef or by providing families with larger quantities than single households. However, this requires extra work from the volunteers and enough knowledge about the beneficiaries. Due to the irregular supply of products and the limited availability of volunteers, accounting for the specific needs of the beneficiaries is often not possible.

A very often heard complaint from the food bank beneficiaries is related to the products in the food parcels. The beneficiaries might not always be familiar with the food items and the ways to prepare meals with them, the products might not be in line with the beneficiaries' food preferences, or the beneficiaries do not use the products before they pass their 'best-before' date. In all these cases, the beneficiaries will not use the products they are given, and the food goes to waste. The social supermarket concept might reduce this issue, including the issue with the dietary constraints. However, not every food bank has the space and the labour capacity to apply this concept.

Finally, there are many global developments that impact demand for food bank support. More recently, this relates, for instance, to increased demand after the start of the COVID-19 pandemic in 2020 and the cost-of-living developments in relation to inflation and rising energy prices in 2022. Furthermore, events such as the 2022 Russian invasion of Ukraine significantly increased the need for food support in Ukraine and surrounding countries receiving Ukrainian refugees. In a recent survey among European food banks, the Ukraine war and the increased food prices were some of the most recognized factors influencing food bank operations (FEBA, 2022b). These examples mainly illustrate demand-side challenges, but such developments could similarly impact the supply side.

4.3. Supply-demand matching challenges

In addition to the challenges related to supply and demand, significant mismatches can arise in terms of the product availability – both at a local level and at a network level and in relation to quantity, quality, and product variety. Local mismatches mean that products might not be useful when they are available in excess (and potentially even wasted), or that specific products might have to be rationed across beneficiaries. At the network level, coordination between food banks might alleviate some of the mismatches, but this is often not done sufficiently in practice. This is often due to a lack of infrastructure for coordination between food banks, a lack of incentives to share information, or a lack of the required human resources.

In the sections below, we discuss the supply-demand matching challenges in more detail, distinguishing among challenges related to (i) perishability and food safety, (ii) health and food security, (iii) voluntary labour, (iv) information technology, (v) transportation and logistics, and (vi) supply chain coordination.

4.3.1. Perishability and food safety

A lot of the donations handled at food banks concern perishable food products. This can be packaged products with best-before or use-by dates but also products without a date stamp (e.g., unprocessed fruits and vegetables). In both cases, managing the short remaining shelf life of products can be challenging. First, it puts additional time pressure on the supply chain as products need to find their way to beneficiaries within a limited period. Second, depending on the type of product that is donated, it might not be possible to use the donated product within the shelf life. For some products (e.g., meat), there might be possibilities to use frozen storage or chilled, but these storage capacities are often limited or absent. For other products, it might mean that part of the donation cannot be used within the available time window, resulting in food waste. Considering that these products were often donated to the food bank to prevent food waste in the first place, this is, of course, not a desirable outcome.

The perishability of food donations also brings a variety of food safety concerns. As an actor in the food system, food banks are mindful about food safety. Depending on local legislation, food banks often need to comply with traceability requirements, which can be quite a burden. Food safety regulations also limit the use of what might still be considered edible food, for instance, when packaging is open or damaged or in situations in which a best-before date is passed, but the product is likely still perfectly fine. Whether or not it is allowed to use products after their best-before date depends on national legislations. An additional concern related to food safety is that potential donors from retail environments or food manufacturers can be hesitant to donate branded products that are close to their best-before dates. Even the slight possibility that a beneficiary would get sick from products bearing their brands, and the potential negative (public) attention that might come with it, could prevent donation.

4.3.2. Health and nutrition

In addition to supplying certain quantities of food, food banks often also aim to provide a certain mix of products that covers different nutritional requirements. There are two main challenges related to the management of health and nutrition in food bank supply chains.

First, nutritional goals are often hard to achieve based on donations, so the challenge is to cover the nutritional goals as well as possible based on the available donations.

Second, in settings in which the beneficiaries have more influence on the products they receive, they might not follow nutritional guidelines. For instance, when food banks operate with social supermarkets, it can be difficult to incentivize beneficiaries to select the healthier products.

In settings with food parcels, a food bank might have more influence on the product mix, but there could be challenges related to whether the beneficiaries end up using the healthier products – either due to unfamiliarity with preparing the items or simply due to the mismatch with existing consumption patterns.

4.3.3. Voluntary labour

Food banks are doing well in attracting volunteers that offer their services to help people in food insecure situations while reducing food waste. Without volunteers, food banks would not exist. Having said that, the fact that food banks are (mostly) run by volunteers has a significant impact on the supply chain management activities. In general, it leads to significantly less control over the workforce, compared to commercial supply chain settings.

The number of available volunteers is often found to be too limited. It can be hard to find new volunteers, and the turnover of volunteers can also be quite high. Therefore, significant effort can be necessary for continuous recruitment of volunteers. In addition to finding volunteers, managing such a volunteer workforce also has its challenges. To maintain volunteers, food banks try not to be too demanding in terms of volunteer effort. However, this means that many volunteers might only work a few hours and that, therefore, the operational workflow never reaches a more streamlined level. In many cases, planning is extremely difficult and short notice as food banks typically do not know in advance how many volunteers are available on a given day. Furthermore, the reason many food banks only have a limited number of pick-up moments per week is also related to the limited number of volunteers. This not only reduces the number of beneficiaries that can be served but also limits the donated food that can be accepted. Another consequence is that some beneficiaries occasionally skip the collection of a parcel when then cannot make it at the provided time slot.

The volunteer workforce can also be extremely diverse, which can have benefits if people bring in useful skills but can also be challenging with regards to mismatches in tasks and skills. In some situations, food banks even have support from people sentenced to community service, which can lead to further skill mismatches and a less motivated labour force.

4.3.3.1. Information technology. As mentioned above, traceability of food is important for food banks. In commercial settings, this often leads to significant investments and utilisation of information technology (IT) solutions. However, this is more difficult to achieve in food bank environments although exceptions exist.

Overall, extremely limited IT infrastructure is available, especially at the local level. This is a result of a combination of factors, including budgetary constraints, suitability of the IT solutions, and limited IT skills of volunteers. Even if funding were not an issue, it is impractical to implement complex IT solutions in situations in which the people that would use these solutions might not have the skills to do so or might not be active as a volunteer long enough to warrant extensive training in using the systems.

4.3.4. Transportation and logistics

For many food banks, transportation activities are a major cost factor. As organization with limited budgets, owning and operating one or more vehicles can easily end up as the largest cost component in the budget. Efficient use of this vehicle capacity is then also relevant, such as the possibility to cover as many pick-up and delivery activities as possible. Transportation and logistics are, however, often not perceived as a main challenge by actors in the food bank supply chain as transportation is often seen as a necessary and relatively straightforward activity, and other challenges are prioritized.

In many cases, especially at the local level, transportation capacity is not considered an expense, as pick-up and delivery activities are done with volunteers' personal vehicles. Of course, this is financially beneficial for the food banks, but it does result in significant uncertainties with regard to the availability of the transport capacity. The coordination of transport may then also be a challenge, especially when time windows for collecting products are narrow for products that are close to their expiration date.

However, in cases where transport is a significant expense, food banks are often actively looking for donations of vehicles and finances to support these activities. One of the food banks we worked with also investigated the possibility of having transportation services donated by, e.g., logistics service providers, but setting up such a collaborative system is not straightforward. Due to the increasing costs of transportation, it is expected that such kind of initiatives will be needed more and more.

4.3.5. Supply chain coordination

Coordinating supply and demand in situations with many challenges related to both the supply and the demand is clearly challenging. Several specific characteristics of food bank supply chains further complicate this coordination effort.

First, food bank supply chains lack transparency. This is related to the limited use of IT solutions and the lack of incentives to share data, and it is a major factor concerning the lack of coordination between food banks. The risk is that the lack of transparency leads to inefficient use of food donations and/or volunteer labour.

Second, food banks are not always part of larger local ecosystems. In most larger cities, many unconnected initiatives exist focused on either supporting people in need or addressing the issue of food waste prevention or reduction. Increased collaboration between these initiatives could be of benefit to the overall goals of these organization. This challenge was also identified in a recent Portuguese study (Augusto, 2021), in which it is suggested that there might also be a need for government mediation. Any form of coordination might, however, make the performance of the individual organization less visible, which is often a significant barrier for (independent) food banks.

A final challenge that food banks mentioned relates to achieving equity in the food support they provide. Differences in local donations mean that the quality and quantity of the contents of food parcels differ per food bank. Reallocation among food banks of the (local) donations can solve this, but this takes time and requires additional transport capacity. In addition, whether such a reallocation is an improvement in the first place strongly depends on one's definition or perception of fairness.

5. Literature review

In the last decade, we have seen an increasing effort from researchers looking into food bank supply chain challenges. To get an overview of this work and to be able to discuss to what extent the challenges described in the previous section have been addressed, in this section, we aim to report on our comprehensive review of this literature. We structure our discussion based on five supply chain related categories that emerged from the review. Fig. 2 in the appendix shows the distribution of the papers per category.

The first two categories relate to challenges at the network level. Here, we distinguish between the literature covering more strategic network design and the literature covering more tactical planning and allocation of products in these networks. The other three categories are related to the operations of individual food banks. First, as donations play a key role in food bank supply chains, the literature on donation management is discussed. Second, the literature regarding collection and delivery operations is discussed. Finally, some of the literature that covers other challenges related to the internal warehouse operations at food banks is discussed. After the review, in Section 6, we discuss to what extent the literature so far has addressed the challenges identified in Section 4.

Almost all studies described below are based on case studies. The majority of case studies are with food banks in the United States. However, some researchers use case studies from other countries such as

Portugal, India, or Mexico. Table 5 in the appendix gives a full overview of the countries studied in the papers.

5.1. Network design

Network design and facility location problems are strategic supply chain studies in which the facility is placed somewhere in a region to maximize the service or the area covered by the facility. In relation to food bank supply chains, such facility location problems often occur.

Martins et al. (2019) studied a network of food bank and charitable organization in the region of south Portugal. Both the location decision and the storage and transportation capacity decisions were studied from an economic, environmental, and social perspective. Several objectives were formulated regarding, e.g., the minimisation of costs, the minimisation of food waste and transportation emissions, and the maximisation of charitable organization served. Using a multi-objective modelling approach, several pareto-optimal solutions were found. Results showed trade-offs between the economic objective and the social and environmental ones. Another study by Ouyang et al. (2020) solves a facility location problem. They developed a solution approach that can deal with forbidden areas, i.e., areas where you cannot place a facility. The goal of their study is to place the facilities in such a way as to maximize the population of homeless people served, under a capacity and a budget constraint for each shelter.

Kaviyani-Charati et al. (2022) developed a multi-objective, multi-period, and multi-product model in which the cold chain transportation and storage facilities, the available vehicles and time limitations are considered for the food bank supply chain. The problem is solved with a two-stage stochastic program. In the first stage, the decision to open a food bank during a specific period is made; in the second stage, the distribution of the available food (donated surplus food and purchased food) within the network is optimized. In both stages, costs as well as environmental and social impacts are considered.

5.2. Network allocation

Network allocation deals with the distribution of goods from a distribution centre to multiple locations within a network of food banks. In many social food chains, regional organizations distribute food among the charitable organization in their regions. The main decision to make regarding these kinds of problems is to determine which organization will receive which part of the available food products.

Network allocation is a well-studied subject in the literature related to food banks. One of the key objectives used in these studies is the equitable and effective distribution of food (Alkaabneh et al., 2020; Fianu and Davis, 2018; Gómez-Pantoja et al., 2021; Lien et al., 2014; Sengul Orgut et al., 2016, 2017, 2018; Hasnain et al., 2021; Islam and Ivy, 2022; Stauffer et al., 2022). For many charitable organizations, serving each person in poverty equally is as important as distributing as much food as possible. Due to the many uncertainties in either the supply of food (Lien et al., 2014) or the capacity of the receiving agencies (Sengul Orgut et al., 2017, 2018), dynamic programming methods are often used to model these stochastic network allocation problems. To solve these models, either approximate dynamic programming (Alkaabneh et al., 2020) is used or different allocation policies are analysed (Lien et al., 2014; Fianu and Davis, 2018). Furthermore, robust optimisation or two-stage stochastic modelling is applied (Sengul Orgut et al., 2017, 2018). Hasnain et al. (2021) solve the problem with an algorithm in which different weights can be given to the equity and effectiveness of the food distribution, such that the food bank manager can optimize the allocation to the specific needs of the served region.

To increase equity, Stauffer et al. (2022) include the allocation of mobile pantries to deliver the food to the beneficiaries directly. With their optimisation model, the number of mobile pantries and the number of visits per county of these trucks can then also be determined. The study by Stauffer et al. (2022) is one of the few studies that incorporate the perishability of donated food.

The allocation of food products also impacts the possible diets that food banks can provide to their beneficiaries. Therefore, in the allocation process, the nutritional value is important as well. Both Alkaabneh et al. (2020) and Gómez-Pantoja et al. (2021), therefore, include the nutritional value or the number of calories within the measure of equity.

Recent work by Blackmon et al. (2021) illustrates the increased importance of efficient allocation of food in the context of the COVID-19 pandemic. The authors describe the development of a decision support system in which an allocation problem is solved with mathematical programming, resulting in reduced distribution costs at a time the food bank system was heavily used.

All these network allocation studies show that there is often a significant potential to improve food bank supply chains by an optimal allocation of donated food.

5.3. Donation management

Obtaining enough donations, either in-kind or monetary, is one of the key challenges for a charitable organization such as a food bank. There are several studies that study donation management, i.e., the incoming flow of goods and money at a food bank. In general, the available literature studies two aspects. First, there are studies that forecast food donations, and secondly, there are studies aiming to increase the amount of incoming donations.

Forecasting food donations is complex due to the high uncertainty present in the donated food (Brock and Davis, 2015; Sawaya et al., 2015). Therefore, forecasting models that can deal with this uncertainty, such as neural networks (Brock and Davis, 2015; Nair et al., 2017) or exponential smoothing methods (Davis et al., 2016), turn out to perform better than other methods. However, Nair et al. (2017) propose to use additional methods, such as structural equation modelling, to gain further insight in the interrelationships between potentially relevant variables in forecasting procedures. Information regarding the type of donor (i.e., a grocery store or a restaurant) as well as the size of the donation and the region in which the donor operates are important predictors for the type and quantity of the donated food (Brock and Davis, 2015; Nair et al., 2017). In the study of Davis et al. (2014), the effect of the forecast on the transportation schedule of the food bank was also included. The study of Davis et al. (2016) further discusses forecast accuracy in relation to, e.g., forecasting at a decentralized level versus a forecast at a network level and how forecasting can inform discussions on donation-increasing efforts. Paul and Davis (2022) improved the results of Davis et al. (2016) even more by clustering (potential) donors and forecasting the donation quantities per cluster. Clustering models are also used to predict the demand of a food bank (Sucharitha and Lee, 2022).

There are several studies that optimize gleaning operations, which is the collection of unharvested crops after the regular (mechanical) harvest. Collecting these crops left in the field both reduces food waste and provides a good opportunity for a food bank to obtain food. Several components of the gleaning process are highly uncertain. This not only refers to the availability of gleaning opportunities but also to the presence of human resources for gleaning. Both Sönmez et al. (2016) and Lee et al. (2017) found a trade-off between the number of gleaning trips and the volume obtained. When too many gleaning trips are scheduled by the food bank, volunteers will become less enthusiastic, which in turn, leads to a reduction in productivity, the so-called gleaner burnout. The simulation model used by Lee et al. (2017) also shows the relationships between the product volumes gleaned on the one hand and the number of volunteers or participating farms on the other hand. Moreover, they mention the benefits of monetary help from the government. Ata et al. (2019) further studied the gleaning context and develop dynamic staffing policies that can help increase gleaning volumes.

Ahire and Pekgün (2018) focused on improving the food bank's

promotional activities. Based on a mathematical programming model, the total yield per year (measured in meals) is maximized under the restriction of human and monetary resources. Several promotional activities are included, which result in monetary or in-kind donations (or both). Using this approach, the specific food bank studied by the authors managed to increase its food donations with 13% and the monetary donations with 46% when the promotional mix was optimized. In situations in which donations must be picked up, the geographical side of increasing the number of donations is especially relevant. Transportation costs could, for instance, decrease significantly if this means that the density of donors is such that the donors furthest away would not be required (Phillips et al., 2013).

Donation management can be a complex task due to uncertainty in supply of goods, available labour and transportation resources. During to the COVID-19 pandemic, these uncertainties only increased. Dalal (2022) studied the problem of which donor should supply which beneficiary considering these uncertainties. Dalal's robust optimisation model determines the optimal connections between the donors and the charitable organization.

Considering the uncertain inflow of food donations, the study of Buisman et al. (2019) incorporated contracts between a donor and a soup kitchen. The type of food, quantity donated per week, and timing of the donation were included in the contract. With a menu planning model, the use of the donations was optimized to minimize costs and reduce food waste. If the quantity of the donated food was in line with the needs of the soup kitchen, most food was used and the costs for the soup kitchen decreased.

All studies related to donation management studied aspects that are very typical for charitable organization, especially regarding the extreme uncertainty in both human resources and food supplies.

5.4. Collection and delivery operations

A significant number of papers deal with the transportation planning problem related to the collection of donations or the delivery of donations to distribution points or beneficiaries. In many cases, collection and delivery is an integrated process and, therefore, also needs an integrated planning approach. In fact, it turns out that studies either focus on transportation related to delivery operations or related to integrated collection and delivery operations. To the best of our knowledge, no studies address only collection operations. Considering the characteristics of these operational transportation planning problems, all papers dealing with this issue develop models and/or solution methods for varieties of the well-known vehicle routing problem (VRP). In some cases, these routing problems are also integrated with tactical or strategic decision problems, such as the selection of locations for delivery, leading to the study of location-routing problems, which also have a rich history in the literature.

In terms of delivery operations, Ghoniem et al. (2013) and Solak et al. (2014) studied a variant of the location-routing problem that addresses the distribution of food products to partner organization that subsequently take care of the final distribution to beneficiaries. The products are delivered to drop-off locations where partner organization subsequently pick up the products. In this setting, the authors (i) selected which drop-off locations to use, (ii) allocated partner organization to these drop-off locations, and (iii) determined the related vehicle routings. They mathematically modelled this decision problem and developed several heuristic approaches to solve the problem. The authors concluded that the developed heuristics provide solutions within reasonable time, allowing for the coordination of the distribution activities with the selected drop-off locations. To further improve the runtime of the solution method, and thus increase the usefulness in practical settings, Reihaneh and Ghoniem (2018) developed an even more efficient heuristic for a similar location-routing setting, based on using multiple initial solutions and improved search methods.

An interesting aspect in the abovementioned research is the fairness consideration in the cost objective. Because the location decision determines the transportation costs incurred by both the central food bank (for the drop-off) and the partner organization (for their pick-up at the drop-off point), the objective contains a weighted average of the costs incurred by the two parties, for which the weight allows a decision maker to specify the importance of the two cost components.

In terms of integrated collection and delivery operations, most papers studied situations in which donations need to be collected and delivered to distribution points directly. Phillips et al. (2013) developed a linear programming model that selects donors to visit with the goal to satisfy a daily demand. They integrate this model in a simulation setting to account for uncertainty in donation volumes. In contrast to most of the research on collection and delivery, Phillips et al. (2013) did not explicitly model the vehicle routing aspects but considered a fixed cost for a pickup (based on the distance to the donor). However, the authors also considered the fact that products can be stored at the donor and at a warehouse to be used on another day, also taking product perishability into account.

A relatively new approach to collection and delivery operations was considered by Mittal et al. (2021), who looked into volunteer-based crowd shipping to redistribute food donations by restaurants. The study shows that, for such a system to be feasible, a good balance should exist between the number of donation requests and available crowd shippers. Managed successfully, such a program has the potential to grow both in terms of food donations and crowd shippers.

Davis et al. (2014) studied a problem similar to the location-routing problems mentioned above. They developed a two-stage solution approach, in which they first identified drop-off locations and allocated the charitable organization that needed it to the drop-off points and, secondly, applied a vehicle routing model to schedule the actual transport operations, including collection and delivery. In the routing problem, the authors also considered that the number of visits to a donor might need to be limited to allow for donations to accumulate and for food deliveries and food collections not to be mixed for food safety reasons. The last issue means that routes are constructed such that delivery from the food bank warehouse takes place first and collection activities form the rest of the route, resulting in donations being delivered to the warehouse for inspection and delivery on the following day.

Balcik et al. (2014), Nair et al. (2016), Rey et al. (2018), and Ghorpade and Corlu (2022) all studied a setting in which donations are collected and delivered in one and the same route. Balcik et al. (2014) develop both an optimisation model and a time-efficient heuristic that specifically aim to achieve a fair distribution among distribution points (by maximising the lowest service level), which implicitly also minimizes waste. Nair et al. (2016) studied their routing problem in a periodic setting, so they could determine regular service schedules for the individual collection and delivery locations. The authors also developed an efficient heuristic to be able to solve larger problem instances. Rey et al. (2018) reformulated the problem such that fair allocation strategies and cost-effective routing decisions can be optimized jointly. The study of Ghorpade and Corlu (2022) distinguishes itself from the other ones by incorporating uncertainty in demand and supply into their collection and delivery model.

Eisenhandler and Tzur (2019a) defined the humanitarian pickup and distribution problem as a simultaneous decision-making process with regards to which donations to collect, which distribution points to deliver to, and how this is subsequently captured in vehicle routes considering several constraints. In addition, the quantities to collect from and deliver to each location need to be determined, often with the aim to achieve a kind of equitable allocation of food. In their work, Eisenhandler and Tzur (2019a) propose a routing problem with an objective that integrates effectiveness and equity in a single measure. In a subsequent paper, Eisenhandler and Tzur (2019b) developed a different mathematical formulation of the problem together with a matheuristic that improves on previous solution methods.

5.5. Warehouse operations

Some planning problems occurring at warehouse locations of food banks are also studied in the literature, specifically in relation to the processing of donations in parcels and the design of the warehouses themselves.

Ortuño and Padilla (2017) addressed the construction of food parcels for distinct types or recipients. Based on information about both family compositions and their nutritional requirement and the available food products and their contributions to different nutrient groups, the authors allocated available food to parcels with an optimisation model that maximizes the energy content sent to the receiving families while considering minimum levels of different nutrient groups per parcel.

Mohan et al. (2013) developed a simulation model for the warehouse operations of a local food bank. At this warehouse, food donations are received and processed before being ready for further distribution. The processing at the warehouse consisted of weighing, initial sorting, registering for accounting and tax purposes, quality inspection, further sorting, and storing. Based on their simulation model, the authors were able to analyse changes to the warehouse design, leading to more effective and efficient operations, including a reduction of waste.

6. Discussion

In the previous sections, a broad range of food bank supply chain management challenges are identified, and we also discussed what the operations and supply chain management literature focused on. In this section, we described to what extent the challenges have been addressed in the literature so far and discussed what opportunities this provides for future research. We do want to emphasize that our discussion is limited to the operations and supply chain management literature reviewed in this paper, but we will also briefly discuss interdisciplinary research in Section 6.2.

6.1. Addressing the challenges – contributions from the literature

Table 2 presents an overview of the extent to which the challenges were considered in the different themes covered in the literature. It clearly shows that some challenges were often addressed in the literature while other challenges were not studied at all.

6.1.1. Supply-side challenges

Starting with the challenges on the supply side, Table 2 shows that we mainly find research dealing with the challenge to ensure enough donations and some research addressing the irregularity in donations. Both challenges are related to the work that is done to develop better forecasting methods for donations. Also, the consideration of uncertainty in incoming.

However, some papers also address the identification of possible donation sources more proactively. For instance, several studies (Sönmez et al., 2016; Lee et al., 2017) have optimized gleaning operations, providing insight and support in maximising the amount of product that can be sourced in that way. Also, Ahire and Pekgün (2018) specifically addressed promotional activities aimed to bring in donations. By choosing the right promotional activities, they showed that it is possible to significantly increase donations. Finally, the donation contracts studied by Buisman et al. (2019) have shown to be a possible way to provide some structure in donation patterns and, as such, improve the utilisation of donations.

The remaining three challenges on the supply side related to the reduction of donations due to waste reducing strategies of companies, the possible competing uses for surplus food, and the potential risks that donors see in donating are not reflected in the current research.

Table 2
Summary of challenges covered in the literature.

	Network design	Network allocation	Donation management	Collection and delivery operations	Warehouse operations
Supply-side challenges					
Obtaining enough food donations			X		
Irregularity in donation offers		X	X		X
Waste reduction strategies of donors reduce food available for donations					
Competing uses for surplus food					
Potential donor sees risks in donating					
Demand-side challenges					
Difficulty in reaching the potential beneficiary	X				
Heterogeneity in dietary requirements		X			X
Beneficiaries do not always use all donated products					
Adverse effects of global developments and shocks		X	X		
Supply-demand matching challenges					
Perishability and food safety					
Short remaining shelf life of donations	X	X	X	X	
Need to comply with traceability requirements				X	
Health and food security					
Difficult to match actual donations with nutritional goals		X	X		X
Difficult to incentivize healthier products					
Voluntary labour					
Limited availability of voluntary labour			X		
Diverse and uncertain skillset among volunteers					
Information technology					
Often limited IT infrastructure					
Easy solutions required for volunteers					
Transportation and logistics					
Lack of coordination of transport activities	X	X	X	X	
Increased transportation costs	X	X	X	X	
Supply chain coordination					
Lacking transparency in supply chain					
Many unconnected initiatives					
Complexity in achieving equitable food support		X		X	

Donations is a key part of the network allocation approaches, which typically aim to identify the best possible way to use the incoming donation uncertainty.

6.1.2. Demand-side challenges

Regarding the challenges on the demand side, we see in Table 2 that only one of the reviewed research papers considered the difficulty in reaching the potential beneficiary. Ouyang et al. (2020) maximizes the service provided to the people within a specific area. How to reach beneficiaries who might not come to the food bank due to shame or unawareness is, however, not present in the reviewed literature even though this is an issue that is discussed outside of the operations and supply chain management literature we have reviewed here.

Some of the literature consider the heterogeneity in dietary requirements. In network allocation approaches, nutritional aspects are sometimes considered. Gómez-Pantoja et al. (2021) for instance distinguished requirements for individual beneficiaries, modelled as a demand in terms of calories, and further specify this with minimum and maximum levels of carbohydrates, proteins, and fat. Furthermore, Alkaabneh et al. (2020) limit the bundles of products that are allocated to distribution points such that there is a certain balance in nutritional value in each allocated quantity.

The impact of global developments and shocks on the demand for food bank services has recently also seen some attention in the literature, mainly driven by the COVID-19 pandemic. Blackmon et al. (2021) developed decision support for the Los Angeles Regional Food Bank to help them integrate a new governmental support program in the food bank operations to deal with the increasing demand caused by the pandemic. Dalal (2022) also addressed the planning of food bank operations in the wake of the pandemic, specifically modelling the decisions of which donors to engage and how to allocate the resulting donations to beneficiaries.

The last remaining challenge on the demand side, the issue of unused products by beneficiaries, is not found in the reviewed research papers.

6.1.3. Supply-demand matching challenges

Regarding the challenges in matching supply and demand, Table 2 shows that several of the challenges are discussed in the literature even though it is limited in relation to the number of challenges and the extent to which they are addressed. In relation to perishability and food safety, some studies on collection and delivery operations have been conducted that explicitly consider perishability (e.g., Phillips et al., 2013), and one network design study also includes food waste minimisation as an objective (Martins et al., 2019). Food safety is sometimes implicitly considered; Davis et al. (2014) specifically schedule delivery before collection to avoid mixing of products and to sallow for the donations to be inspected at the warehouse before delivery on later days.

The challenge of considering health concerns and food security at the supply chain level is mainly reflected in studies that consider dietary issues in the processing and distribution of donations. This includes the allocation of products to the location where they are distributed to beneficiaries based on a certain target nutritional balance, as mentioned above (Alkaabneh et al., 2020), but also some research combining donations based on specific nutritional considerations. For instance, some research includes aspects related to meal variety in determining menu plans (Buisman et al., 2019) and some research considers family composition in assembling food parcels (Ortuño and Padilla, 2017).

The challenges related to the fact that most food bank supply chains rely heavily on voluntary labour does not receive much attention. A notable exception is the work by Sönmez et al. (2016), Lee et al. (2017), and Ata et al. (2019) on the planning of gleaning operations. They specifically consider the fact that a volunteer workforce can be difficult to manage in terms of capacity and that over-asking volunteers to help in specific operations (in this case gleaning) might lead to (temporary) unavailability in the future. Furthermore, research by Ataseven et al. (2018, 2020) demonstrates that efficient supply chain integration in the context of food banks relies heavily on human capital and that the reliance of food banks on external partners emphasises the importance of external supply chain integration, as opposed to for-profit supply chains, in which internal integration efforts between different functional areas are often more important. Management of the volunteer workforce is important, but not many studies provide guidance on how to do this.

Surprisingly, issues related to limited IT infrastructures and the need for easy solutions are not found in the current literature either. In some cases, research mentions some implementation efforts with regards to decision support models and data availability, but specific consideration of implementation in food bank environments and how this differs from commercial environments is scarce. For instance, vehicle routing models can be complex to implement in the context of food banks, due to the requirements in terms of IT infrastructure and data availability. The use of fixed collection and delivery schedules based on vehicle routing studies can however be achieved. To some extent, this is reflected in the way routing models are used in the literature (e.g., Davis et al., 2014) and is also something that we experienced in our work with food banks. Even though there is significant value in the decision support models developed in literature, unfortunately implementation challenges do often hamper the adoption of such modelling approaches.

Coordination of transport activities clearly received the most attention in the literature, with many contributions addressing both the detailed vehicle routing involved in collection and delivery operations and the consideration of transport distances in network design and network allocation studies. Brock and Davis (2015) also discuss the connection between forecasting donations and transport operations, such that the limited transport capacity can be used as effectively as possible. Most of the literature focuses on transportation issues at the network level, studying the collection and delivery of donations to food banks or distribution points. Related to the IT challenges discussed above, this might also be related to the fact that it is more likely for data to be available with the national or regional organization, who typically work with larger donations and have better developed IT infrastructures (partly also required by donors). Performing and implementing routing studies at the local level is often difficult due to limited data collection activities and limited IT infrastructure. Many of the modelling approaches for network design and allocation, donation management, and collection and delivery operations depend heavily on transportation costs. As a result, increased transportation costs also lead to different solutions to these problems, and the available models might, therefore, also be relevant to help deal with the increasing transportation costs experienced in 2022.

Finally, various aspects related to supply chain coordination also came up as challenges. A variety of the abovementioned aspects (related to, e.g., forecasting donations, network design and allocation, and efficient use of donations in menu plans and food parcels) contribute to an improved coordination of the supply chains. However, specific challenges related to the lack of transparency in food bank supply chains and the prevalence of many unconnected initiatives have not received much attention even though addressing these challenges might lead to significant improvements in the coordination within and across food bank supply chains. The only exception here is the equitable distribution of food, which is often included in the literature related to network allocation or the collection and delivery operations.

6.2. Addressing the challenges – discussion and future research

The operations and supply chain management literature has made some important contributions to the challenges found in food bank supply chains, as summarised in the previous sections. However, it is also clear that many challenges have only been partially addressed or have not been addressed at all. This leads to many relevant and important research challenges for the operations and supply chain management community. In addition to the gaps pointed out in Section 6.1, we will next discuss six overarching insights and challenges.

First, with many of the research contributions focusing on modelling approaches for network design, network allocation, and vehicle routing, the operations and supply chain community has clearly built on their strengths in terms of addressing the challenges in food bank supply

chains. It likely also reflects a motivation of researchers to use their skills and methodologies to address societal issues. Furthermore, for the actors in food bank supply chains – who typically do not have operations or supply chain backgrounds – the challenges are often not perceived as operations or supply chain challenges. As volunteers, they focus on the primary process of serving the food bank beneficiaries. However, when we consider food banks from an operations and supply chain perspective, many of the challenges are linked to the goal to make the most out of the available resources, with considerations related to constraints and uncertainties in supply, workforce, and capacities. Together with the need for collaboration and multiple objectives related to efficiency, sustainability, and a fair distribution of food, this results in many research challenges that relate to operations and supply chain management research. Furthermore, as in other non-governmental organization (NGO) contexts, social capital is an important factor in the development of successful cross-sectoral relationships (Moshtari and Vanpoucke, 2021). For the food bank context, this is especially relevant in managing supply chain relationships with donating businesses.

Second, it is important to emphasize that there are many interdependencies between the challenges. These should be addressed in future research. For instance, in most cases, food banks experience large fluctuations in donations (e.g., through specific donation campaigns around Christmas). Together with the storage limitations caused by small-scale storage facilities and possible perishability of products, there are often limited possibilities to match supply and demand efficiently. Moreover, possible ways to improve the efficiencies in the matching are not always identified due to a lack of transparency in the supply chain or inefficient collaboration between independent local initiatives. Another example is the challenge related to high quality and traceability requirements. Due to the limited skillset of volunteers or the financial means, it is not always possible to use professional tracking and tracing tools. This then might affect potential donors as they might worry about their brand image in the case of food safety incidents.

Third, the fact organizations such as food banks rely heavily on voluntarily donated resources completely changes the incentive structures around resource utilisation. In for-profit supply chains, efficient use of labour is often a key factor in the planning and control of supply chain operations. For food banks, there is an intrinsic incentive for volunteers to 'donate' time and resources. Therefore, a more efficient use of human resources would not have any financial benefits – even though it might lead to an increased performance for the beneficiaries of food banks. For instance, in situations in which transport capacity is donated (as is often the case at the local level using the volunteers' personal vehicles), there is no clear incentive for an efficient use of this transportation capacity even though this capacity might be limited. We realize that this efficient utilisation perspective is a fairly one-sided view on (human) resources in food bank supply chains and that approaching these resources in this way is not always useful and can be inappropriate. However, we would like to stress that this is an important aspect to consider in future research by the operations and supply chain community.

Fourth, the interdependencies between the challenges also extend to different disciplines as not all the challenges that were identified are purely supply chain management issues. On the demand side, a clear link to research on health and nutrition can be identified. It is evident that the purpose of food banks is to provide nutrition to their beneficiaries, and research on matching supply and demand in food bank supply chains should always consider this nutritional aspect in, e.g., the combination and allocation of donations in the supply chain. Here, connections can be made to existing work in the health and nutrition field, where researchers also notice that supply chain aspects such as cold storage capacity and information sharing are important factors in improving the nutrition provided through food banks (e.g., Mousa and Freeland-Graves, 2017; Wetherill et al., 2019). In addition to the health and nutrition field, there is a connection to the social sciences, both in terms of the sociological side of food assistance and the psychological side of motivations of people deciding to volunteer at food banks (e.g., Rombach et al., 2018; Bowe et al., 2019). Finally, the field of economics and policy might contribute to discussions on establishing regulatory frameworks that help to repurpose food that would potentially be wasted, just like some governments have started to do with regulations requiring charitable donations instead of wasting food (e.g., Albizzati et al., 2019; Kinach et al., 2020).

Fifth, many improvements to food bank supply chain management rely on both an increased availability of data and some availability of IT infrastructure. In some cases, the results of research can lead to simple rules and heuristics that might be implemented without much effort, but in many cases the implementation of solutions based on quantitative decision support models is difficult without a proper IT infrastructure and the availability of the skills to use these solutions in the (voluntary) workforce. Currently, this means that, potentially, more opportunities exist to implement research results in the management of regional DCs or the coordination of network allocation activities as the IT infrastructure is likely to be more developed at this level in the food bank supply chain in comparison with local food banks and their distribution points. Improved digitalisation would provide many opportunities and is, therefore, also on the agenda of many organizations active in food bank supply chains. Recent survey results confirm that digitalisation is a short-to medium-term objective for 62.1% of European food banks (FEBA, 2022b). For instance, there is an initiative in Germany (Tafel Deutschland, 2021b) aiming to develop digital solutions that should improve the collaboration between donors and local food banks, for instance, by supporting and simplifying the donation process and improving the use of food donations through better distribution within and between food banks. Regarding the implementation of digitalisation and efficiency improvements, the human factor in the food bank context has to be considered; specifically, the many volunteers making up the food bank workforce also need to be able to accept these changes (similar to the third insight mentioned above). If this is not managed properly, such initiatives might lead to volunteers developing their own practices or even leaving.

Finally, many of the challenges relate to collaboration across the supply chain. These include managing 'supplier' relationships with donating parties to ensure enough donations, managing 'customer' relationships in terms of reaching the right beneficiaries and understanding their needs, and managing connections between the initiatives in the larger food charity ecosystem. Therefore, similar to Harland's (2021) recent perspective on humanitarian aid supply chains, effective food bank supply chains require a systems approach that focuses on regional or national levels as a supplement to the traditional firm-level perspective.

7. Conclusions

Food banks have a significant social and environmental role in the food supply chain. They support people in need by redistributing food, and by doing so, they contribute positively to reducing the environmental problem of food waste. As food banks usually rely on volunteers, have limited budgets, and redistribute food with short remaining shelf life, managing food bank supply chains can become very complex. In this paper, we aim to provide an improved basis for future research on food bank supply chain management and, by doing so, improve the food security and sustainability of the food system.

Based on a wide range of interactions with actors in the food bank supply chain, we identified a range of challenges, which we classified in three categories: demand-side challenges, supply-side challenges, and challenges in matching supply and demand. This empirical part of our study is based on the food bank supply chains in the Netherlands, Germany, and the United Kingdom. We see that most of the existing operations and supply chain management literature considers US food banks. In the United States, food banks usually do not serve beneficiaries directly, like in, for instance, Estonia, the Netherlands, or Germany, but

serves other charitable organization such as pantries, homeless shelters, or soup kitchens. This is comparable to the role of the distribution centres in the United Kingdom and similar to most European countries (except the three mentioned above). Therefore, the focus of the challenges might be different, and it partly explains the emphasis on equitable network allocation contributions in the United States, but it does not lead to completely different challenges. So, even though there are differences found in how these supply chains are organized in different countries, the challenges experienced by the actors in the chains are similar. Even for other countries, the challenges are expected to be similar as most food banks have similar goals and face similar limitations (e.g., González-Torre and Coque, 2016; Baglioni et al., 2017; Ataseven et al., 2018; Augusto, 2021; FEBA, 2021; Capodistrias et al., 2022).

After presenting a comprehensive review of the available research related to food bank supply chains, we assess the extent to which the challenges faced by the food banks are addressed in the literature. We observe that many challenges have not been addressed yet. So far, most of the literature deals with classical, model-based operations and supply chain issues, such as vehicle routing, network design, and network allocation, which are then applied to food bank contexts. Important challenges related to dealing with voluntary labour and managing highly perishable products are only addressed to a limited extent. The often-lacking IT infrastructure and the impact this has on improving food bank supply chains are not addressed in the literature. Food banks could benefit much more from supply chain research if IT infrastructures and data availability were to improve. The fact that, in many countries, digitalisation projects have been started at food banks leads to a promising environment for the operations and supply chain community to perform relevant and impactful research. On the other hand, it might still be necessary to also consider the development of methods and tools that would not require much IT infrastructure as this would greatly benefit implementation, especially in relation to the difficulties resulting from working with an often highly diverse volunteer labour force. Finally, an important observation is the interdependency between challenges at the demand, supply, and supply-demand matching level and the resulting need for interaction with different research disciplines.

We sincerely hope that this paper motivates both researchers in the operations and supply chain community and researchers in related fields to continue and intensify research on improving food bank supply chain management and extend the work on the challenges identified in this paper.

Data availability

No data was used for the research described in the article.

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Appendix

Table 3
Overview of research activity per country.

Country	Research activity
The Netherlands	NL1: 9 MSc thesis projects/internships between 2014 and 2022, each lasting 4–6 months with local and with national food bank organizations. NL2: Interviews (formal and informal) with the chair of the Dutch food bank, with board members, the IT specialist, the logistics manager, planners, and drivers at the Amsterdam food bank between 2014 and 2022. NL3: Workshop with 15 representatives of food banks in the Netherlands on challenges and opportunities in food bank logistics. NL4: 2 projects with the Dutch national food bank organization on logistics, including a survey involving all 170 local food banks in The Netherlands.
Germany	GE1: 2 MSc thesis projects in 2015 and 216, each lasting 6 months, partly in collaboration with a local food bank. GE2: 3 student group projects in 2015 and 2016, each performed by two students, lasting about 2 months. GE3: Interviews with food bank representatives in 2016 and 2021.
United Kingdom	UK1: Informal interviews with board members, operations managers, and front workers at local food bank (during a 1-month research visit in 2019 by one of the authors). UK2: Informal interview with operation manager and planner at regional distribution centre (1-month research visit in 2019 by one of the authors).

Table 4
Overview of the challenges and the sources from which they were identified (coding for the sources are references to Table 3).

Sources	NL1	NL2	NL3	NL4	GE1	GE2	GE3	UK1	UK2	EU1*
Supply-side challenges										
Obtaining sufficient food donations		x	x			x		x	x	
Irregularity in donation offers	x	x	x		x	x	x	x	x	
Waste reduction strategies of donors reduce food available for donations		x	x	x		x				x
Competing uses for surplus food		x	x					x	x	
Perceived donor risk in donating		x	x			x	x		x	
Demand-side challenges										
Difficulty in reaching the potential beneficiary	x	x	x	x			x	x	x	
Heterogeneity in dietary requirements of beneficiaries		x	x		x	x	x			
Beneficiaries do not always use all donated products	x	x	x							
Adverse effects of global developments and shocks		x								x
Supply-demand matching challenges										
Perishability and food safety										
Short remaining shelf life of donations	x	x	x		x	x	x	x	x	

(*continued on next page*)

Table 4 (*continued*)

Sources	NL1	NL2	NL3	NL4	GE1	GE2	GE3	UK1	UK2	EU1*
Need to comply with traceability requirements		x	x		x	x	x	x	x	
Health and food safety										
Difficult to match actual donations with nutritional goals	x		x		x			x		
Difficult to incentivize healthier products			x							
Voluntary labour										
Limited availability of voluntary labour	x		x			x	x	x		
Diverse and uncertain skillset among volunteers	x		x			x	x			
Information technology (IT)										
Often limited IT infrastructure		x	x	x			x	x		
Easy solutions required for volunteers	x	x					x			
Transportation and logistics										
Lack of coordination of transport activities	x			x		x		x		
Increased transportation cost	x	x		x						x
Supply chain coordination										
Lacking transparency in supply chain	x		x	x	x	x				
Many unconnected initiatives	x	x					x	x		
Complexity in achieving equitable food support	x			x	x					

*The EU1 column only contains the additional challenges identified by FEBA. The validation process also included the confirmation of the other challenges.

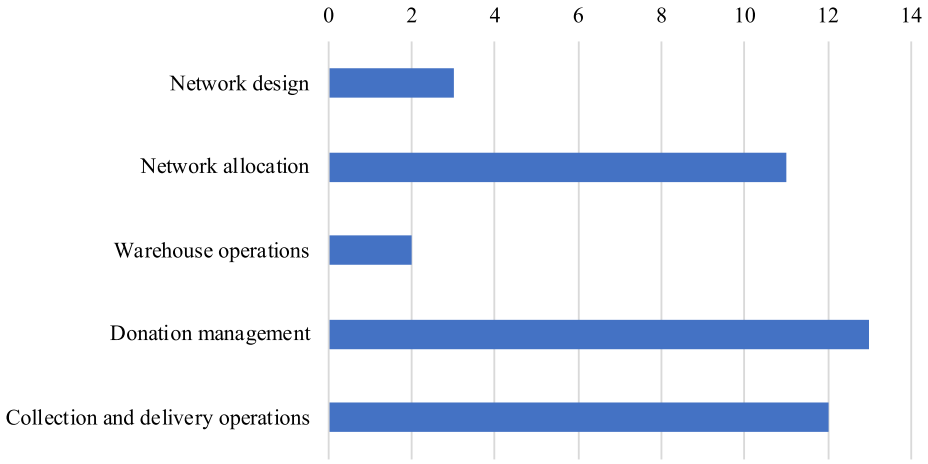

Fig. 2. Number of available research papers per category.

Table 5
Overview of existing research by country of case study.

Country	Paper
USA	Ahire and Pekgün (2018), Alkaabneh et al. (2020), Ata et al. (2019), Balcik et al. (2014), Blackmon et al. (2021), Brock and Davis (2015), Davis et al. (2014, 2016), Eisenhandler and Tzur, 2019a,b, Fianu and Davis (2018), Ghoniem et al. (2013), Hasnain et al. (2021), Islam and Ivy (2022), Lee et al. (2017), Lien et al. (2014), Mittal et al. (2021), Mohan et al. (2013), Ouyang et al. (2020), Paul and Davis (2022), Phillips et al. (2013), Sawaya et al. (2015), Sengul Orgut et al. (2016, 2017, 2018), Solak et al. (2014), Sönmez et al. (2016), Stauffer et al. (2022), Sucharitha and Lee (2022)
Mexico	Gómez-Pantoja et al. (2021), Ortuño and Padilla (2017)
Australia	Nair et al. (2016, 2017), Rey et al. (2018)
India	Dalal (2022)
Israel	Eisenhandler and Tzur (2019a,b)
Iran	Kaviyani-Charati et al. (2022)
Portugal	Martins et al. (2019)
Not specified	Buisman et al. (2019), Ghorpade and Corlu (2022), Reihaneh and Ghoniem (2018)

References

Ahire, S.L., Pekgün, P., 2018. Harvest Hope Food Bank optimizes its promotional strategy to raise donations using integer programming. Interfaces 48 (4), 291–306.
Albizzati, P.F., Tonini, D., Chammard, C.B., Astrup, T.F., 2019. Valorisation of surplus food in the French retail sector: environmental and economic impacts. Waste Manag. 90, 141–151.
Alkaabneh, F., Diabat, A., Gao, H.O., 2020. A unified framework for efficient, effective, and fair resource allocation by food banks using an Approximate Dynamic Programming approach. Omega 100, 102300.
Ata, B., Lee, D., Sönmez, E., 2019. Dynamic volunteer staffing in multicrop gleaning operations. Oper. Res. 67 (2), 295–314.
Ataseven, C., Nair, A., Ferguson, M., 2018. An examination of the relationship between intellectual capital and supply chain integration in humanitarian aid organizations: a survey-based investigation of food banks. Decis. Sci. J. 49 (5), 827–862.
Ataseven, C., Nair, A., Ferguson, M., 2020. The role of supply chain integration in strengthening the performance of not-for-profit organizations: evidence from the food banking industry. J. Humanit. Logist. Supply Chain Manag. 10 (2), 101–123.
Augusto, F.R., 2021. Food assistance in Portugal: organizational challenges in three different contexts. Journal of Organizational Ethnography 10 (3), 244–257.
Baglioni, S., De Pieri, B., Tallarico, T., 2017. Surplus food recovery and food aid: the pivotal role of non-profit organisations. Insights from Italy and Germany. Voluntas 28 (5), 2032–2052.
Balcik, B., Iravani, S., Smilowitz, K., 2014. Multi-vehicle sequential resource allocation for a nonprofit distribution system. IIE Trans. 46 (12), 1279–1297.

Bazerghi, C., McKay, F.H., Dunn, M., 2016. The role of food banks in addressing food insecurity: a systematic review. J. Community Health 41 (4), 732–740.
Blackmon, L., Chan, R., Carbral, O., Chintapally, G., Dhara, S., Felix, P., Jagdish, A., Konakalla, S., Labana, J., McIlvain, J., Stone, J., Tang, C.S., Torres, J., Wu, W., 2021. Rapid development of a decision support system to alleviate food insecurity at the Los Angeles regional food bank amid the Covid-19 pandemic. Prod. Oper. Manag. 30 (10), 3391–3407.
Bowe, M., Wakefield, J.R.H., Kellezi, B., McNamara, N., Harkin, L., Jobling, R., 2019. Sometimes, it's not just about the food': the social identity dynamics of foodbank helping transactions. Eur. J. Soc. Psychol. 49 (6), 1128–1143.
Brock, L.G., Davis, L.B., 2015. Estimating available supermarket commodities for food bank collection in the absence of information. Expert Syst. Appl. 42 (7), 3450–3461.
Buisman, M.E., Haijema, R., Akkerman, R., Bloemhof, J.M., 2019. Donation management for menu planning at soup kitchens. Eur. J. Oper. Res. 272 (1), 324–338.
Capodistrias, P., Szulecka, J., Corciolani, M., Strøm-Andersen, N., 2022. European food banks and COVID-19: resilience and innovation in times of crisis. Soc. Econ. Plann. Sci. 82, 101187.
Coleman-Jensen, A., Rabbitt, M.P., Gregory, C.A., Singh, A., 2021. *Household Food Security In the United States in 2020*, ERR-298. U.S. Department of Agriculture, Economic Research Service.
Dalal, J., 2022. Food donation management under supply and demand uncertainties in COVID-19: a robust optimization approach. Soc. Econ. Plann. Sci. 82, 101210.
Davis, L.B., Sengul Orgut, I., Ivy, J.S., Brock, L.G., Miles, L., 2014. Scheduling food bank collections and deliveries to ensure food safety and improve access. Soc. Econ. Plann. Sci. 48 (3), 175–188.
Davis, L.B., Jiang, S.X., Morgan, S.D., Nuamah, I.A., Terry, J.R., 2016. Analysis and prediction of food donation behavior for a domestic hunger relief organization. Int. J. Prod. Econ. 182, 26–37.
Day, J.M., Melnyk, S.A., Larson, P.D., Davis, E.W., Whybark, D.C., 2012. Humanitarian and disaster relief supply chains: a matter of life and death. J. Supply Chain Manag. 48 (2), 21–36.
Dowler, E., Lambie-Mumford, H., 2014. Food aid: living with food insecurity, working papers of the communities & culture Network+, 3. Available at: www.communitiesandculture.org/files/2013/01/Living-with-Food-Insecurity-CCN-Report.pdf.
Eisenhandler, O., Tzur, M., 2019a. The humanitarian pickup and distribution problem. Oper. Res. 67 (1), 10–32.
Eisenhandler, O., Tzur, M., 2019b. A segment-based formulation and a matheuristic for the humanitarian pickup and distribution problem. Transport. Sci. 53 (5), 1389–1408.
Eisenhardt, K.M., 2021. What is the Eisenhardt Method, really? Strat. Organ. 19 (1), 147–160.
Eriksson, M., Spångberg, J., 2017. Carbon footprint and energy use of food waste management options for fresh fruit and vegetables from supermarkets. Waste Manag. 60, 786–799.
EU Platform on Food Losses and Food Waste, 2019. Redistribution of surplus food: examples of practices in the member states. Research Report, EU Platform on Food Losses and Food Waste.
Eurostat, 2021a. Living Conditions in Europe - Poverty and Social Exclusion - Statistics Explained. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Living_conditions_in_Europe_-_poverty_and_social_exclusion#Key_findings.
Eurostat, 2021b. Inability to afford a meal with meat, chicken, fish (or vegetarian equivalent) every second day by level of activity limitation, sex and age. https://ec.europa.eu/eurostat/databrowser/view/HLTH_DM030_custom_2280495/default/table?lang=en.
FareShare, 2021. Our History. Retrieved June 11, 2021, from. https://fareshare.org.uk/what-we-do/our-history/.
FEBA, 2021. Annual Report 2020. European Food Banks Federation, Brussels, Belgium.
FEBA, 2022a. Activities of our members. Available at: https://www.eurofoodbank.org/activities-of-our-members/.
FEBA, 2022b. Assessment of FEBA Member Activities: July 2021 to June 2022. European Food Banks Federation, Brussels, Belgium.
Fianu, S., Davis, L.B., 2018. A Markov decision process model for equitable distribution of supplies under uncertainty. Eur. J. Oper. Res. 264 (3), 1101–1115.
Ghoniem, A., Scherrer, C.R., Solak, S., 2013. A specialized column generation approach for a vehicle routing problem with demand allocation. J. Oper. Res. Soc. 64 (1), 114–124.
Ghorpade, T., Corlu, C.G., 2022. A simheuristic algorithm for the stochastic one-commodity pickup and delivery travelling salesman problem. J. Simulat. (in press).
Gómez-Pantoja, J.Á., Salazar-Aguilar, M.A., González-Velarde, J.L., 2021. The food bank resource allocation problem. Top 29, 266–286.
González-Torre, P.L., Coque, J., 2016. How is a food bank managed? Different profiles in Spain. Agric. Hum. Val. 33 (1), 89–100.
Harland, C., 2021. Discontinuous wefts: weaving a more interconnected supply chain management tapestry. J. Supply Chain Manag. 57 (1), 27–40.
Hasnain, T., Sengul Orgut, I., Ivy, J.S., 2021. Elicitation of preference among multiple criteria in food distribution by food banks. Prod. Oper. Manag. 30 (12), 4475–4500.
Holguín-Veras, J., Jaller, M., Van Wassenhove, L.N., Pérez, N., Wachtendorf, T., 2012. On the unique features of post-disaster humanitarian logistics. J. Oper. Manag. 30 (7–8), 494–506.
Islam, M.H., Ivy, J.S., 2022. Modeling the role of efficiency for the equitable and effective distribution of donated food. Spectrum 44, 485–534.
Jessri, M., Abedi, A., Wong, A., Eslamian, G., 2014. Nutritional quality and price of food hampers distributed by a campus food bank: a Canadian experience. J. Health Popul. Nutr. 32 (2), 287–300.
Kaviyani-Charati, M., Ameli, M., Souraki, F.H., Jabbarzadeh, A., 2022. Sustainable network design for a non-profit food bank supply chain with a heterogeneous fleet under uncertainty. Comput. Ind. Eng. 171, 108442.
Kinach, L., Parizeau, K., Fraser, E.D.G., 2020. Do food donation tax credits for farmers address food loss/waste and food insecurity? A case study from Ontario. Agric. Hum. Val. 37 (2), 383–396.
Lee, D., Sönmez, E., Gómez, M.I., Fan, X., 2017. Combining two wrongs to make two rights: mitigating food insecurity and food waste through gleaning operations. Food Pol. 68, 40–52.
Lien, R.W., Iravani, S.M.R., Smilowitz, K.R., 2014. Sequential resource allocation for nonprofit operations. Oper. Res. 62 (2), 301–317.
Martins, C.L., Melo, M.T., Pato, M.V., 2019. Redesigning a food bank supply chain network in a triple bottom line context. Int. J. Prod. Econ. 214, 234–247.
Midgley, J.L., 2014. The logics of surplus food redistribution. J. Environ. Plann. Manag. 57 (12), 1872–1892.
Mittal, A., Gibson, N.O., Krejci, C.C., Marusak, A.A., 2021. Crowd-shipping for urban food rescue logistics. Int. J. Phys. Distrib. Logist. Manag. 51 (5), 486–507.
Mohan, S., Gopalakrishnan, M., Mizzi, P.J., 2013. Improving the efficiency of a non-profit supply chain for the food insecure. Int. J. Prod. Econ. 143 (2), 248–255.
Moshtari, M., Vanpoucke, E., 2021. Building successful NGO–business relationships: a social capital perspective. J. Supply Chain Manag. 57 (3), 104–129.
Mousa, T.Y., Freeland-Graves, J.H., 2017. Organizations of food redistribution and rescue. Publ. Health 152, 117–122.
Nair, D.J., Grzybowska, H., Rey, D., Dixit, V., 2016. Food rescue and delivery: heuristic algorithm for periodic unpaired pickup and delivery vehicle routing problem. Transport. Res. Rec. 2548, 81–89.
Nair, D.J., Rashidi, T.H., Dixit, V.V., 2017. Estimating surplus food supply for food rescue and delivery operations. Soc. Econ. Plann. Sci. 57, 73–83.
Neter, J.E., Dijkstra, S.C., Visser, M., Brouwer, I.A., 2016. Dutch food bank parcels do not meet nutritional guidelines for a healthy diet. Br. J. Nutr. 116 (3), 526–533.
Ortuño, J.C., Padilla, A.G., 2017. Assembly of customized food pantries in a food bank by fuzzy optimization. J. Ind. Eng. Manag. 10 (4), 663–686.
Ouyang, R., Beacher, M.R., Ma, D., Noor-E-Alam, M., 2020. Navigating concave regions in continuous facility location problems. Comput. Ind. Eng. 143, 106385.
Paul, S., Davis, L.B., 2022. An ensemble forecasting model for predicting contribution of food donors based on supply behavior. Ann. Oper. Res. 319, 1301–1329.
Phillips, C., Hoenigman, R., Higbee, B., Reed, T., 2013. Understanding the sustainability of retail food recovery. PLoS One 8 (10), e75530.
Polman, M., 2021. 4 x sociale supermarkten in Nederland [Four times social supermarkets in The Netherlands]. Food Inspiration. May 5, 2021. Available at: https://www.foodinspiration.com/nl/4x-sociale-supermarkten-in-nederland/.
Reihaneh, M., Ghoniem, A., 2018. A multi-start optimization-based heuristic for a food bank distribution problem. J. Oper. Res. Soc. 69 (5), 691–706.
Rey, D., Almi'ani, K., Nair, D.J., 2018. Exact and heuristic algorithms for finding envy-free allocations in food rescue pickup and delivery logistics. Transport. Res. E Logist. Transport. Rev. 112, 19–46.
Rombach, M., Kang, E., Bitsch, V., 2018. Good deeds revisited: motivation and boundary spanning in formal volunteering. International Review on Public and Nonprofit Marketing 15, 105–126.
Rong, A., Akkerman, R., Grunow, M., 2011. An optimization approach for managing fresh food quality throughout the supply chain. Int. J. Prod. Econ. 131 (1), 421–429.
Sawaya III, W.J., Pathak, S., Day, J.M., Kristal, M.M., 2015. Sensing abnormal resource flow using adaptive limit process charts in a complex supply network. Decis. Sci. J. 46 (5), 961–979.
Sengul Orgut, I., Ivy, J.S., Uzsoy, R., Wilson, J.R., 2016. Modeling for the equitable and effective distribution of donated food under capacity constraints. IIE Trans. 48 (3), 252–266.
Sengul Orgut, I., Ivy, J.S., Uzsoy, R., 2017. Modeling for the equitable and effective distribution of food donations under stochastic receiving capacities. IISE Transactions 49 (6), 567–578.
Sengul Orgut, I., Ivy, J.S., Uzsoy, R., Hale, C., 2018. Robust optimization approaches for the equitable and effective distribution of donated food. Eur. J. Oper. Res. 269 (2), 516–531.
Solak, S., Scherrer, C., Ghoniem, A., 2014. The stop-and-drop problem in nonprofit food distribution networks. Ann. Oper. Res. 221 (1), 407–426.
Sönmez, E., Lee, D., Gómez, M.I., Fan, X., 2016. Improving food bank gleaning operations: an application in New York state. Am. J. Agric. Econ. 98 (2), 549–563.
Stauffer, J.M., Vanajakumari, M., Kumar, S., Mangapora, T., 2022. Achieving equitable food security: how can food bank mobile pantries fill this humanitarian need. Prod. Oper. Manag. 31 (4), 1802–1821.
Sucharitha, R.S., Lee, S., 2022. GMM Clustering for in-depth food accessibility pattern exploration and prediction model of food demand behavior. Soc. Econ. Plann. Sci. 83, 101351.
Tafel Deutschland, 2021a. Tafel Deutschland – Zahlen & Fakten *[Facts and figures]* (version May 3, 2021). Available at: https://www.tafel.de/presse/zahlen-fakten/.

Tafel Deutschland, 2021b. Tafel macht Zukunft – gemeinsam digital [Tafel creates the future – digital together]. Available at: https://www.tafel.de/projekte/tafel-macht-zukunft-gemeinsam-digital/.
The Trussel Trust, 2021. Our story. Available at: https://www.trusselltrust.org/about/our-story/.
Voedselbanken Nederland, 2020. Annual report 2020. Available at: https://voedselbankennederland.nl/wat-we-doen/beleid-en-jaarverslagen/.
Wetherill, M.S., White, K.C., Seligman, H.K., 2019. Nutrition-focused food banking in the United States: a qualitative study of healthy food distribution initiatives. J. Acad. Nutr. Diet. 119 (10), 1653–1665.
Yin, R.K., 2018. Case Study Research and Applications: Design and Methods, sixth ed. Sage Publications, Los Angeles.