Chapter 2: Literature review

2.1. Introduction

The previous chapter provides detailed introduction on the food banks and its associated concepts. The past decade has witnessed an increasing interest towards the multifaceted research on the phenomenon of the food banks. In addition, it has gained wide-attention attention on the decision-making process at specific levels exploiting the decision-support model. These decision support models can be classified into three categories- *strategic* decisions such as facility location-allocation problem (Ghahremani-Nahr et al., 2023; Kaviyani-Charati et al., 2022; C. L. Martins et al., 2019b), *tactical* decisions such as resource allocation problem (Orgut et al., 2017) and *operational* decisions such as VRP (Amiri et al., 2023; Mahmoudi et al., 2022). Food banks have been studied diversely on various research dimensions such as food insecurity, food recovery, food aid and donation, policy and behavioral studies, health and nutrition and uncertainty in supply and demand. The different research dimension of food banks is shown in Figure 2.1.

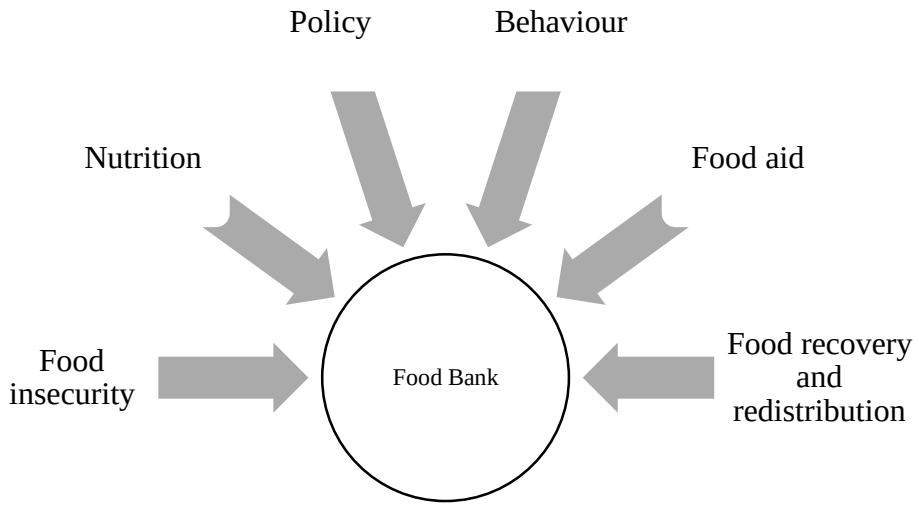

Figure 2.1: Various research dimensions for study of food banks

Food banks have started gaining significant attention in those multi-dimensional research areas from the past decade. We have explored Scopus database with key words such as “foodbanks”, “food aid”, “food donation”, “food redistribution” to validate the assertion. We have generated network map using the VOSviewer software and is presented in Figure 2.2. It shows that it’s a matter of past decade most of the studies pertain to food banks have initiated.

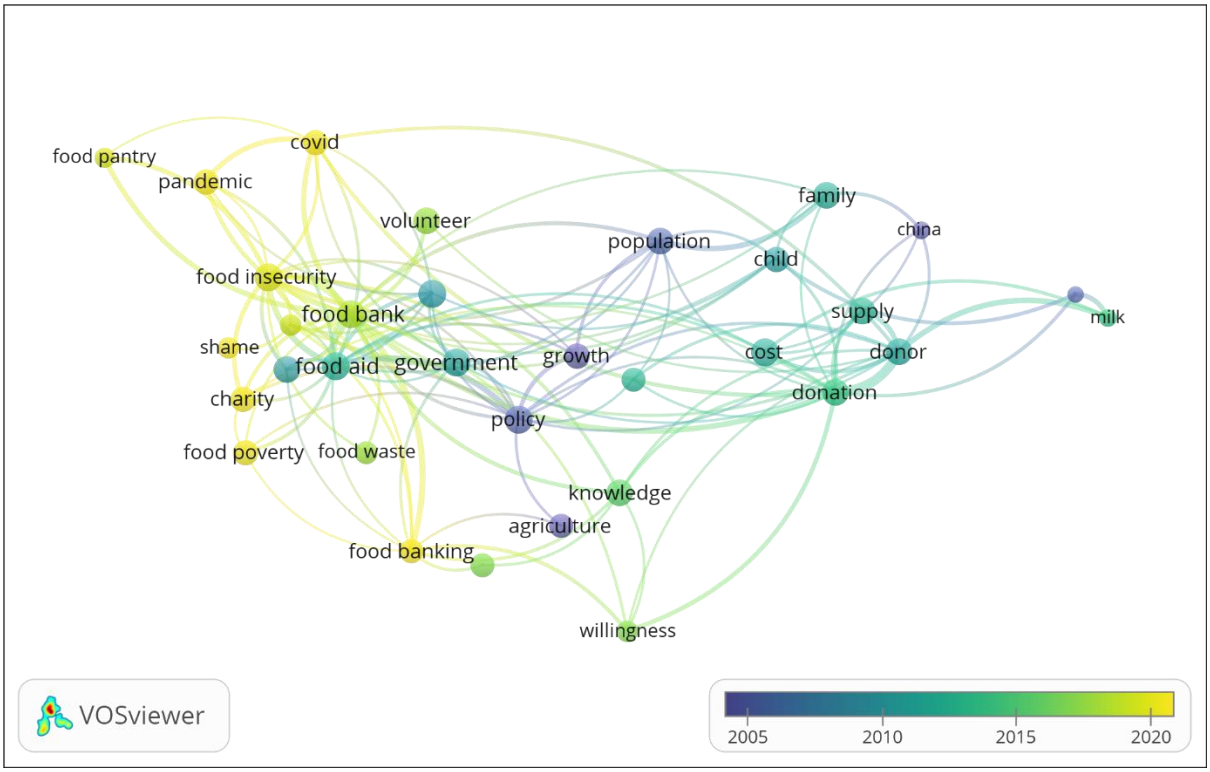

Figure 2.2: Food banks and its associated timeframe in literature

Despite growing body of literature on food banks and increased momentum among research and practitioners, there is a dearth of contributions from developing countries such as India in the literature related to food banks. The challenges associated with the less penetrated and disorganized food banks operating in the developing countries are yet to be addressed in the literature. There could be various research dimensions that food banks and its operations could be explored as shown in Figure 2.1. Apart from that there are other research dimensions liked

with social factors. In this literature review, we endeavor the literature pertaining but not limited to the nodes given in Figure 2.2.

Our observation reveals that the majority of existing studies centered around food banks tend to constrain their scope to address specific challenges or issues (Millar et al., 2020). For instance, Hermsdorf et al. (2017) considered only legal, infrastructure and human resources as barriers for food redistribution units. While such focused investigations are undoubtedly valuable in endeavoring specific aspects of food bank operations, they may not fully capture the intricate interactions, challenges and interdependencies within and outside the broader operational context. All the challenges or barriers associated with growth of a food bank are hardly ever encapsulated in a single work. Motivated from these two aspects, we undertake the present work that aims to identify barriers to the adoption and growth of food banks in India through the extant literature and expert opinions. Our approach seeks to transcend these limitations by adopting a holistic perspective, encompassing multifaceted considerations and presenting all the challenges and its impact on the food banks growth.

2.2.Barriers

The literature pertaining to food banks is characterized by its diversity, spanning various domains such as socio-economic aspects (Davis et al., 2014), food insecurity (Bazerghi et al., 2016), food bank operations (Brock & Davis, 2015) and nutrition studies (Millar et al., 2020). Navigating through this extensive and fragmented landscape poses the challenge of systematically identifying studies that comprehensively address the several issues and challenges associated with food banks. To meet this challenge, a systematic literature review was conducted, leveraging popular databases including Google Scholar, Scopus, ProQuest, ScienceDirect, and Web of Science. The search utilized keywords such as "food bank," "food

donation," "food recovery," "food redistribution," and "food insecurity." Furthermore, the review exclusively considered papers published in the English language to ensure consistency and comprehensiveness. Through this systematic search, we have procured a total of 58 research articles that specifically delve into the various challenges associated with food banks. These challenges have been systematically categorized into seven distinct groups, as illustrated in Figure 2.3. Subsequent paragraphs present a detailed description on these challenges

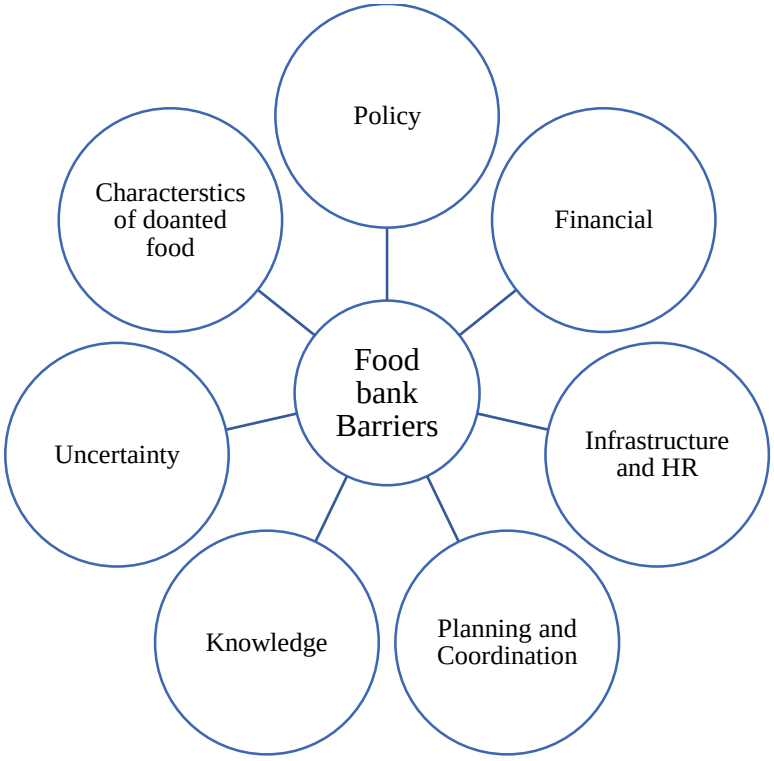

Figure 2.3: Various research dimension for barriers of food banks

Legal policies play a pivotal role in establishing the standardized operational guidelines for food banks (Parfitt et al., 2010). Nevertheless, multiple authors have highlighted the significant obstruction posed by the absence of a comprehensive legal framework for the collection and redistribution of surplus food items (De Pieri et al., 2017; Hermsdorf et al., 2017). The necessity for legislative measures to effectively manage surplus food is highlighted in the work of Parfitt et al. (2010). Midgley (2014) further advocates the need for policymakers to establish

a clear delineation for the optimal utilization of surplus food in the form of community resource. Santini and Cavicchi (2014) assert the pivotal role of policies in the operational efficacy of food banks. Facchini et al. (2018) emphasized that government policies can strengthen food banks by fostering institutionalization and incentivizing donations. Vlaholias et al. (2015) call for increased attention to food banks by both practitioners and policymakers. De Boeck et al. (2017) identified the bottlenecks of food donation that aligns with legal structures and food safety management. Consequently, we identify the *'low penetration of policies and regulation*s' as a challenge hampering the growth and adoption of food banks.

The operational sustainability of food banks and its functioning pivots on securing funding, labor, surplus food, and a diverse array of resources (Lindberg et al., 2014). Foremost among the challenges faced is the acute shortage of adequate funds crucial for supporting the functionality and expansion of food banks (Hecht & Neff, 2019; Mousa & Freeland-Graves, 2017; V. Tarasuk & Eakin, 2005; Vander Vennen, 2020). Specific works have extensively addressed the topic of financial assistance to food banks, food recovery and redistribution (Adivar et al., 2010; Davis et al., 2016; V. Tarasuk & Eakin, 2005). Frasz et al. (2015) highlighted the scarcity of funding as a significant barrier encountered by food rescue organizations, highlighting the lack of financial support as a major challenge. Adivar et al. (2010) highlighted the necessity of governmental financial support for the sustained operation of food banks. The recurring issue of a financial crunch has been consistently reported as a persistent challenge confronting food banks (Wingrove et al., 2017). Therefore, we have included ‘limited financial support’ as one of the barriers of food banks in this study.

The barrier of *'lack of infrastructure and human resources*' poses a significant operational challenge for food banks on a day-to-day basis (Kinach et al., 2020). At the core of food bank

operations lies the essential tasks of collecting and distributing food to individuals in need (Eisenhandler & Tzur, 2019a; Nair, Rashidi, et al., 2017), demanding ample resources, well-established infrastructure, and a skilled workforce. The scarcity of these essential elements acts as a formidable obstacle for food banks (Gharehyakheh & Sadeghiamirshahidi, 2018; F. Schneider, 2013a; Thyberg & Tonjes, 2016). Notably, Hermsdorf et al. (2017) highlighted that limited storage and logistical support present considerable barriers to the collection and redistribution of surplus food items, emphasizing the heightened reliance of food banks on volunteer assistance. The constrained availability of donated food and strict time windows allocated for collection/redistribution have been focal points for several researchers (Eisenhandler & Tzur, 2019b; Nair, Rey, et al., 2017). Numerous studies have identified the limited logistics support as a pivotal barrier to the effective operations of food banks (Hecht & Neff, 2019; C. L. Martins et al., 2019a; Vander Vennen, 2020; Walia & Sanders, 2019).

Holweg et al. (2010) assert that retailers often avoid redistribution due to a lack of logistics and concerns about additional costs. Tsang et al. (2011) and Bierma et al. (2019) further identify the absence of transportation facilities as a major challenge for food banks. Grace et al. (2007) emphasizes that the inadequate collection and distribution facilities represent a significant hurdle to effective food redistribution. Similarly, Millar et al. (2020) highlights the lack of infrastructure, including storage (both dry and cold) and transportation resources, as a substantial challenge in managing food donations, aligning with the findings of Campbell et al. (2013) and Gooch et al. (2019) concerning the storage, transportation, and utilities needs of food banks. In addition to infrastructure shortcomings, the insufficient availability of manpower stands out as one of the most prominent challenges faced by food banks (Hecht & Neff, 2019; Mousa & Freeland-Graves, 2017; Vander Vennen, 2020). Limited availability of

manpower also contributes to the issue of high dependence on volunteers (Hermsdorf et al., 2017). These humanitarian organizations heavily rely on their volunteer chain for day-to-day operations, encompassing both collection and distribution drives performed by food banks, which may not be as efficient and effective as the dedicated employees of the food banks.

The other challenge originated during the comprehensive literature review is the *'lack of planning and coordination*' within food banks (Brock & Davis, 2015; Facchini et al., 2018; Lee et al., 2017; C. L. Martins et al., 2019a). Planning encompasses various activities such as scheduling collection and distribution drives of food items (Eisenhandler & Tzur, 2019b; Gunes et al., 2010; Lien et al., 2014; Nair et al., 2018; Nair, Rey, et al., 2017), setting annual targets (Phillips et al., 2011), conducting awareness programs through regional campaigns and nationwide awareness efforts (Riches, 2002), accurate forecasting of supply donations (Davis et al., 2016; Gharehyakheh & Sadeghiamirshahidi, 2018; C. L. Martins et al., 2019a; Nuamah et al., 2015; Paul & Davis, 2019; Pugh & Davis, 2017), record-keeping (Feingold et al., 2019), logistic planning (Caraher & Cavicchi, 2014) human resources planning, collaboration with regional food banks and food industries (Mousa & Freeland-Graves, 2017), reducing the impact of uncertainty (Brock & Davis, 2012), and establishing Decision Support Systems (DSS) to assist personnel and volunteers in day-to-day operations (Esparza, 2019). Coordination among food banks involves sharing information and resources, working together to achieve common goals (De Pieri et al., 2017; Facchini et al., 2018; Forcada et al., 2017; Hecht & Neff, 2019; Mousa & Freeland-Graves, 2017; Thyberg & Tonjes, 2016). The absence of planning and coordination leads to poor performance and hinders the smooth operations of food banks.

The challenge related to knowledge is the 'lack of awareness,' leading to missed opportunities for services from potential volunteers and dedicated employees, while also limiting the outreach of food banks to those in need (Lindberg et al., 2014; Mittal et al., 2019; Riches, 2002). Nationwide awareness is crucial for food banks to attract donations from businesses, industries, and corporations, ultimately fulfilling the demand of individuals in need (Frasz et al., 2015).

On the demand side, there exists a notable variation in the number of individuals seeking assistance from food banks, both across different geographical areas and over time (Gharehyakheh & Sadeghiamirshahidi, 2018; Seligman et al., 2015; V. Tarasuk & Eakin, 2005). Numerous studies assert that the demand for food consistently exceeds the available donated supply (Tarasuk & Beaton, 1999; Wilson & Tsoa, 2002). Martins et al. (2019a) highlight that food banks struggle to meet demand due to insufficient donations. Similar to the pattern of demand side, uncertainties are associated with the supply side of food banks. The literature documented around that suggests the challenge of uncertainty in donations for food banks (Brock & Davis, 2012, 2015; Davis et al., 2016; Millar et al., 2020; Nair, Rashidi, et al., 2017). Alkaabneh et al. (2021) emphasize the inherent difficulty in accurately predicting donations for food banks. High variations in the supply of donated food, including quantity, frequency, and timing of donations, have been addressed in the works of Nair, Rashidi, et al. (2017), and Brock and Davis (2015). Such uncertainty in both supply and demand for donated food significantly impacts the planning and overall performance of food banks (Okore-Hanson et al., 2012).

Other challenges identified in the literature include perishability and the limited shelf life of donated food (Buzby et al., 2014; Caraher & Cavicchi, 2014; Eisenhandler & Tzur, 2019a;

Kinach et al., 2020; Thyberg & Tonjes, 2016; Walia & Sanders, 2019). The low nutritional value of donated food was addressed (Irwin et al., 2007), and it is a widespread concern among food banks worldwide (Alkaabneh et al., 2021; Bazerghi et al., 2016; Mourad, 2016; Simmet et al., 2017; V. Tarasuk & Eakin, 2003; Warshawsky, 2015; Wingrove et al., 2017). Food banks are primarily concerned with these characteristics of donated food. Table 2.1 shows the identified barriers to the acceptance, growth and expansion of food banks.

Table 2.1: Identified Barriers for adoption and growth of food banks in India

Sr. No.	Main Barrier Criteria	Sub-barrier criteria	References
1.	Policy	Low penetration of policies & regulations for donation	De Boeck et al. (2017); De Pieri et al.(2017); Facchini et al. (2018); Hermsdorf et al. (2017); Midgley (2014); Parfitt et al. (2010); Santini and Cavicchi (2014)
2	Financial	Limited funds /commodities raised from the donation	Davis et al. (2016); Hecht and Neff (2019); Lindberg et al. (2014); Mousa and Freeland-Graves (2017); Tarasuk and Eakin (2005); Vander Vennen (2020)
3		Limited financial support from the government	Adivar et al. (2010); Frasz et al. (2015); Tarasuk and Eakin (2005); Wingrove et al. (2017)
4	Infrastructure and Human resources	Lack of storage	Campbell et al. (2013); Gooch et al. (2019); Hecht and Neff (2019); Hermsdorf et al. (2017); Holweg et al. (2010); Kinach et al. (2020); Martins et al. (2016); Millar et al. (2020); Vander Vennen (2020)
5		Lack of transportation facilities	Bierma et al. (2019); Campbell et al. (2013); Eisenhandler & Tzur (2019a); Gooch et al. (2019); Hecht and Neff (2019); Hermsdorf et al. (2017); Holweg et al. (2010); Kinach et al. (2020); Martins et al. (2016); Millar et al. (2020); Nair, Rey, et al. (2017); Tsang et al. (2011); Vander Vennen (2020); Walia and Sanders (2019)
6		Lack of collection and distribution facilities, handling & operations	Millar *et al.* (2020), Vander Vennen (2020), Gooch *et al.* (2019), Eisenhandler and Tzur, (2019b), Hecht and Neff, (2019), Walia and Sanders, 2019, Kinach *et al.*,

Sr. No.	Main Barrier Criteria	Sub-barrier criteria	References
			2019), Hermsdorf *et al.* (2017), Nair *et al*. (2017), Martins *et al*. (2016), Campbell *et al.* (2013), Holweg *et al*. (2010)
7		Lack of manpower	Vander Vennen, (2020), Hecht and Neff (2019), Gharehyakheh and Sadeghiamirshahidi (2018), Hermsdorf *et al.* (2017), Mousa and Freeland-Graves (2017), Thyberg and Tonjes (2016), Schneider (2013)
8	Planning & Coordination	Lack of strategic/tactical level planning & Decision Support System (DSS)	Martins *et* al., (2019), Paul and Davis (2019), Eisenhandler and Tzur (2019b), Facchini *et al*. (2018), Nair *et al*. (2018), Lee *et al*. (2017), Mousa and Freeland-Graves (2017), Nair *et al*. (2017), Pugh and Davis (2017), Davis *et al*. (2016), Brock III and Davis (2015), Nuamah *et al*. (2015), Davis *et al*. (2014), Lien *et al*. (2014), Brock III and Davis (2012), Gunes *et al*. (2010),
9		Lack of coordination among food banks	Facchini *et al*. (2018), Mousa and Freeland-Graves (2017), Forcada *et al.* (2017), De Pieri *et al*. (2017), Hecht and Neff (2017), Thyberg and Tonjes (2016)
10	Knowledge	Lack of awareness about food bank	Mittal *et al*., (2019), Frasz *et al*. (2015), Lindberg *et al*., (2014), Riches (2002)
11	Uncertainty	Uncertainty in demand	Okore-Hanson *et al*. (2012), Martins *et al*., (2019), Gharehyakheh and Sadeghiamirshahidi (2018), Seligman *et al.* (2015), Tarasuk and Eakin (2005), Wilson and Tsoa (2002), Tarasuk and Beaton (1999)
12	Characteristics of donated food	Low nutritional value in donated food	Alkaabneh *et al*. (2021), Millar *et al.* (2020), Wingrove *et al*. (2017), Simmet *et al*. (2016), Mourad (2016), Bazerghi *et al*. (2016), Warshawsky (2015), Tarasuk and Eakin (2003), Irwin *et al.* (2007)
13		Perishability and limited shelf life of food items	Eisenhandler and Tzur (2019), Walia *et al*. (2019), Kinach *et al*. (2019), Thyberg and Tonjes (2016), Buzby *et al*. (2014), Caraher and Cavicchi (2014)
14		Uncertainty in supply	Alkaabneh *et al*. (2021), Millar *et al.* (2020), Martins *et al*. (2019), Gharehyakheh and Sadeghiamirshahidi (2018), Nair *et al.* (2017), Davis *et al*., (2016), Brock III and Davis (2015), Brock III and Davis (2012)

2.3. MDVRP

2.3.1. Single Objective

The inception of routing models for food rescue and delivery can be traced back to the literature on the 'meals on wheels' program, as documented by Bartholdi et al. (1983). This initial exploration was later extended by Wong and Meyer, (1993) and Gorr et al. (2001), who incorporated geographic information systems to evaluate its efficiency. A comprehensive review of variant types of the Vehicle Routing Problem (VRP) is presented in the literature with a specific focus on the collection of donations (Gutiérrez-Sánchez & Rocha-Medina, 2022). Operational decisions comprehend effective transportation schedules for daily operations, the number of vehicles needed for the collection and distribution of donated food which all come under the purview of VRP.

Within the realm of food bank operations, the VRP with Demand Allocation Problem (VRDAP) emerges as a popular variant. In VRDAP, delivery points are initially selected, and efficient routes are subsequently developed to minimize the total transportation cost for both food banks (donors) and charitable agencies (distribution partners) (Ghoniem et al., 2013). A similar methodology is adopted in the work of Davis et al. (2014), where food delivery points are determined using the capacitated set covering problem, and delivery routes for each day are later developed using the VRP with backhauls. Solak et al. (2014) propose VRDAP as a variant of the location routing problem, modeling it as a stop and drop routing problem. Rancourt et al. (2015) specifically address facility location planning decisions for food banks in Kenya. Building upon the foundational work of Ghoniem et al. (2013), Reihaneh and

Ghoniem (2018) extended their contributions by introducing a multi-start heuristic. This strategic enhancement aimed to disentangle the interdependencies inherent in routing and assignment decisions within the VRDAP problems. Notably, these studies highlight the significance of first determining the optimal locations for delivery points before formulating efficient routes to visit these points. A recurring theme in the aforementioned studies is the operational requirement for charitable agencies, responsible for distributing the food to beneficiaries, to physically visit the selected delivery points. These designated points serve as hubs for receiving donations from food banks, which, in turn, maintain stocks of food contributed by individual or institutional donors.

The Pickup and Delivery variant (PDP) of the Vehicle Routing Problem (VRP), contextualized within the framework of food banks, was initially introduced by Gunes et al. (2010) for a single commodity. Subsequently, Nair et al. (2016, 2018) proposed a scheduling and routing model for the food rescue and distribution problem, formulating it as a periodic unpaired Pickup and Delivery VRP spanning a planning horizon of seven days. They employed the Tabu search meta-heuristic for its solution. Eisenhandler & Tzur (2019a) integrated the Pickup and Delivery problem with effective and equitable distribution to charitable agencies, addressing it using both an exact method and a variable neighborhood search heuristic. Extending their efforts, Eisenhandler and Tzur (2019b) introduced a segment-based metaheuristic tailored to solving the same problem, considering multiple vehicles and time windows. Gasque and Munari (2022) contributed to the field by proposing a mixed-integer linear programming model for the multi-commodity Pickup and Delivery variant of VRP, incorporating a heterogeneous fleet of vehicles and time windows. Their work focused on a paired pickup and delivery variant, where each customer is paired with a corresponding

delivery customer. In contrast, the present study explores the unpaired Pickup and Delivery variant within the context of a multi-depot VRP.

In addition to these two categories of problems, some studies focus on specific attributes, such as time windows and equitable distribution (Cheng et al., 2021). Li (2015) and Arenas et al. (2017) introduced a Vehicle Routing Problem (VRP) with time windows to address the pickup or collection of donations for food banks. Subsequently, Schneider and Nurre (2019) incorporated the concept of multiple time windows (TW) into the VRP model, specifically for on-site audits conducted by charitable agencies serviced by food banks. Efforts have also been directed towards enhancing vehicle utilization, reducing transportation costs, and conducting service gap analyses. Alhindi et al. (2020) emphasized the advantages of improved vehicle utilization by allowing multiple pickup points in the same route for collecting surplus food in the VRP model. Chen et al. (2016) performed service gap analysis, optimizing routes for trucks engaged in the collection and distribution of donated food to charitable agencies within the Foodbank Inc. program. Furthermore, discussions on fair allocation of demands to charitable agencies have been presented in the works (Nair, Rey, et al., 2017). (2017) and (Rey et al., 2018). It is noteworthy that the consideration of VRP with simultaneous pickup and delivery is beyond the scope of this literature review, as our problem context does not involve nodes with both pickup and delivery requests concurrently (Wang et al., 2013).

A summary of contributions pertaining to the utilization of Vehicle Routing Problem (VRP) in the domain of food banks is presented in the second column of Table 2.2. Subsequently, additional columns provide details on the specific problem settings, characteristics of objective functions, decisions related to vehicle hiring, solution methodologies, descriptions of case

studies, and the instance sizes employed, forming a comprehensive overview of the amalgamated literature on VRP and food banks.

Table 2.2: Detailed description of problem setting for VRP and food banks literature

References	VRP variant	Type of food distribution	Application side of routing	Type of fleet	Solution Approach	Objective type	Beneficiary	Hiring decision	Case study	Instances	Network size
Bartholdi (1983)	VRP	Front-end	Distribution	Homogenous	Heuristics	Single	End customer	No	Connecticut, MOW	Case study	200
Gunes et al. (2010)	PDP	Front-end	Distribution	Homogenous	ILOG solver	Single	End customer	No	Pittsburgh FB	Case study	130
Ghoniem et al. (2013)	VRPDAP	Back-end	Distribution	Homogenous	Heuristic using AMPL & CPLEX solver	Single	End customer & Charitable Agencies	No	South-eastern US	Randomly generated dataset	60
Davis et al. (2014)	VRPDAP	Back-end	Collection & distribution	Homogenous	GAMS/ CPLEX	Single	Charitable agencies	Yes	Second Harvest Food bank, North Carolina	Case study	151
Li (2015)	VRPTW	Back-end	Distribution	Homogenous	Meta-Heuristics (ACO)	Single	Charitable agencies	No	St. Mary's food bank, Arizona	Case study	--
Solak et al. (2014)	VRPDAP	Back-end	Distribution	Homogenous	Exact (Bender's decomposition)	Single	Charitable agencies	No	South-Eastern US	Case study	75
Arenas et al. (2017)	VRPTW	Back-end	Collection	Homogenous	GNU solver	Single	Donors	No	The Archdiocesan Food Bank, Bogotá	Case study	20
Reihaneh & Ghoniem (2017)	VRPDAP	Back-end	Distribution	Homogenous	Heuristic using CPLEX solver	Single	Charitable agencies	No	South-eastern US	Randomly generated dataset	100
Nair et al. (2017)	VRPDAP	Back-end	Collection & distribution	Homogenous	Goal programming Heuristic	Bi-objective	Charitable agencies	No	OzHarvest, Australia	Case study	200
Nair et al. (2018)	PDP	Back-end	Collection & distribution	Homogenous	Meta-heuristic (Tabu search)	Single	Charitable agencies	No	OzHarvest, Australia	Case study and small size benchmark instance	C-334 B-25

References	VRP variant	Type of food distribution	Application side of routing	Type of fleet	Solution Approach	Objective type	Beneficiary	Hiring decision	Case study	Instances	Network size
Rey et al. (2018)	VRPDAP	Back-end	Collection & distribution	Homogenous	Exact-Bender's decomposition Heuristic-greedy & local search using	Single	Charitable agencies	No	OzHarvest, Australia	Randomly generated	--
Eisenhandler & Tzur (2019a)	VRPDAP with TW	Front-end	Collection & distribution	Homogenous	Exact-Heuristic-CPLEX Large neighbourhood search-Python	Single	Charitable agencies	No	Israeli FB & Houston FB	Case study & randomly generated dataset	C1-67 C2-22 D-100
Eisenhandler & Tzur (2019b)	VRPDAP with TW	Front-end	Collection & distribution	Homogenous	Metaheuristic	Single	Charitable agencies	No	Israeli FB & Houston FB	Case study & randomly generated dataset	100
Schneider & Nurre (2019)	VRPTW	Back-end	Audit schedule	Homogenous	Exact & heuristic	Multi-objective (weighted sum)	Charitable agencies	Yes	Foodbank Inc., Dayton	Case study	101
Alhindi et al. (2020)	VRP	front-end	Collection	Homogenous	Simulation	Single	Donors	No	Ekram, Saudi Arabia	Case study	20
This work	**MD-VRP-TW-SP-SD**	**Front-end**	**Collection & distribution**	**Heterogeneous**	**Metaheuristic -GA Solver-GUROBI**	**single**	**End customers**	**Yes**	**Robin Hood Army, India**	**Benchmark and Case study**	**B-266 C-54**

ACO-Ant Colony Optimization; PSO- Particle Swarm Optimisation; C-Number of nodes in case study B-Number of nodes in benchmark dataset; R-Number of nodes in randomly generated dataset; C1- Number of nodes in Israeli food bank, C2- Number of nodes in Houston food bank, FB- Food bank, MOW- Meals on Wheel program

Nevertheless, certain practical complexities such as the division of pick-up and delivery loads and the consideration of multiple depots have yet to be addressed in the realm of routing models for food banks. Research has demonstrated that the splitting of delivery loads in Vehicle Routing Problems (VRP) significantly reduces transportation costs under specific conditions (Archetti et al., 2011; Lei et al., 2020; Nowak et al., 2008). Recent contributions have underscored the importance of split pickup and split delivery (Gasque & Munari, 2022). Additionally, Wolfinger (2021) introduced a large neighborhood search for the pickup-delivery problem with time windows and split loads. The incorporation of multiple depots into VRP has been explored by various authors (Montoya-Torres et al., 2015; Renaud et al., 1996; Wang, Li, Guan, Fan, et al., 2021; Wang, Li, Guan, Xu, et al., 2021; Zhen et al., 2020).

The Multi-Depot Vehicle Routing Problem (MDVRP) has been extended to include a heterogeneous fleet of vehicles (Irnich, 2000; Máximo et al., 2022; Salhi & Sari, 1997), a time window variant (Cordeau et al., 2001; Polacek et al., 2004), and a pickup-delivery variant (Chen et al., 2021; Nagy & Salhi, 2005). Recent work has introduced the concept of split loads to the MDVRP problem with time windows, utilizing a customer clustering approach to select customers whose demands need to be disintegrated, and creating separate depots for collecting and distributing commodities (Wang, Li, Guan, Fan, et al., 2021; Wang, Li, Guan, Xu, et al., 2021). While the split delivery variant of MDVRP has been addressed in the literature (Gulczynski et al., 2011; S. Liu et al., 2009), the concept of splitting both pickup and delivery demands of customers for MDVRP with time windows has been scarcely studied. This research aims to bridge this gap with the proposed work.

Thus, with a novel problem setting, we contribute to the body of the literature both related to VRP and its application in the context of food banks.

2.3.2. Multi-objective

In the previous section, we have investigated the literature associated with single objective of food banks – total cost minimization. However, food banks unlike commercial entities strive to achieve social objectives as wee. Food banks strive to achieve three primary objectives. The first objective pertains to efficiency, involving the minimization of the total cost incurred in transportation (Sengul Orgut et al., 2016). Given that food banks operate as non-profit organizations with limited budgets for daily operations, reducing transportation costs is essential for their sustainability and the ability to provide food assistance to a greater number of individuals in need. The second objective focuses on effectiveness, aiming to minimize shortages in demand, thereby maximizing the fulfillment of demand to beneficiaries from available supply donations (Sengul Orgut et al., 2016). The third objective seeks to establish a degree of equity among all beneficiaries of food banks (Sengul Orgut et al., 2016). Equity in this context refers to fulfilling the demand of each beneficiary in proportion to their respective needs (Firouz et al., 2021; Sengul Orgut et al., 2016, 2018). Given that supply donations typically fall short of demand in nearly all food banks globally, these organizations aim to distribute food effectively and equitably, minimizing food wastage and ensuring fair allocation. The literature on the Vehicle Routing Problem (VRP) in the context of food banks has addressed a combination of these three objectives (Eisenhandler & Tzur, 2019a, 2019b; Nair, Rey, et al., 2017; Sengul Orgut et al., 2018).

The pickup and delivery variant of VRP has been addressed (Bowden & Ragsdale, 2020). Similarly, multi-depot variant of VRP has been endeavored in-depth in the recent literature (Ramos et al., 2020). Multi-depot VRP (MDVRP) in association with time-windows have been addressed with an objective to reduce the fleet size (Bezerra et al., 2023). Torres-Pérez et al.

(2022) addressed the MDVRP in context of customer assignment to respective depots. Soriano et al. (2023) addressed MDVRP with profit fairness and (Wen et al., 2022) addressed MDVRP with time-windows. Geetha et al. (2013) proposed cluster and then route model for solving MDVRP. Time-dependent MDVRP with time-windows have been addressed for MDVRP (Afshar-Nadjafi & Afshar-Nadjafi, 2016). Despite the extensive body of literature on Vehicle Routing Problems (VRP) and its various derivatives, the multi-depot variant of VRP within the domain of food banks has been relatively underexplored, especially when considering a multi-objective modeling framework (Mahmoudi et al., 2022). While some researchers, such as Rey et al. (2018), have proposed multi-objective models aiming to achieve equitable allocation and minimize travel costs, the current state of the literature reveals a notable gap, particularly in the context of Indian food banks. This highlights the need for further research to address the unique challenges posed by Indian food banks and leverage multi-objective optimization to enhance decision-making processes. The scarcity of studies exploring the multi-objective modeling of the multi-depot variant of VRP, specifically tailored for Indian food banks, implies that crucial considerations like efficiency, effectiveness, and equity are not fully addressed. The complexity of food bank operations demands a more nuanced approach that accounts for the distinctive characteristics of the Indian context. The proposed study aims to contribute to this underrepresented area in the literature by offering insights into the optimization of operational decisions within the Indian food bank system, aligning with the broader goals of efficiency, effectiveness, and equity. Incorporating a multi-objective framework allows for a comprehensive examination of the intricate trade-offs involved in food bank operations. It enables the simultaneous consideration of efficiency, effectiveness, and equity, offering a holistic approach to address the multifaceted objectives of food banks. By

extending the existing body of literature, our research endeavors to enhance the understanding of the operational dynamics of Indian food banks within the broader spectrum of multi-depot VRP, providing valuable insights for both academia and practitioners in the field. In addition, MO framework requires different exact and metaheuristics techniques to solve the problem. Melachrinoudis and Min (2011) proposed a tabu search heuristic for multi-depot, multi-vehicle dial-a-ride problem for healthcare units. Branch and price algorithm is proposed for solving VRP with demand allocation (Reihaneh & Ghoniem, 2019). Due to associated complexities of VRP, metaheuristics have been widely used in literature to solve larger scale problem efficiently under multi-objective scenario (Liu et al., 2020). Khatibi et al. (2019) presented utilized NSGA-II algorithm for solving a multi-objective model for scheduling operations on airport. NSGA-II introduces elitism in the evolution process and results in efficient solutions (Deb et al., 2002). Verma et al. (2021) presented a comprehensive review on Non-dominated Sorting Genetic Algorithm (NSGA-II) and depicts the superiority of NSGA-II in several combinatorial optimization problems.

2.4. Integrated Food bank network

The food bank supply chain consists of donors (suppliers), food banks (distributors), and beneficiaries (consumers). Food bank supply chain network varies from traditional food supply chain network in terms of its primary objective and therefore addressing supply chain network design of food banks becomes challenging. Food banks are a type of humanitarian supply chain which primarily works for alleviating hunger (Reusken et al., 2023). Unlike, for-profit supply chains, humanitarian supply chains not focus on profit maximization or demand maximization instead they focus on optimal utilization of resources to cater as much demand as possible from the available donations (Cheng et al., 2021). Though commercial supply chain network design

problem has attracted considerable work (Farahani et al., 2014), however, humanitarian counterpart received lesser attention (Charles et al., 2016) especially literature is scarce for humanitarian supply chain design caused due to long run disaster like food insecurity, hunger, poverty, and malnutrition (Besiou et al., 2021). Recently, due to Covid-19 pandemic, humanitarian supply chain network design has attracted considerable attention. Food banks can be a solution to these long run disasters, if strategically planned. However, food banks nearly everywhere emerged as an ad-hoc solution for hunger and poverty (Sengul Orgut et al., 2016; Tarasuk et al., 2014) which leads to inefficient and poor resource utilization that ultimately fails to achieve the primary objective of food banks –hunger alleviation (Bazerghi et al., 2016). Therefore, it puts forward considerable scope for work in supply chain network design for food banks. Although, food banks have attracted researchers from wide domain concerning uncertainty (Sengul Orgut et al., 2018), food donation (Dalal, 2022; F. Schneider, 2013b, 2013b), vehicle routing problem (Nair, Rey, et al., 2017), location-routing problem (Yildiz et al., 2013), food insecurity(Sengul Orgut et al., 2016), food bank supply chain network (C. L. Martins et al., 2019a), literature is extant for supply chain network design of food banks. We tried to visualize the studies in literature in different domains linked to food banks using VOSviewer software by exporting SCOPUS database. The keyword used during the search was “food banks”. Figure 2.4 depicts the network visualization of literature associated with food banks and potential areas of studies.

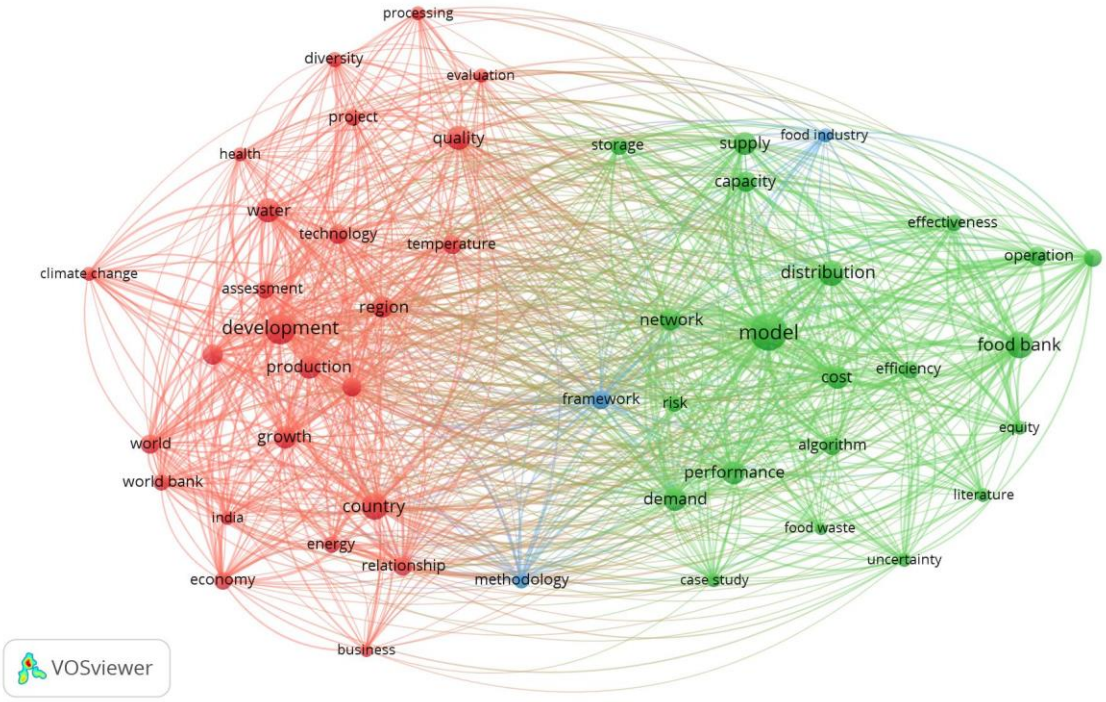

Figure 2.4: Network visualization of food bank's literature

Food banks supply chain networks comprises donations from donors (supplies), beneficiaries (demand), food (commodities), and volunteers (workforce). These entities are integral part of entire food banks supply chain network. To the best of our knowledge there are only few articles which focuses on supply chain network design problem for food banks. A recent survey paper pointed out that there is only one paper which considers the optimal location of food banks in supply chain network design problem (Mahmoudi et al., 2022). In this review we will present an in-depth review of literature pertaining to food banks supply chain network and put forward the existing research gaps. Initially, Martins et al. (2019a) addressed the supply chain network redesign problem for FPBA. The authors considered two-echelon network structure wherein donors are suppliers, food banks assist operations and charitable agencies were the beneficiaries. The redesign network undertook decisions pertaining to opening food banks at

potential location, closing existing food banks, capacity acquisition decisions, food purchase decision and travelling decisions. Moreover, the capacity planning decision only dealt with expansion and installation of storage and transport capacities. Specifically, number of volunteers (human capital) needed for the operations has not been addressed instead the amount of social work generated due to installation or expansion of each unit of storage capacity has been undertaken as a part of social objective. Ataseven et al. (2018) pointed out the significant role of human assets in humanitarian organizations and therefore this is a potential research gap which needs to be addressed. Similar to this, the work due to Kaviyani-Charati et al. (2022) formulates the food bank supply chain network planning multi-objective MILP problem considering uncertainty. Authors included opening decisions, capacity acquisition decisions, food purchase and travelling decisions. Similar to the former study workforce planning is not taken care of instead amount of job created is considered as a part of social objective. Authors proposed two-stage stochastic programming approach to deal with associated uncertainty. The work due to Sedehzadeh and Seifbarghy (2021) points out that increasing food banks could help in achieving a sustainable network. There are other papers related to network design but instead of finding optimal locations for food banks, it explores some intermediate food delivery points and try to minimize the total cost of travelling cost (Davis et al., 2014; Ghoniem et al., 2013; Reihaneh & Ghoniem, 2018; Solak et al., 2014).

Apart from that, efficiency, effectiveness and equity are the potential objectives for non-profit organizations like food banks (Hasnain et al., 2021). Food banks aims to achieve these objectives for collection and distribution operations. Martins et al. (2019a) ensured the equity in distribution of donated food among all the charities by integrating it with social objective. Moreover, efficiency and effectiveness has been incorporated in economic and environmental

objective function. Alkaabneh et al. (2021) undertaken the effectiveness as a measure of nutritional value of the allocated food to the agency. These three objectives also play a crucial role in routing problems for food rescue and food bank operations (Nair, Rey, et al., 2017; Rey et al., 2018; Sengul Orgut et al., 2016). Since the literature is extant for network design problem concerning food banks, we believe there is further scope of contribution in terms of different types of objective function and constraints for ensuring these three primary objectives.

Food is the most central part of food bank supply chain. Though distributing food, thus alleviating hunger is the primary objective of food banks, the food should contain the necessary nutrients in order to meet recommended daily intake. A comprehensive survey has been conducted on 137 US food banks to document, understand and analyse the culture, capacities and practices related to nutrition of food banks in order to improve the beneficiary's health (Campbell et al., 2013). Similarly, Bazerghi et al. (2016) conducted literature review to investigate if the nutritional requirements of the beneficiaries are being met by the food bank programmed. The authors concluded that food banks are unable to meet the nutritional requirements of the beneficiaries and more attention is needed to align with the nutrition policies (Neter et al., 2016; Oldroyd et al., 2022). (Ghahremani-Nahr et al., 2023) presented a non-linear multi-objective mathematical formulation for food bank supply chain network design problem and uncertain parameters are investigated using fuzzy robust model. In addition to all the strategic decisions, authors considered charities as their end beneficiaries and maximize the nutritional value in the food packets of those charities. To the best of our knowledge there is only one study which addresses and proposes mathematical model concerning the nutritional aspects of food banks. Practically a charity can serve food to different class of beneficiaries such as children, boys, girls, men, and women. Each of these

beneficiary type has different nutritional requirements. There nutritional requirement of each beneficiary type should be met according to the recommended daily intake of their age group which is a potential research gap that we are going to address in this study.

2.5. Conclusion

In conclusion, the broad literature analysis provided light on a variety of obstacles faced by food banks, including legal and financial impediments as well as infrastructure, staffing, and planning issues. The findings highlight the importance of a comprehensive and systematic strategy to addressing these difficulties, given the complex character of food bank operations. Barriers to food banks in India are discerned through extensive review of relevant literature. A total of 14 barriers have been identified, categorized into 7 main clusters, providing a comprehensive overview of the challenges faced by food banks in the country. According to the reviewed literature, regulatory frameworks, financial backing, suitable infrastructure, and sufficient people are some of the challenges for food banks It emphasizes the need of planning and collaboration in overcoming operational challenges, as well as the importance of raising awareness at the community and national levels in order to mobilize support and donations. Due to interdependencies and complex structure, it becomes consequential to identify the most critical barriers its cause and effect on the overall system which has not been addressed in the literature.

The extensive literature analysis gives a full picture of the obstacles encountered by food banks, with an emphasis on vehicle routing problems (VRP) and its variations. By combining ideas from a variety of research, the study offers light on the complex operational dynamics and crucial variables that influence food banks' daily operations. Though there are contributions for modelling the daily collection and distribution problem of food banks using

VRP, yet literature is relatively under explored for the multi-depot variant of VRP especially in the context of food banks. Our review suggests that there are other realistic intricacies that are often under looked in the existing studies. These intricacies comprise of characteristics related to problem setting such as limited shelf life of donated food or limited capacity of vehicle used for pickup and distribution. In the context of limited availability of vehicles, the literature associated with food banks is under explored for modelling, evaluating and assessing the impact of introducing split loads i.e., splitting the pickup and delivery demands. Our review suggests that splitting loads could lead to potential performance improvement and better utilization of available resources. These typical characteristics need to be addressed for in the context of VRP. The other problem based characteristics that has potential scope to explore is solving the food banks operational problem in the context of several central hubs or depots.

The lack of research investigating the multi-objective modelling of the multi-depot variation of VRP, especially designed for Indian food banks, suggests that important factors such as efficiency, efficacy, and equality have not been properly addressed. The intricacy of food bank operations necessitates a more sophisticated strategy that takes into consideration the peculiarities of India food banks.

In addition, food is the center of the entire food banks operations, yet the literature is under explored for meeting the dietary needs of the recipients for food banks. The existing body of research is mostly concerned with improving logistics, transportation costs, and equitable distribution, with little mention of nutritional factors. This omission is notable considering the importance of nutritional requirements, particularly in the context of giving aid to needy communities via food banks. This is a potential limitation of the existing studies which we aim to address in this study.