

Extended Abstract

Food banks are non-for profit organizations that play a significant role to ensure food security, reduce food wastage and alleviate hunger. Their primary role concerns recovery and redistribution of surplus or leftover food to economically deprived and marginalized people. Food banks acts as a bridge between the food insecure and food surplus population. The primary goal of food banks to alleviate hunger aligns with the second goal – zero hunger of United Nations Sustainable Development Goals (SDGs). In addition, food banks agenda of reducing food wastage aligns with goal -12 of SDGs encompassing responsible consumption and production. Food banks are gaining momentum globally but still it is in a preliminary stage in several developing countries including India. Food banks faces several challenges ranging from strategic to operational aspect. These challenges typically concern with identifying critical challenges, addressing the daily operational problem of collection and distribution and designing integrated food banks network model encompassing underlying characteristics of Indian food banks. These challenges have significant impact on the daily operation and overall effectiveness of food bank. These challenges have paramount impact especially on food banks that are in nascent stage in developing countries like India. Therefore, these critical challenges need to addressed to increase the overall effectiveness of food banks.

The study aims identify challenges and barriers that impede the growth and adoption of food banks in the Indian context and to evaluate critical barriers by prioritizing them. A total of 14 barriers have been identified through literature survey, qualitative interviews with different stakeholders of food banks in India and expert's inputs. These barriers have been clustered into 7 categories - Policy and regulation, financial resources, infrastructure and human resources, planning and coordination, knowledge, uncertainty, and characteristics of food, of main barriers. Then, DEMATEL is used to find the cause-effect relationship among the identified barriers. A network of inter-relationship among the identified barriers is devised using Analytic

Network Process (ANP) using the output from DEMATEL. Results of DEMATEL indicates that lack of planning and coordination is the most significant barrier that hinders the growth and sustenance of food banks in India. Also, lack of infrastructure and human resources are the major effect of the other barriers. Further, the financial barrier attains maximum weight in the ANP process and came out to be the most critical barrier. This study can be help food banks and policy makers to devise the plans for sustenance of the food banks. To the best of our knowledge, this is the first attempt ever to identify and prioritize the barriers for the food banks.

Collection and distribution of donated food is the core of food bank operations. The problem faced by the food banks operating on the front-end model is the collection of surplus food from donation points and re-distribution of it to the demand points. These operation is carried out using a fleet of vehicles available at different volunteer locations/depots within specified time windows. Sometimes, the quantity of supply donation and demand exceeds the available vehicle capacity leading to multiple visits to those supply (pickup) and demand points. Thus, demand splitting is allowed at the pickup as well and delivery points. Therefore, this problem can be seen as a rich variant of the vehicle routing problem (VRP) and named as a multi-depot VRP with time windows, split pickup and split delivery (MDVRP-TW-SP-SD). The problem is to determine the optimal number of vehicles from each depot to be hired and their optimal routes (sequence for visiting pickup and demand nodes) such that the total cost of hiring the vehicles, routing cost and penalty for unmet demand are minimized and it is formulated as a mixed-integer programming problem. We have used single composite objective of total transportation cost and penalty minimization to model this problem. To the best of our knowledge, this is the first attempt to formulate the MDVRP-TW-SP-SD. We have endeavored both exact techniques and metaheuristics to solve the problem. To efficiently and effectively solve the single-composite objective problem, an elitist GA and a GA hybridized with the local search are proposed. The performance of the proposed algorithms is tested through extensive

computational experiments carried out on 180 modified benchmark problem instances from the literature. The overall computational experiments are carried out on PARAM SHIVAY super computer. The results of computational experiments show the superiority of the GA hybridized with 3-opt local search. In addition, our proposed algorithms outperform state-of-the-art solver Gurobi both in terms of solution quality and efficiency. A case of the Robin Hood Army operating in the Lucknow city of India is also presented to demonstrate the applicability of the proposed model to practice and several insights were outlined. The result of case study demonstrates higher utilization of bigger vehicles, average 28% and 17% multiple visits to pickup and delivery nodes, respectively. Additionally, the analysis indicates a higher utilization of four-wheeler vehicles as opposed to two-wheeler vehicles, attributed to the latter's limited capacity.

Unlike commercial institutions, food banks operate in non-profit model and aims to achieve social goals along with cost minimization. We endeavor three primary objectives of food banks - efficiency, effectiveness, and equity. The measure for efficiency is minimum total transportation cost, minimum total shortage for effectiveness, and minimum of the maximum shortage of network is taken for equity. These objectives have underlying trade-offs and therefore we need a multi-objective model to analyze these conflicting objective using pareto-front. This paper proposes a MILP model for multi-objective optimization of surplus food recovery and redistribution in India. Specifically, the problem is formulated MO-MDVRP-TW-SP-SD (Multi - Objective MDVRP-TW-SP-SD) problem. To the best of our knowledge, our study is the first to evaluate Indian food banks from a multi-objective perspective. To solve the proposed problem, state-of-the-art-solver Gurobi is used for weighted sum method, augmented ϵ -constraint method, and augmented weighted Tchebycheff methods. Non-dominated Sorting Genetic Algorithm (NSGA-II) is developed to solve the larger size problems. The results of the computational experiments show significant trade-off behavior

between efficiency and effectiveness. The outcomes demonstrate that the weighted sum method, augmented ϵ -constraint method, and augmented weighted Tchebycheff method yield 5%, 19%, and 15% distinct non-dominated solutions, respectively. It is noteworthy that even with extensive computational capabilities of the supercomputer, the exact methods failed to provide optimal solutions for specific combinations within a one-hour runtime. NSGA-II remarkably produces near-optimal solutions within 76 seconds for the larger network.

Despite of non-profit nature, these food banks incurs cost for storage, transportation and food purchase. The architecture of Indian food banks differs widely from other food banks in terms of hierarchical framework of food banks on the basis of their scale of operation and type of food donors. Specifically, food banks operate in two different tiers based on the types of donor, beneficiaries, food and scale of operation. Food banks operate in resource scarce environment and this hierarchical framework of Indian food banks brings additional challenges to food bank supply chain network design. This study is motivated from Indian food banks and it presents a mixed – integer linear programming model and its variation for integrated network design of food banks with different objectives concerning efficiency, effectiveness and equity. The novelty corresponds to the inclusion of aspects related to nutritious meal in our work. To the best of our knowledge, food bank network design model has not been investigated for ensuring the nutritional requirements of the beneficiaries according to their age-group profile. We endeavor to fill this research gap in our proposed study. We conducted a realistic data based case study to design integrated food bank network encompassing nutritional aspect, in Delhi, the capital of India, with an aim to provide some insights for their better functioning. The computational experiment is carried out on the case problem and proposed mathematical model and its variation is solved using state-of-the-art solver Gurobi. An extensive sensitive analysis is performed on the mathematical model to assess the performance of the proposed model and generate insights for the food banks. The results indicate that considerable portion (around 77

to 79%) of strategic budget has been used for manpower hiring. The findings indicate that achieving a zero total shortage in the system necessitates a significant strategic budget and, on average, a 37.5% increase in the number of volunteers is required. Based on the work proposed in this study, we presented some promising avenues for future research directions to further enhance the proposed models.