Chapter 6: Conclusions and Future Research Directions

In this chapter, we present the summary of the research work along with its limitations, key findings of study, scope for future work and managerial implications.

6.1.Conclusion

Food insecurity is a global challenge that is the root cause for several linked problems such as malnutrition, stunting and anemia. It is indispensable for all the countries to achieve food security. Food banks are one such not-for-profit entities that helps to alleviate hunger of vulnerable populations. The cases of hunger and malnutrition is more prevalent in developing countries. As critical components of social welfare systems, food banks play a central role in recovering and redistributing surplus and leftover food. It facilitates food waste reduction by ensuring that edible surplus/leftover food does not end up in landfills and reaches to those in need, hence contributing to mitigate of food insecurity among the beneficiaries.

Food banks have gained wide attention around the globe in the past decade among research and practitioners. The key objectives of food banks link their work to bigger global initiatives and are closely aligned with the United Nations' Sustainable Development Goals (SDGs). The SDGs, notably Goal 2 - Zero Hunger, highlight the importance of providing universal access to safe, nutritious, and adequate food. Food banks help to achieve this aim by recovering surplus and leftover food and redistributing it to the vulnerable population. Furthermore, their work goes beyond alleviating acute hunger and addresses the environmental problems by reducing food waste and supporting social sustainability. Despite its contribution in SDGs defined by UN, food banks have its own set of impediments especially for the developing countries like India. Chapter 1 outlines the status of hunger, food insecurity and agriculture

produce in India. It also highlights the existence of hunger in India in a paradoxical environment of growing agriculture produce. Later, we presented the description of several initiatives that are instrumental in ensuring food security in India. We presented the role of food banks, associated entities and how the interact within the system. These descriptions are instrumental in understanding the existing problem associated with food banks. Thus, it paves the way and provide the required motivation for problem definition associated with operational and strategic aspects of food banks.

Chapter 2 presents review of body of literature pertaining to the challenges of food banks and solution methodology. It is categorized in 3 sections. The first section provides a comprehensive review the challenges documented in literature. Food banks have been studied for diverse domains ranging from social stigma associated with taking food assistance to address the operational problem of food bank. The scope of our literature review typically encompasses the challenges associated with operational, tactical and strategic aspect of food banking system. It depicts that most of the existing studies usually addresses one specific challenge and there is dearth of contributions for prioritization and classification of the challenges documented in the literature. This strategic viewpoint of prioritization and classification endeavors to provides a more profound and nuanced understanding of the complexities that characterize the functioning of food banks. The second section endeavors the literature associated with food banks daily operational problem of collection and distribution. The studies documented addresses collection and distribution as a variant of VRP. Based on the literature review, we found potential gaps in addressing several realistic intricacies in the problem definition modeling and solution. The third section presents review of literature associated with strategic planning – food bank network design problem. Specifically, it reviews

the existing literature for the social and cost minimization related objectives. The review highlights dearth of contribution addressing these goals. In addition, it has been observed that existing studies have limitation associated with addressing the nutritional requirements of the beneficiaries in the food bank network design model.

Chapter 3 addresses the prioritization and classification of challenges documented in literature. In addition, it asses the applicability of those challenges in Indian context. It presents 14 potential barriers for the growth and adoption of food banks in India. It classifies these barriers in causes and effects using DEMATEL and later prioritizes using hybridized DEMATEL-based ANP. Understanding the relative significance of these impediments is important in solving them and devising strategies to accelerate the growth of food banks. The outcomes of the DEMATEL analysis indicate that sub-barriers low penetration of policies, limited funds/commodities raised from donations, limited financial support from the government, lack of strategic/tactical level planning and Decision Support System (DSS), lack of coordination among food banks, uncertainty in demand, low nutritional value in donated food, and uncertainty in supply are categorized under the 'cause' group and the remaining sub-barriers are classified under the 'effect' group. The results of DEMATEL-based ANP depicts that financial and economic barriers emerge as the most pivotal barrier. The significance of addressing it becomes paramount for fostering the growth of Indian food banks.

Chapter 4 addresses the operational problem of food bank comprising of collection and distribution of surplus or leftover food. As the literature review suggests that realistic intricacies such as limited vehicle capacity, perishable nature of donated food, context of several central hubs from where route starts and ends has been overlooked. Specifically, it addresses these realistic intricacies and formulates a MILP model for the collection and

distribution problem of food banks, specifically as MD-VRP-TW-SP-SD. This chapter has 2 section addressing single and multi-objective framework. Both the section presents case study on an Indian food bank and applies the proposed solution methodology to solve the case problem. In the first section, to ensure scalability in solution methodology, elitist GA and two variants of GA hybridized with local search 3-opt (GA_LS_1 and GA_LS_2) has been proposed. Results demonstrates that GA_LS_2 excels in terms of solution quality, while GA_LS_1 demonstrates computational efficiency in relation to CPU time. In addition, both proposed metaheuristics outperforms GUROBI. The result of case study demonstrates higher utilization of bigger vehicles, average 28% and 17% multiple visits to pickup and delivery nodes, respectively. Different scenarios are generated based on a base case scenario where supply donation is less that demand and results were analyzed. The result demonstrates that GA_LS_2 yields low routing cost and on an average 5 routes to cover all supply and demand nodes. It is worth noting that that first section considers composite single objective comprises of routing cost, vehicle hiring cost and penalty cost for not meeting demand. The section 2 of the chapter presents the operational problem in multi-objective framework. Food bank is a kind of social welfare system and therefore ensuring social goals such as equitable distribution is consequential. This section considers 3 conflicting objectives – minimization of total transportation cost, meeting equitable distribution among beneficiaries and minimization of total shortage in the system. The results indicate that the augmented $\in$-constraint method, augmented weighted Tchebycheff method and weighted sum method, method generate 19%, 15% and 5% distinct non-dominated solutions, respectively. Notably, despite utilizing the extensive computational capabilities of the Param Shivay Supercomputer, the exact methods failed to produce optimal solutions for certain combinations within a one-hour runtime. To

ensure scalability, NSGA-II is utilized to solve the case problem. The findings highlight a significant cost is incurred for ensuring both effectiveness and equity in the system.

Chapter 5 presents integrated food banking network design problem considering hierarchy and nutritional aspect depending upon age and gender profile of beneficiaries. The chapter proposed a base MILP model and 10 variations of the base model depending upon different requirements of food banks. A case problem is proposed and solved for all the 10 variations of base model. n the majority of models, the availability of manpower is a significant constraint for Indian food banks, requiring a substantial portion of the strategic budget (ranging from 77% to 79%) to be allocated to hiring manpower, regardless of the chosen objective function (whether it's total cost minimization, shortage reduction, equity, etc.). The result demonstrated that to reduce the total shortage in system to zero, a considerable strategic budget should be incurred and on an average 37.5% increase in number of volunteers are required.

Despite of significant contribution, the present study has some limitations that could be taken as motivation for future research work.

6.2. Limitations and Future Research direction

In Chapter 3, we have identified barriers from literature review and assess their applicability in Indian context. Consequently, the applicability of the identified barriers heavily relies on insights gathered from qualitative interviews with food bank executives. Moreover, the input pool for the DEMATEL method was limited to a minimal number of experts actively involved in the weighing process. Future research endeavors could replicate similar studies in the context of both developing and developed countries. We have proposed hybridized DEMATEL based ANP technique for barrier classification and prioritization. These techniques sometimes introduce underlying biasness because of expert views and

unidimensional scale used in the evaluation methodology. The scope of the study could be expanded in the future by incorporating fuzzy logic within hybrid MCDM models.

Chapter 4 offers multiple avenues for future research work. The proposed MILP model considers single commodity and single time windows for each request. The future scope of the given study could be to enhance the existing model further by considering multi-commodity and multi-time windows in the formulation and problem definition. In the proposed model, we have not considered the uncertain nature of supply and demand donation. The scope of the study could be expanded in the future by incorporating uncertainty and addressing it with suitable modeling techniques such as two-stage stochastic optimization or robust optimization. Chapter 5 witnesses' variations due to uncertain supply and demand donation. The future scope for the current study could be to model these variations. Moreover, exploring the combined impact of an overall budget constraint and equity considerations presents an intriguing avenue for future research. The other promising avenue for future research is to prioritise the different objectives proposed in the chapter and explore pre-emptive goal programming model to solve the problem. This study expresses equity using different measures, alternative representations of equity could be examined. The model could be further enriched by encompassing multi-objective framework for all the three objectives - cost efficiency, effectiveness and equity. This chapter primarily deals with strategic model, and so collection and distribution costs are considered as proportional to distance between node pairs. Integrating routing decisions although increase the computational complexity, yet it could enhance the model further.