Chapter 8

Conclusion and Future Research Direction

This chapter addresses the overall concluding remarks regarding our proposed works that are presented in Chapter 2 to Chapter 7. Ultimately, the potential avenues of our research problems are discussed.

8.1 Conclusion

Transportation framework design is a vital strategic issue. In the transportation framework, various decisions, as well as location decisions, are also taken. In this dissertation, we have mainly made connections between FLP and different kinds of transportation frameworks in several environments. Especially, here, six (06) optimization problems in FLPs are considered.

The first study, designated as T-LP has been introduced a practical problem for a transportation network that aims to minimize the total transportation cost along the entire supply chain and to select potential facility sites for different plants. Thereafter, some fundamental propositions and a theorem on T-LP have been introduced to investigate the nature of T-LP. In addition to the aforementioned achievements, the development of novel versions of two approaches is analyzed to solve the proposed problem efficiently. The studied model and developed procedures have been tested by a real-life example. Finally, the obtained computational results from our two approaches have been compared with suggestions for selecting the potential facility sites. In comparison, the iterative approach is more appropriate to solve the T-LP with small sizes, for which it is possible to generate better solutions with a reasonable timeframe. The Loc-Alloc heuristic is more suitable for T-LP of larger size since it can generate comparable solutions in less computational time. In fact, the formulation presented here can be employed in large-scale industrial applications such as the manufacturing of plants, transportation systems, emergency services, and online-shopping systems.

The second problem has been portrayed as a new practical problem for a logistics system that objectives to reduce the total logistics cost along with the fixed cost on the entire supply chain and to select potential facility sites for different plants. To the best of the knowledge, for the first time in research, the proposed design has been provided a way of analyzing the connection between FLP and FCTP. Thereafter, some fundamental propositions and theorem on FCT-LP have been included to investigate the nature of FCT-LP. Despite the over, the development of a new version of approach has been incorporated to tackle the proposed problem proficiently. The studied model and developed procedure have been tested by a real-life example. Finally, the obtained computational outcomes from the approximation approach have been discussed with the suggestions for selecting the potential facility sites. The approximation approach has been used to find optimal solutions for FCT-LP with the larger size in a less computational timeframe. However, the formulation has been presented here can be applied in industrial applications such as the manufacturing of plants and applications.

The third study has been presented a new practical problem for a solid logistics modeling with the goal of minimizing the total transportation cost by different types of transportation modes on the entire supply chain and to seek facilities sites for plants. According to our knowledge, for the first time in research, we have introduced a connection between STP and FLP. Afterwards, a theorem and few fundamental propositions on ST-LP have been stated to inspect the nature of our formulation. In addition to the preceding achievements, we improved two heuristic approaches to solve the stated problem in an efficient way. The proposed formulation and developed heuristics have been evaluated by a real-life based example. Therefore, the derived computational outcomes from our two heuristics have been compared with suggestions for locating the facilities. In comparison, the Loc-Alloc heuristic approach is appropriate to solve the ST-LP program with small sizes. The approximate heuristic is more suitable for ST-LP of larger size since it can generate optimal solutions in less computational burden. Finally, a sensitivity analysis has been provided to validate the ranges of the parameters in our formulation. Moreover, the formulation presented here can be employed in large-scale industrial applications, such as the manufacturing of plants, genetic-metabolic, financial and further applications.

The fourth study has been presented a practical formulation for planning and transportation system with the objectives of minimizing the total transportation cost, total transportation time, and total carbon emission cost under TCTP on the entire transportation chain, and at the same time, it also asks the potential facility sites along with the amounts of transported goods simultaneously. To the best of authors' knowledge, the problem of designing the MOT-LP, considering variable carbon emission under TCTP, has not been studied before. Additionally, we have improved a hybrid approach to solve the proposed problem effectively. The stated formulation and improved hybrid approach have been tested by a real-life based example. Thereafter, the effect of variable carbon emission under TCTP is investigated by two special cases. In fact, we explore the optimal decision to reduce carbon emission for companies under TCTP. Therefore, the nature of the obtained compromise solution is analyzed by four lemmas. Lastly, the sensitivity analysis has been given to check the resiliency of the parameters in the MOT-LP. Moreover, our formulation can be utilized in other industrial applications like the manufacturing of plants, green supply chain model, production-inventory system, financial and further applications.

In the fifth research work, we have introduced an unprecedented formulation of integrated supply chain management and location decisions with the objects of reducing the overall logistics cost, shipping time and inventory cost along with carbon emission cost in a solid transportation network. At the same time, it also asks the optimal locations for the potential facilities as well as the amounts of distributed goods by different transportation modes simultaneously. To the best of the authors' knowledge, there is no research so far integrating by the FLP, inventory management and STP in a multi-objective environment. Besides, a hybrid approach is introduced to solve the stated formulation in a successful way. Thereafter, the aforementioned model and solution procedure have been validated by a numerical example. Therefore, the decisions regarding reducing carbon dioxide due to transportation systems are also discussed. The characteristic of the optimal compromise solution is described by two propositions. In fact, this study of decision making will help the DMs to deal with the other multi-objective decision-making applications such as the production-inventory system, green supply chain model, financial and further applications.

In the sixth research work, a strategic problem of integrated green logistics systems and location decisions has been introduced by considering economical, customers' satisfaction level and environmental objectives under two-fold uncertainty. To support the decision, an unprecedented multi-objective model has been formulated with the above three conflicting objectives under a carbon policy. At the same time, it also asks the optimal locations for the potential facilities in the Euclidean plane as well as the amounts of distributed goods by different transportation modes simultaneously. Besides, this study makes various major contributions such as fixed-charge cost, maintenance cost, dwell time, variable budget constraints, loading and unloading time. Thereafter, a new form of trapezoidal type-2 fuzzy number has been presented to handle the uncertainties. A simple linear ranking function has been introduced, significantly defuzzified the aforementioned uncertainty under a smaller computational effort. A fuzzy technique and a non-fuzzy technique are used to solve the stated formulation in a successful way. Thereafter, the aforementioned model and solution procedures have been validated by two examples. Finally, decisions regarding reducing CO_2 due to transportation systems have been discussed, too. We may also draw the conclusion that our problem formulation and solution can control the carbon emission due to the logistics system.

In a nutshell, it is concluded that this dissertation is endeavored to set up different kinds of connections between FLP and TPs under various environments to handle real-life phenomena. Besides, a few methodologies are utilized and developed to unravel various kinds of integrated FLP models. A brief discussion of the impact of carbon emission under *several carbon policies is analyzed. From that analysis, organizations can understand when their profit will be less (more). Accordingly, they can adjust their benefits and environmental awareness, which may lead to a gain of reputation in the worldwide market.*

8.2 Future research direction

In this dissertation, we have mainly made connections between FLP and different kinds of logistics problems under several environments. Herein, the potential avenues of our stated problems are discussed.

For T-LP, several research directions remain open, so that scientists can initiate the problem treatment by alternative methodologies such as Lagrangian relaxation heuristic, genetic algorithm, branching method, greedy algorithm, etc. Moreover, they can use different distance functions (or, cost functions) like rectangular distance, block distance, signed distance, Hausdorff distance, etc. One may consider uncertain environments such as intuitionistic fuzzy, rough set and grey numbers within the frame of our proposed model.

We should highlight that in connection with FCT-LP, so many research directions remain open, so, researchers can initiate the problem by different distance functions (or, cost functions) like as block distance, rectangular distance, Hausdorff distance, signed distance, etc. and they can use alternative methodologies such as Lagrangean relaxation heuristic, greedy algorithm, genetic algorithm, branching method, etc. One may consider the uncertain environments such as rough set, intuitionistic fuzzy and grey numbers in the proposed model.

There is a large number of associated research directions for ST-LP. The scientist can state the problem by different distance functions (or, cost functions) like Hausdorff distance, signed distance block distance, rectangular distance, etc. In fact, they can employ alternative methodologies such as e.g., genetic algorithm, greedy algorithm, and Lagrangean relaxation heuristic. One may analyze our model in uncertain environments such as type-2 fuzzy sets, intuitionistic fuzzy sets, rough sets, grey numbers or stochastic calculus.

We must underscore that in association with MOT-LP, there are other lines of research work of absolute significance and importance that we have not raised because they are outside the objectives initially set; however, in the future investigation, one can analyze MOT-LP with neutrosophic parameters, and discuss the effect of variation in solution of MOT-LP. Another scope is to consider our model in the stochastic environment, then one may perform the statistical inference analysis using nonparametric hypothesis testing. Similarly, the possibilities of using Genetic Programming, Monte Carlo Method [79], Simboloc Regression, techno-economic (cost) analysis and payback period are the interesting lines to be investigated in the forthcoming paper(s). In fact, researchers can then compare the study with our proposed study. Furthermore, interested scientists can analyze our model in different uncertain environments, e.g., type-2 fuzzy sets, intuitionistic fuzzy sets, rough sets or grey numbers. Besides, one may consider the membership functions as hyperbolic, exponential, etc., instead of linear membership functions for solving MOT-LP. In addition, researchers may employ different types of distance functions such as rectangular distance, signed distance, Hausdorff distance, etc. The incorporation of fixed-charge costs in MOT-LP can be a more realistic research modification. In this regard, a line of study that we design to explore in the future is the application of meta-heuristic algorithms to solve such problems. Nature-motivated metaheuristic algorithms, such as particle swarm optimization, genetic algorithm, simulated annealing, etc. seem faster to successfully solve these problems with large scale entries and will be the fields for future research works.

For MOST-LP, there are different emerging areas that we need not emphasize here as they are exterior the objectives feasible set. Nevertheless, there can be interesting topics for future research; for instance, one may analyze MOST-LP with intuitionistic fuzzy parameters. In fact, researchers may consider different kinds of metrics, e.g., rectangular, block, Hausdorff, etc., instead of Euclidean distance. Moreover, one can analyze our model in different uncertainties, e.g., interval numbers, type-2 fuzzy set, neutrosophic sets, rough sets, grey numbers or stochastic ones. Additionally, interested scientists may apply the membership and non-membership functions as exponential, hyperbolic, etc., rather than linear function to handle MOST-LP. The inclusion of fixed-charge costs in MOST-LP can be a progressively practical research alteration. In this regard, the delineation of specific heuristic algorithms is beyond the scope of this study. Therefore, heuristic and hybrid solution procedures, for example, genetic algorithm, greedy algorithm, simulated annealing, etc., might be faster for solving large-scale instances and will be the future study.

We should highlight that in connection with MOGST-LP, there are different emerging areas that we need not consider here as they are exterior of the objectives' feasible set. Nevertheless, there can be interesting topics for future research; for instance, one may analyze MOGST-LP with different kinds of metrics, e.g., rectangular, block, Hausdorff, etc., instead of Euclidean distance. Moreover, one can elaborate our model in different uncertainties such as neutrosophic sets [36], rough sets [33], risk management [117], robust environment [60, 77] and stochastic [79] ones. Additionally, interested scientists may design the membership and non-membership functions as exponential, hyperbolic, etc., rather than linear function to handle the MOGST-LP. For all these reasons, heuristic, hybrid and stochastic solution procedures like genetic algorithm, greedy algorithm, simulated annealing, etc., might be more realistic or faster for solving large-scale instances and will be subject to our future study.

Apart from these directions, the researchers may consider FLP in the following research fields as their future scopes:

- **Reliability:** Each located facility can confront interruptions like cataclysmic events or man-made fiascos. This can prompt individuals' demises and tremendous misfortunes. These sorts of problems can be addressed as "*location-reliability problems*".

- **Game theory:** Game theory is an incredible procedure in "*competitive location problems*". Employing FLPs in a business situation can prompt utilizing "cooperative and non-cooperative games", and a few exceptional procedures like bi-level [28] and multi-level programming.

- **Sustainability:** In the present era, considering goals other than financial functions is turning into an absolute necessity. Sustainability forces any improvement and pattern in strategic planning must likewise consider environmental and social objective functions [40]. In this manner, we can ponder about a term like a sustainable location problem.

- **Supply chain:** In a highly competitive market, technologies and several innovative ideas are implemented in a supply chain inventory model to tackle a new and tough challenging problem. In fact, it becomes a challenge for the companies to optimize the total operational cost of ensuring a higher satisfaction level of the customers. A supply chain model is always concerned with the total level of inventories and the location of inventories. In this regard, Melo et al. [105] presented a review to coordinate FLPs with other decision-making problems of a supply chain network.

- **Stochasticity and robustness:** Most of the facility location models, the parameters are considered in precise nature while tackling models involving uncertainty, robustness or randomness are progressively practical. Along these lines, utilizing robustness and stochastic optimization [113] around there can be a significant scope.