Ain Shams University
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Application of Multi-Objective Optimization Model for Supply Chain Network Design

A thesis Submitted in Partial Fulfillment of the Requirements for
M.Sc. in Mechanical Engineering

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Statement

This thesis is submitted in the partial fulfillment of a Master of Science degree in Mechanical Engineering, to Ain Shams University.

The author carried out the work included in this thesis, and no part of this thesis has been submitted for a degree or qualification at any other university.

Signature

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“...And my success is not but through Allah. Upon him I have relied, and to Him I return.”

(Hud, 88)

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Abstract

Research in the field of the multi-objective supply chain was given little attention as compared to that given to the single objective supply chain problems. In addition, most of researches, which tackle the multi-objective problems, aim at finding either one non-dominated solution for dynamic problem or Pareto front for static problem. Little attention has been given to consider the role of dynamic location allocation on designing supply chain.

In the present work multi-objective four echelons single product supply chain network design in dynamic environment is considered. The network under study consists of suppliers, plants, distributors and customers echelons. This problem is concerned with finding the Pareto front includes different SCNDs with trade-off between two objectives. These objectives are minimizing the total cost and maximizing the service level. At each solution, two decisions are taken. These decisions are locating plants and distributers in any period when they are needed and allocating quantities between each two successive echelons.

A Genetic Algorithm is developed to solve this problem. The developed algorithm applies a new chromosome representation with its decoding-encoding procedures to effectively tackle the multi-objective supply chain with dynamic nature.

The model has successfully tackled the multi-objective supply chain network design problem with dynamic location allocation. The results are more practical as it considers the Pareto front for minimizing the total cost and maximizing the service level, other than optimizing only one of these objectives. The results proved that considering different capacities for the potential plants and distributors is better than similar capacity as it leads to less total cost. The dynamic location allocation approach proved to be superior to the static location dynamic allocation approach in increasing and product life cycle demand patterns, while in decreasing and constant demand patterns are approximately the same.

Keywords: Dynamic Supply Chain Network Design; Genetic Algorithm; Multi-objective Optimization.

Summary of the M.Sc. Thesis
"Application of Multi-Objective Optimization Model for Supply Chain Network Design"

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Supply chain network design is one of the widely discussed problems in the supply chain management domain. Supply chain network design is considered as location allocation problem, where locating of different facilities and allocate the quantities to be transported between these facilities decisions are taken with respect to some objectives. The design of a supply chain is critically important for implementing an efficient and effective supply chain.

Most of the developed models targeted the supply chain design problems in which single economical objective is considered. Much less work was done to consider objectives other than the economical ones or to consider multi-objective models. For the multi-objective supply chain network design, the majority of the researchers developed algorithms either to find the Pareto front (a set of non- dominated solutions) for static models or to find only one single non-dominated solution for dynamic models. Many researchers deal with dynamic supply chain problems by taking static location and only dynamic allocation decisions. Few researches deal with dynamic supply chain problems by taking dynamic location allocation decisions.

Due to the combinatorial nature of the problem, as it is proven to be NP-Hard problem, efforts are diverted to heuristic techniques and algorithms, opting to reach near optimal solutions besides they can easily be applied. One of the algorithms which proved to be superior in solving the supply chain network design problem and also finding the Pareto front in general is the Genetic Algorithm.

The purpose of this research is to solve a multi-objective four echelons single product dynamic supply chain network design. The network under study consists of suppliers, plants, distributors and customers echelons. A dynamic location allocation is considered, where plants and distributers can be opened in any period when they are needed, yet any opened location cannot be closed later and allocating quantities between each two successive echelons. The capacities and locations of the suppliers, plants and distributors are known. Customers demands are known. It is not allowed to keep inventory from period to another at any echelon; while, order splitting between any two successive echelons is allowed.

The model explores the Pareto optimal front that includes non-dominated solutions offering different alternatives of designs that trade-off between two objectives. These objectives are minimizing the total cost and maximizing the service level. The total cost consists of plants fixed cost, distributers fixed cost, plants fixed operating cost, distributers fixed operating cost, plants variable operating cost, distributors variable operating cost, transportation costs, unutilized capacity cost, penalty cost.

In order to solve such problem, Genetic Algorithm is used, where one of the Pareto-ranking approaches is used namely non-sorting genetic algorithm II (NSGA-II). The developed chromosome consists of three parts. The first part represents the maximum number of plants and distributors that may be opened at each period. The second part represents the priority of each plant to be opened. The third part is as the same as the second one but for the distributors. Two crossover operators are used, simple crossover for the first part and Position based crossover for both the second and third parts. Also, two mutation operators are used simple mutation for the first part and modified swapping mutation for both the second and third parts. The initial population is generated randomly and the selection function is tournament.

The developed model is tested on 10 benchmark problems to find the minimum total cost in order to test the ability of the new encoding-decoding procedures to solve static single objective supply chain network design problems. The developed model is used to solve dynamic problems to study the effect of changing the different cost parameters, customers locations and potential plants capacity on the Pareto front and the obtained supply chain network designs. The cost parameters are generated and set to be fixed then each of them is changed separately the problem is solved using the developed model to understand their effect on the Pareto front.

Experiments are made to compare between considering single objective and multi-objective while designing the supply chain. Generated problems are used to compare between having different and similar capacity for the potential plants and distributors under similar cost parameters and demands. Other problems are used to compare the performance of static location dynamic allocation and dynamic location allocation approaches under different demand patterns. Each problem is solved twice, once to find the Pareto front with the static location dynamic allocation approach, and the other to find the Pareto front with the dynamic location allocation approach.

The model has proved to be successful in reaching minimum cost of the tried benchmark problems. The results are more practical as it considers the Pareto front for minimizing the total cost and maximizing the service level, other than optimizing only one of these objectives. The results proved that considering different capacities for the potential plants and distributors is better than similar capacity as it leads to less total cost. The dynamic location allocation approach proved to be superior to the static location dynamic allocation approach in increasing and product life cycle demand patterns, while in decreasing and constant demand patterns are approximately the same.

List of Tables