A Web Based Optimization System Using Goal Programming for Supply Chain Network

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***Abstract*— Considering high competitive nature of today's industries, being on plan is very vital for supply chain network of an organization. All the flows of materials from initial suppliers to final customers need to be smooth. Hence, distribution network design is an important strategic decision problem for the supply chain managers. The aim of this research is to propose a web-based Decision Support System (DSS) for optimizing fuzzy distribution network in the context of supply-chain management. A fuzzy goal-programming model has been designed for the proposed DSS to consider the uncertain and imprecise data. This research focuses on four conflict fuzzy goals of (i). all demands must be covered by distribution center, (ii). investment goals for opening new sites considering fix costs, (iii). Investment goals for opening new distribution centers considering fix costs, (iv). Supply costs goals, to meet the optimized results. Hence with those attributes of membership function of goals, the decision makers can apply this model to obtain the investment policy and the achieved level of each individual goal.**

***Keywords*—** *Distribution Network Optimization, Fuzzy Goal Programming (FGP), SCN, Web-Based Decision Support System*

1. Introduction

Supply-chain management and distribution networks design have attracted the attention of many researchers during recent years. Satisfying the customers' demands on time will lead to cost reductions, and will also increase the service level of the supply chain [1]. The best organizations around the world are trying to empower supply-chain management what encompasses all of those integrated activities that bring product to market and create satisfied customers more and more. A supply chain consists of the series of activities and organizations that materials move through on their journey from initial suppliers to final customers [2].

Nowadays with the increasing of industry's competitive nature, it is very critical for organizations that supply chains continue to work as planned, with smooth and uninterrupted flows of materials from initial suppliers through to final customers. In today's world, customers are tightening their requirements in terms of throughput time and perfect-order delivery while demanding continuous reductions in supply chain cost. At this point, distribution network design (DND) emerges as a major problem faced by the supply chain managers. DND problem consists of selecting locations to install factories, warehouses, and distribution centers; assigning customers to serving facilities; and interconnecting facilities by flow assignment [3].

To design and solve a distribution network problem, Decision Support System (DSS) is a useful methodology. DSS helps to manage supply chain networks effectively and efficiently.
The advantages of DSS can be listed as obtaining real data, documents, models or knowledge to decision makers. In addition DSS is a tool that helps to achieve better understanding of business, provide fast response to unexpected and uncertain situations, minimize cost and time, obtain better decisions and better use of data resources assuring more effective teamwork and visualizing graphical information [4].

Moreover, by using Web-based DSS, the benefits that wide accessibility, ease of use, portability, effectiveness and time reduction can be achieved and reduction of limitations such as poor

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maintainability, poor flexibility and less reusability are provided [5], [6].

Decision making problems have complexity and limitations arising from uncertain and imprecise data increase. Fuzzy set theory can be used to deal with uncertainty in different disciplines, such as operations research, management science, control theory and artificial intelligence [7]. Fuzzy goal programming is one of the most powerful decision making tools based on the fuzzy set theory and expectation levels.

The inspiration of this study is to present a web-based Decision Support System (DSS) for distribution network optimization with fuzzy goal programming basis. The rest of this paper is organized as follows. In Section 2, literature regarding to the distribution network design is reviewed. In Section 3, fuzzy goal programming method is explained. In Section 4 and 5, web-based DSS architecture and fuzzy goal programming model (MILP) are described respectively.

2. Literature Review

Facility location theory is the most important base that developed mathematical models of network design. Recent literature reviews on supply chain management and facility location are introduced by Arabani and Farahani (2012), Van der Vaart and van Donk (2008), Gebennini *et al.* (2009) and Melo *et al.* (2009). This Literature leads us to a large amount of researches and technics for designing and control of complex distribution systems. [8].

Pyke and Cohen (1993) succeeded to propose a mathematical programming based model to design an integrated supply chain that involves manufacturers, warehouses and retailers using stochastic sub-models. Ozdamar and Yazgac (1997) developed a distribution/production system, which involves a manufacturer center and its warehouses. Schütz *et al.* (2009) presented a supply chain design problem modeled as a sequence of splitting and combining processes. Ahumada and Villalobos (2009) worked on the main articles in the field of production and distribution planning for agri-foods based on agricultural crops. Pishvae *et al.* (2010) developed a mathematical model designing an integrated logistics network which emphasised on necessity of avoiding the sub-optimality caused by a separate, sequential design of forward and reverse logistics networks.

Stochastic programming methods were the main themes of the previous studies focusing on the uncertainty in logistics network design. . Though, the high computational complexity of stochastic programming models and insufficient historical data of uncertain parameters are main causes of inappropriateness of this method for real life cases . To accomplish this task, the fuzzy mathematical programming method, which is an effective tool for handling uncertainty, is recently used in the problems related with logistics network design. A fuzzy multi-objective linear programming model with piecewise linear membership function to solve integrated multi-product and multi-time period production/distribution planning decisions problems with fuzzy objectives was proposed by Liang (2008). Afterwards, a model which integrates the network design decisions in both forward and reverse supply chain networks offered by Pishvae and Torabi (2010), besides, it incorporates the strategic network design decisions along with tactical material flow ones to avoid all the sub-optimalities led from separated design in both parts. To solve the proposed possibilistic optimization model, an interactive fuzzy solution approach is developed combining a number of efficient solution approaches. A fuzzy programming tool used by Qin and Ji (2010), to design the product recovery network. Three types of optimization models are proposed based on different criteria and some properties of them are investigated. The solvation of the offered models, was a hybrid intelligent algorithm, which combined fuzzy simulation, and genetic algorithm. Percin and Min (2013) created a fuzzy decision making methodology for selection of 3PL (third part logistics provider).

Every organization has some special levels of expectance, which are described as goals. To achieve these level of expectance, we need a very special tool to consider all factores and give us a model. Practically usefulness of Fuzzy Goal Programming (FGP) have been proven through many applications. Pickens and Hof, (1991) mentioned that these applications are useful in many different fields such as the selection of the sequence of timer harvests applied over time to a forest, the stochastic transportation problem under budgetary constraint (Chalam, 1994), the control problem (Stewart, 1992), the solid waste management (Chang and Wang, 1996, 1997) and the water quality management problem (Lee and Wen, 1997). Other investigations include the expert system (Rasmy et al., 2002) and portfolio selection (Parra et al. 2001). Pendharker (1997) for application of production and operation management, applied a fuzzy linear programming model aimed production planning in coal mines, while multi-objective project network problem was the subject that Arikan and Güngör (2001) investigated, and a fuzzy goal programming method for vendor selection in a supply chain was proposed by Kumar et al. (2004). The land-use planning problem in agricultural system modelled and solved by, Biswas and Pal (2005) using the fuzzy goal programming technique. The importance of the machine selection problem in building an FMC, gives rise this paper, implements the machine purchasing problem constrained by machine speed, utility and precision for an FMC via the fuzzy goal programming model with four fuzzy goals: number of machines, total floor space, total purchasing cost, and total productivity [9].

When considering the literature of supply chain management and fuzzy goal programming, it is revealed that there is insufficient number of papers handling the distribution network optimization problem with fuzzy parameters. To the best of our knowledge, there is no study presenting a web-based DSS using fuzzy goal programming model to solve above-mentioned problem in uncertain conditions. In this study, imprecise parameters and fuzzy situation in distribution network optimization is addressed. A web-based DSS architecture is presented. Furthermore, a fuzzy goal programming model is proposed for the web-based DSS architecture.

3. Fuzzy Goal Programming

According to the Girod and Triantis (1999), the information level of decision makers depend on the decision-maker's technology knowledge and his/her production experience. In this case fuzzy numbers can be used as a constraint to define the information level. In this study, all occurrences of constraints each input and output values are chosen from closed interval [10].

3.1. The FGP Models

Goal programming (GP) model was developed by Charnes and Cooper in early 1961 as a linear model. As an advantage, GP is modelling while considering complex objectives, moreover it helps to simplify designed system. In addition, Multiple objectives are considered in GP according to the goals. The main objective function is minimized the weighted sum of deviations from respective goal [11].

Goal programming problems can be divided into two parts which are Non pre-emptive and Pre-emptive goal programming. Non pre-emptive has the same levels of goals importance and the Pre-emptive goal programming has a hierarchy of priority levels for the goals.GP models has three main parts. These are objective function, a set of goal constraints considering target values expectations, and non-negativity requirements. When considering real world applications, fuzziness can be used in target values associated with each goal. Therefore, fuzzy sets theory can be analysed in recent researches [12]. μ can be denoted as membership function.

The grade of membership functions can be vary on between 0 and 1.Many types of membership functions can be used. Also for different analysis; diverse membership functions, such as linear, piecewise linear, exponential, and hyperbolic functions can be used in studies. For inequalities or equal relationships the non-increasing and non-decreasing linear membership functions are implemented for the analysis. Fuzzy objective can be obtained in a fuzzy environment by the intersection of those membership functions corresponding to fuzzy objectives [13], [14].

Zimmermann (1978) was the first one who developed a fuzzy programming approach for linear programming problems with several objectives. Dealing with fuzzy priority helped Narasimhan (1980) to propose a complex method for dealing with the goal-programming problem with fuzzy goal and discussed an approach. Later, Hannan (1981, 1982) introduced a simplified procedure to formulate a FGP problem and pointed out the distinction between the fuzzy goal programming and fuzzy multi-criteria programming. Ignizio (1983) tried to do documentation and reviewing the history of fuzzy goal programming.

Rubin and Narasimhan (1984) proposed the methodology, which was based on the use of a nested hierarchy of priorities for each goal. Demonstration of a computational algorithm for solving an FGP problem with symmetrical triangular membership functions of fuzzy goals and preemptive priority structure was the other subject that Tiwari et al. (1986) mentioned. Subsequently, these authors introduced an additive model, which used arithmetic addition to aggregate the fuzzy goals to construct the relevant decision function [15]. Tiwari et al., 1986 and Chen 1994, tried to provide a modified solution approach that reduced the number of sub-problems. Examination of the fuzzy nonlinear goal programming problem was the important issue that Yang and Ignizio (1991), Rao et al., (1992), Roy and Maiti (1998) worked out on it. Furthermore, Kim and Whang (1998) proposed the unequal weight unbalanced triangular membership functions with a tolerance approach to solve an FGP problem. Pre-emptive structure via utilizing a penalty cost was the approach providing by Wang and Fu (1997) to solve the FGP problem. In order to solve GP problems with pre-emptive priority for achieving of the highest degree of each of the membership function, motivated Pal and Moitra (2003) to propose a multi-stage DP model. The characteristics of DP helped Arora and Gupta (2009) to present an interactive FGP method for bi-level programming problems.

3.2. FGP Model Structure

From the mentioned description, one can derive the four goals for supply chain network web based optimization problem as:

(i). All demands must be covered by distribution center.

(ii). Investment goals for opening new sites considering fix costs.

(iii). Investment goals for opening new distribution centers considering fix costs.

(iv). Supply costs goals.

According to Zimmermann (1978) and below described notations, a linear membership function μ_t for the t[th] fuzzy goal $G_t \le g_t$ can be expressed as:

Notations:

G_i : The tth goal function.

L_t : The lower tolerance limit for the tth fuzzy goal.

U_t : The upper tolerance limit for the tth fuzzy goal.

g_t : The aspiration level of the tth fuzzy goal.

μ_t : The grade of membership or achievement level of goal t.

$$\mu_t = \begin{cases} 1 & ,if \quad G_t \le g_t \\ \dfrac{U_t - G_t}{U_t - g_t} & ,if \quad g_t \le G_t \le U_t \\ 0 & ,if \quad G_t \ge U_t \end{cases}$$

And for the case of $G_t \ge g_t$

$$\mu_t = \begin{cases} 1 & ,if \quad G_t \ge g_t \\ \dfrac{G_t - L_t}{g_t - L_t} & ,if \quad L_t \le G_t \le g_t \\ 0 & ,if \quad G_t \le L_t \end{cases}$$

4. DSS Architecture

"Portneo Optimizer" which the proposed DSS is analysed the supply chain network operations of the company from suppliers to customers. There are four layers in the network, these are suppliers which provides raw materials, plants, distribution centers and customer. Raw materials are processed in plants and finished products are sent to the distribution centers [8]. Figure 1 represents the supply chain network.

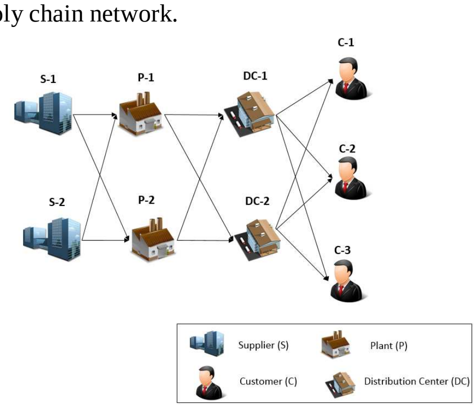

Figure 1. Supply chain network

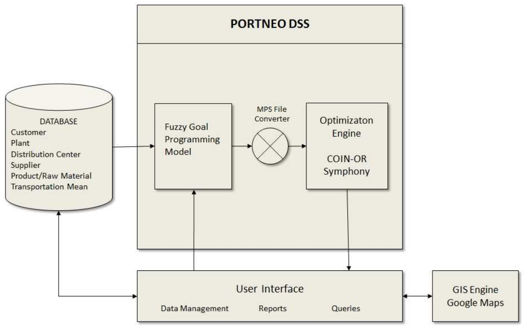

Figure 2. Portneo DSS Architecture [8].

The Figure 2 represents the architecture of DSS.As seen in the Figure 2, database, optimization engine, GIS engine and user interface are the components of DSS. Databases are created by using MySQL and user interfaces are designed in Microsoft Silverlight technology for the Web-based optimization system. Google Maps is used as GIS Engine; additionally COIN-OR Symphony is used as the open-source optimization solver in the DSS (COIN-OR Symphony Project)[8].The figure 3 and 4 shows the user interfaces for network building and location determination. The goal programming model is constructed using the input data and then converted into an .mps file.

The .mps file is used by Symphony. Optimization is provided and by using solutions, user interface are used to create reports. Different scenarios can be considered by changing parameter values. Google maps can be used to calculate the road distances and indicate the locations of each facility. Figure 5 depicts interface for location determination using Google Maps User interface for network building. In addition the graphical representation of supply chain network is designed.

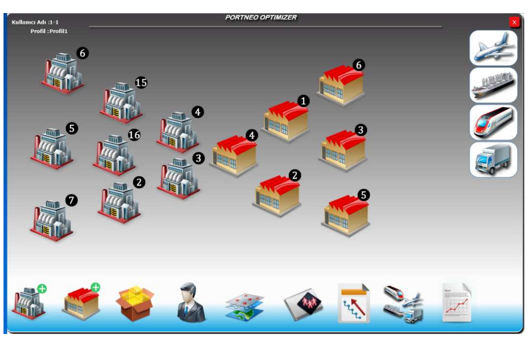

Figure 3. User interface for network design [8].

Figure 4. User interface for network design problem [8].

Figure 5. User interface for location map[8].

5. Fuzzy MILP Model

In the proposed DSS, Supply chain network's entities are suppliers, production plants, distribution centers and customers. Firstly, raw materials are sent from suppliers to production plants with different types of transportation vehicles. Finished products are shipped to the distribution centers from plants. Finally, customer demands are met by the distribution centers. Multiple distribution centers and production plants can be used to provide demand to customer completely. As customer demand, fixed costs of opening plants and distribution centers have fuzzy values, on the other hand parameters have crisp values in the model. The parameters of the model are given below [8]:

According the assumptions following goals are described:

(i). $Q_{ejv} \geq \hat{\delta}_j = g_1$.

(ii). $\hat{Fp}_i \leq$ Considered maximum investment level (g_2)

(iii). $\widehat{Fd}_i \leq$ Considered maximum investment level (g_3)

(iv). Supply cost $\leq$ considered cost level (g_4)

Notations:

P : Number of customer demand points

T : Number of potential production plants

S : Number of suppliers

V : Number of transportation vehicles

J : Potential customer set

D : Location number of potential distribution centers

$\widehat{\delta}_j$: Annual demand of customer j

Cp_i : Capacity potential of production plant of site i

Cs_h : Supply capacity of supplier h

Cv_v : Transportation capacity of vehicle p

Cd_i : Capacity potential of e site distribution center

$\widehat{Fp}_i$: Fixed cost of opening a plant in site i

$\widehat{Fd}_i$: Fixed cost of opening a distribution center in site e

$\widehat{c}_{hiv}$: Unit cost of shipping from hth supplier to i^{th} production plant site with the vth vehicle

$\widehat{c}_{iev}$: *Unit* cost of production and shipping from ith production plant site to the eth distribution center with the vth vehicle

$\widehat{c}_{ejv}$: Unit cost of shipping from eth distribution center to the jth customer with the vth vehicle

The goal of the DND model is to identify locations of production plants and distribution centers as well as transportation vehicles and quantities shipped between various points that minimize the total fixed and variable costs.

The decision variables are given below:

Q_{hiv} : Shipped quantity amount from hth supplier to i^{th} production plant site with the vth vehicle

Q_{iev} : Shipped quantity amount from ith production plant site to the eth distribution center with the vth vehicle

Q_{ejv} : Shipped quantity amount from eth distribution center to the jth customer with the vth vehicle

$$y_i = \begin{cases} 1 & \textit{if production center is placed at site } i \\ 0 & \textit{Otherwise} \end{cases}$$

$$y_e = \begin{cases} 1 & \textit{if distribution center is placed at site } e \\ 0 & \textit{Otherwise} \end{cases}$$

The problem formulation as a fuzzy Goal programming:

$$\textit{Maximize} \quad f(\mu) = \sum_{t=1}^{4} \mu_t$$

Subject to

$$\mu_1 = \frac{G_1 - L_1}{g_1 - L_1}$$

$$\mu_t = \frac{U_t - G_t}{U_t - g_t} \quad , t = 2,3,4$$

$$G_1 = \sum_{e \in D} \sum_{v \in V} Q_{ejv}$$

$$G_2 = \sum_{i \in T} \widehat{Fp}_i \times y_i$$

$$G_3 = \sum_{e \in D} \widehat{Fd}_e \times y_e$$

$$G_4 = \sum_{v \in V} \left(\sum_{h \in S} \sum_{i \in T} \widehat{c}_{hiv}.Q_{hiv} + \sum_{e \in D} \sum_{i \in T} \widehat{c}_{iev}.Q_{iev} + \sum_{e \in D} \sum_{j \in J} \widehat{c}_{ejv}.Q_{ejv} \right)$$

$$\sum_{i \in T} \sum_{v \in V} Q_{hiv} \leq CS_h \quad , h \in S$$

$$\sum_{v \in V} \left(\sum_{h \in S} Q_{hiv} - \sum_{e \in D} Q_{iev} \right) \geq 0 \quad , e \in D$$

$$\sum_{j \in J} \sum_{v \in V} Q_{ejv} \leq Cd_e \times y_e \quad , e \in D$$

$$\sum_{h\in S}\sum_{i\in T}Q_{hiv}+\sum_{i\in T}\sum_{e\in D}Q_{iev}+\sum_{e\in D}\sum_{j\in J}Q_{ejv}\le Cv_v$$

$$0\le \mu_t \le 1, t=1,2,3,4$$

$$y_i, y_e \in \{0,1\}$$

$$Q_{hiv}, Q_{iev}, Q_{ejv} \ge 0$$

6. Conclusion

Nowadays, Decision support systems are integrated into business processes and information systems. As the aim of this study; a web-based DSS using fuzzy goal programming model for supply chain network in uncertain conditions, is presented. To design and solve a distribution network problem, Decision Support System (DSS) is a useful methodology. DSS helps to manage supply chain networks effectively and efficiently. Fuzzy logic helps to optimize networks for specific uncertainty, so the planner can understand the range of optimum network planning costs. To do this, a user friendly, web-based DSS architecture framework is designed.

The visual capabilities and ease of use are superiorities of the proposed DSS. Different fuzzy programming methods and implementation part of DSS for distribution network design can be added for future research.

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