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A Goal Programming Approach for Multiple Objective Green Supply Chain Managment

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A GOAL PROGRAMMING APPROACH FOR MULTIPLE OBJECTIVE GREEN SUPPLY CHAIN MANAGMENT

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I. Introduction

Supply chain management system is established by money, component, processes, information flow and the operation in supply chain management and SCM is the most important economic activities in the business. We deal with all aspects of logistic in supply chain management such as transportation, warehouse and inventories, and address are related environmental aspect such as emissions of greenhouse gases, noise that these are the main cause of global warming, air and water pollution , acid rain, etc.

We should balance economics, environmental and social performance to achieve sustainable development is a major business objective of organization due to the challenge of increasing environmental laws and regulations, demanding organizational stake holders pressures and gaining competitive advantage's (Boiral,2006;Lee.et al.,2009;Jabbour and Jabbour ,2009). Recently researches shows environmental challenge, such as green decreases by limited energy and resources and green supply chain (GSC) management is now suggested as an efficient tactics to decrease.

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Operation research (OR) help us to described it as the science, traditionally supply chain management focuses on minimizing the cost of existing processes but todays it is not only profit, in our opinions operation research must consider impact to be more efficient, so OR help us to identify the trade-offs between environmental aspect such as emission of greenhouses costs also OR suggests more efficient of resource and facilities. An important method in this respect is multi objective decision that reduction emission and decreases the benefits of supply chain.

The body of this paper comprises six sections. This paper starts with this introductory section, which provides a general idea about the research topic. Section2 reviews the literature related to a sustainable facility location in green supply chain, practices and performance for sustainable facility location in green supply chain. Section3 addresses the methodology and Section4 presents themultiple objective decision making model. Section5 illustrates the applicability of the model through a numerical. Finally, Section6 relates the conclusions, implications and poses questions for future research, there by fulfilling the purpose of the paper.

II. Literature Review

In order to obtain the greatest benefit from environmental and society, firm must integrate all member in the green supply chain (GSC)(Lee, Kang, Hsu, & Hung,2009).Hence , strategic intercommunity with economically powerful with environmentally socially should be considered within green supply chain(GSC) to reducing lead time and cost ,eliminate wastage, improving quality, so we focus on the structure and discuss the main physical drivers in GSC. We will not different between green logistics and green supply chain management while we mainly focus on transportation; we take a border (supply chain) perspective.

There is a whole stream of research on facility location, which demonstrated by OR, that focuses trade-off the number and location of distribution centers (DCs). Environmental aspects of network supply chain design and facility location recently received considerable attention. Li et al. (2008) with a bi objective attempted to maximize the cost and minimize the emission by mathematical programing methodology to optimize distribution center location center location taking into with consideration transportation cost and transportation carbon emission. Mallidis et al.(2010) prop use a multi-objective mixed integer programming model (MIP) to examine how distribution center location (DCs) leasing transportation and warehouse operation so decisions on using dedicated versus shared warehouse and transportation and that model by focus on the transportation operation minimizes the amount of CO2 and PM emissions. Diabat and Simchi-levi (2009) they consider MIP model with a cap on the amount of CO2 that CO2 emission come from warehouse, plants and transports to customers ,finally they show that supply chain cost increase if the cap become tighter. Ramudin and Chaabane (2010) they consider internal and external control mechanisms to propose strategic planning model for supply chain network design. Chaabane et al.(2012) extend the previous approach and introduce a mixed-integer linear programming based on supply chain design that consider life cycle assessment (LCA) ,principles the traditional material balance constraints at each node in the supply chain. Herris et al. (2011) use of simulation model. They consider both logistics cost and CO2 emissions in supply chain optimization. They consider different fright vehicle utilization ratio to account the number of depots the uncertain factor in supply chain make the incorrect estimate. Thus uncertain factor of demand will be considered to support more realistic decision to estimate facility location. Within uncertain patterns, fuzzy numbers will be used to describe this uncertain factor. those fuzzy mathematical programming will be adopted for modeling Wang et al.(2010) Listes and Dekker(2005) they use a stochastic programming model by because of the uncertain demand in the model, As a result this paper shows the product recovery network design in different location. Listes (2007) and Salema et al. (2007) have focused on the uncertainly issues and used specific scenarios to illustrated it. Basic factors that usually create uncertain in the supply chain management are demand, landfilling and recovery rate.

III. Fuzzy Set and Fuzzy Number and Fuzzy Programming Solution Approach

In our real-life we faced many uncertain situations so decision makers cannot use exact value such as exact date and exact number /rate.

Fuzzy logic is an approach to computing based on "degrees of truth" rather than the usual "true or false" (1 or 0) Boolean logic on which the modern computer is based. The idea of fuzzy logic was first advanced by Dr. LotfiZadeh of the University of California at Berkeley in the 1960s. Dr. Zadeh was working on the problem of computer understanding of natural language. Natural language (like most other activities in life and indeed the universe) is not easily translated into the absolute terms of 0 and 1. (Whether everything is ultimately describable in binary terms is a philosophical question worth pursuing, but in practice much data we might want to feed a computer is in some state in between and so we need another way to describe its).Fuzzy logic seems closer to the way our brains work.

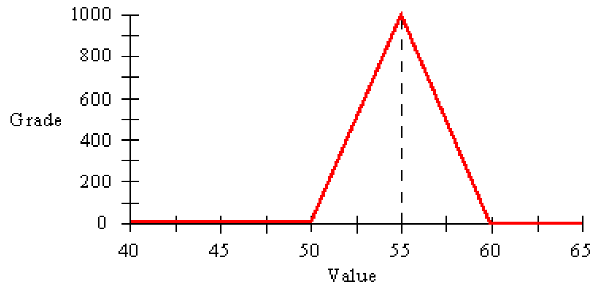
It may help to see fuzzy logic as the way reasoning really works and binary or Boolean logic is simply a special case of it.A fuzzy number is a quantity whose value is imprecise, rather than exact as is the case with "ordinary" (single-valued) numbers.

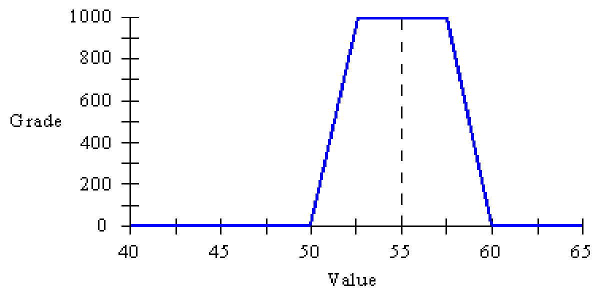
A Fuzzy set $\widetilde{A}$ in X is set of ordered pairs:

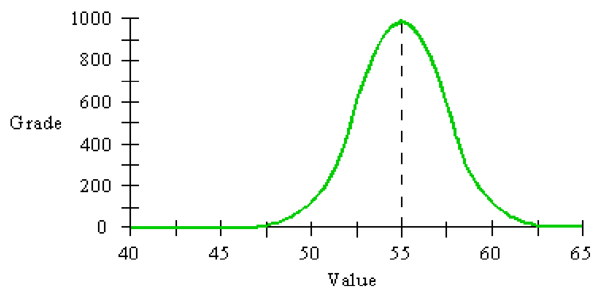
$$\widetilde{A} = \{(x, \mu\widetilde{A}\,(x) \mid x \in X\}$$

$\mu\widetilde{A}\,(x)$ is called the membership function or grade of membership ,often it is appropriate to consider those element of the universe that have nonzero degree of membership in a fuzzy set also membership function can be used in the fuzzy set.

This member in the fuzzy set may have a larger or smaller membership grade, this membership grades are very often represented by real value ranging in the closed interval between 0 and 1. The red curve (top) represents a triangular fuzzy number; the blue curve (middle) shows a trapezoidal fuzzy number; the green curve (bottom) illustrates a bell-shaped fuzzy number. These three functions, known as membership functions, are all convex (the grade starts at zero, rises to a maximum, and then declines to zero again as the domain increases). However, some fuzzy numbers have concave, irregular, or even chaotic membership functions. There is no restriction on the shape of the membership curve.







Nowadays fuzzy programming approach is being applied for solving multi objective linear programming models. There, becausefuzzy approaches is that they able to measure satisfaction of each objective, in Warners (1988)fuzzy and operator and Tiwari et al (1987)weighted additive approach the FGP are introduced. Goal approach is one of the most powerful, multi –objective decision making approaches in practical decision making. However there are two important difficulties when apply GP to the real life. First one is that decision maker to get desirable level of goal mathematically and the second is the need to optimize simultaneously all goal.in this situations, fuzzy set can help us.

Applying fuzzy set theory (Zadeh, 1965) into goal programming has the advantage for decision maker, which can then be qualified by some natural language term. When vague information related to the objectives are present then the problem can be formulated as a fuzzy goal programming problem. Someof the researchers which worked on the decision problem using in the Fuzzy goal programing theory are presented: such as, Narasimhan (1980) was first on that consider the Fuzzy set theory in goal programming. Narasimhan and Rubin (1984), Hannan (1981), Ignizio (1982) and Tiwari et al, (1986, 1987) applied the fuzzy set theory in the goal programing. Ramik (2000), Rao et al. (1988), Wang and Fu (1997), Mohamed (1997), Ohta and Yamaguchi (1996), El-Wahed and Abo-Sinna (2001) and Mohammed (2000).

Sometimes the coefficients are defined as triangular fuzzy numbers; the fuzzy vector is defined as follow

$$\tilde{c} = (c^p + c^m + c^0)$$

There are different approaches to solve the problem;one of the approaches combining conventional parameters fuzzy numbers or fuzzy variable stands for a factor in this case is a definite problem into a lineament problem. A combination of methods, parameters is fuzzy numbers using the following formula:

$$C = \frac{c^p + 4 * c^m + c^0}{6}$$

In science, operations research, different methods to solve multi-objective optimization problems when there are definitive. One of the best ways is to use a phased approach, after application of fuzzy sets is established. Membership functions optimally with any of these methods try to optimize the degree of increase. Therefore, it is first necessary to obtain Optimized membership function.

$Z_1^l = min\ (C^m - C^p)\ X$
$AX \le b$
$X \ge 0$
$Z_1^u = max\ (C^m - C^p) X$
$AX \le b$
$X \ge 0$

$$\mu_{z1}(z_1) = \begin{cases} 1\ ; & Z_1 \le Z_1^l \\ \frac{Z_1^u - Z_1}{Z_1^u - Z_1^l}\ ; & Z_1^l \le Z_1 \le Z_1^u \\ 0\ ; & Z_1 \le Z_1^u \end{cases}$$

So that we have:
$Z_1 = (C^m - C^p) X$

Optimized membership functionZ_2 andZ_3 the same way the following objectives are achieved:

$$\mu_{z2}(x) = \begin{cases} 1\ ; & CmX > Z_2^l \\ \frac{CmX - Z_2^l}{Z_2^u - Z_2^l}\ ; & Z_2^l \le Z_1 \le Z_1^u \\ 0\ ; & CmX < Z_2^l \end{cases}$$

$$\mu_{z1}(z_1) = \begin{cases} 1\ ; & (Cp - Cm)X > Z_3^u \\ \frac{(Cp - Cm)X - Z_3^l}{Z_3^u - Z_3^l}\ ; & Z_3^l \le (Cp - Cm)X \le Z_3^u \\ 0\ ; & (Cp - Cm)X < Z_3^l \end{cases}$$

Eventually it becomes a single objective linear programming problem is determined as follows:
Maximize λ

Subject to
$\lambda(Z_1^u - Z_1^l) \le Z_1^u - (Cm - Cp)X$
$\lambda(Z_2^u - Z_2^l) \le CmX - Z_2^l$

$\lambda(Z_3^u - Z_3^l) \leq (Cm - Cp)X - Z_3^l$

$AX \leq b$

$X \geq 0$

$\lambda \in [0,1]$

the main producers of gases are the industrial companies, for green planning the network of supply chain management ,many companies have set voluntary target in term of greenhouse gases emission or set a subject to a new regulation that named capof greenhouse gases emissions ,when the emission carbon dioxide is under the approved emission Scheme carbon dioxide is tradable, also based greenhouse gases emissions reduction target often established by government .the difference between the proposed target and actual target maybe offset by the other things. Also companies that have emission less than the cap target will have sold their credit to make the generate profit.

I this paper we used the upper bound for green supply chain that is variable.

IV. Problem Definition and Modeling

Consider a supply chain network G=(N,A), where N set of node and A set of arc .N composed by the set of supplier ,S, facilities, and customer, C, in this models we consider the CO2 emission in each process of the whole network. Let me define:

a) Parameters

c^P unit of transportation cost in tons per km for product p

$\widetilde{d_k^p}$ The demand of customers for product

s_i^p The supply of supplier for product

d_{ij}^p Transportationdistance for product from supplier i to facility j

d_{jk}^p Transportationdistance for product from facility j to customer k

r_j^p Capacities consumed by handling a unit of products in facility j

f_j Set of cost of facility j

u_j Thehandeling capacity in facility j

l_j^p Handling cost of product p in facility j

w_α CO_2 emissions factor of a facility, in tons per ft^3

w_β CO_2 emissions factor per unit distance, in tons per km

L the lower bound of total produced emission

U the upper bound of total produced emission

b) Decision variable

x_{ij}^p The flow of production p from supplier i to facility j

x_{jk}^p The flow of production p from facilityj to customer k

z_{jl} Facility j with environment protection level l

c) Objective function

$$\mathrm{Min} \sum_{p\in P}\sum_{i\in S}\sum_{j\in F} c^p d_{ij}^p x_{ij}^p + \sum_{p\in P}\sum_{j\in J}\sum_{k\in C} c^p d_{jk}^p x_{jk}^p + \sum_{j\in F}\sum_{l\in L} f_{jl} z_{jl} + \sum_{p\in P}\sum_{j\in F} l_j^p \sum_{i\in S} x_{ij}^p$$

$$\mathrm{Min} \sum_{j\in F}\sum_{p\in P}\sum_{l\in L} w_\alpha z_{jl}^p u_j + \sum_{p\in P}\sum_{i\in S}\sum_{j\in J} w_\beta d_{ij}^p x_{ij}^p + \sum_{p\in P}\sum_{j\in J}\sum_{k\in C} w_\beta d_{jk}^p x_{jk}^p$$

$$\sum_{i\in S} x_{ij}^p - \sum_{k\in c} x_{jk}^p = 0 \quad \forall j \in F, \forall p \in P \qquad (1)$$

$$\sum_{j\in F} x_{jk}^p = \widetilde{d_k^p} \quad \forall k \in C, \forall p \in P \qquad (2)$$

$$\sum_{j\in F} x_{ij}^p \leq s_i^p \quad \forall i \in S, \forall p \in P \qquad (3)$$

$$\sum_{i\in S}\sum_{p\in P} r_j^p x_{ij}^p \leq u_j z_{jl} \quad \forall j \in F, \forall l \in L \qquad (4)$$

$$\sum_{l\in L} z_{jl} \leq 1 \quad \forall j \in F \qquad (5)$$

$$L \leq \sum_{j\in F}\sum_{p\in P}\sum_{l\in L} w_\alpha z_{jl}^p u_j + \sum_{p\in P}\sum_{i\in S}\sum_{j\in J} w_\beta d_{ij}^p x_{ij}^p + \sum_{p\in P}\sum_{j\in J}\sum_{k\in C} w_\beta d_{jk}^p x_{jk}^p \leq U, \forall i \in S, \forall j \in F, \forall k \in C, \forall p \in P, \forall l \in L \qquad (6)$$

$$x_{ij}^p, x_{jk}^p \geq 0 \quad \forall i \in S, \forall j \in F, \forall k \in C, \forall p \in P, \forall l \in L \qquad (7)$$

$$z_{jl} \in \{0,1\} \quad \forall j \in F \quad \forall l \in L$$

The demand in this model is uncertain so we need to change it to DE fuzzy so in this paper use of under formula:

$$d_j^p = \frac{d(u)_j^p + 4d(m)_j^p + d(l)_j^p}{6} \qquad (8)$$

Above model provide a multi-objective mixed-integer programing for the supply chain network design problem, this model consider environmental investment decision in the supply network design, this model introduce a new category of decision variable to consider environmental issues, and also it can use e specific product or a category of products.

This paper consider two objective functions, first objective measures the total cost first and second part is the transportation cost and the third part is the fixed set up cost and last part is the total handling cost. Second objective measures the total CO2 emission; the first part measures the total emission in the all facilities and the other part measures emission during the arc.

Constraint (1) note that our model there is no inventory stored in each facility. Constraint (2) requires that the all of the fuzzy demands should be satisfied. Constraint (3) shown that each product p flowing out of the supplier I should not exceed the total supply amount of suppliers. constraint (4)state that the total processing handling in facility j should not exceed the capacity if the facility is open(if facility j is open yj=1 and otherwise yj=0).constraint (5) requires that decision makers choose one level for facility j. constraint (6) consider value of emission cap(a carbon-capped supply chain network problem Diabat et al.(2009) .constraint (7) restrict x_{ij}^{p}, x_{jk}^{p} are non-negative and yj are binary integer variable and zj are integer in interval [0,1].

Assumptions:

1. In this model do not consider the bill of material
2. We only consider CO2 emission which is a very popular environment index and can be measured easily.
3. We assume that carbon emission in this model come from two sources:
   a) the facility that the amount of emission is proportional to the volume of this facility
   b) From the transportation vehicle that traveled distance between nodes.
4. We use zjl that means the facility j with l level of environment protection and higher level need more sophisticated equipment or technology is installed.
5. value of emission parameters used according to (a carbon-capped supply chain network problem Diabat et al.(2009))
   $w_{\alpha}=0.5$
   $w_{\beta}=0.7$

With this model decision maker should determine:

1. Where to set up facility
2. Which supplier should be selected for each facility
3. Which facility should be selected for each costumer
4. How many/much produced should be transported each supplier to each facility
5. How many/much produced should be transported each supplier to each facility

V. Computational Experiment

We consider 8-node network there are in total 2 supplier, 3facilities and 3 customers in this network with this data and this solved by solver Excel 2010

P=1

CO_2^{CAP}= *(L=1600, U=2500)*

$\tilde{d}_{C1}^{1}$=(23,26,29),$\tilde{d}_{C2}^{1}$=(22,26,30) ,$\tilde{d}_{C3}^{1}$=(35,38,41)

$s_1^1 = 60$,$s_2^1 = 80$

$d_{S1a}^1 = 10, d_{S1b}^1 = 12, d_{S1c}^1 = 22, d_{S2a}^1 = 15,$

$d_{S2b}^1 = 11, d_{S2c}^1 = 21, d_{ab}^1 = 20, d_{ac}^1 = 18,$

$d_{bc}^1 = 16$

$, d_{aC1}^1 = 21, d_{aC2}^1 = 18, d_{aC3}^1 = 14,$

$d_{bC1}^1 = 12, d_{bC2}^1 = 15, d_{bC3}^1 = 11, d_{cC1}^1 = 13,$

$d_{cC2}^1 = 14, d_{cC3}^1 = 17$

C^p=5$

f_a= 2090 ,f_b=2260,f_c=2210

$r_A^1 = 1, r_B^1 = 1, r_C^1 = 1$

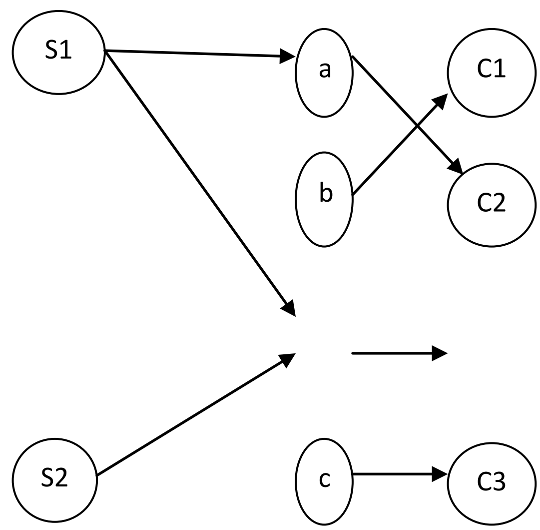
$u_A = 60, u_B = 80, u_C = 100$

Result:

Obj_1^u=15520, obj_1^l=23560

Obj_2^u= 1637, obj_2^l=2500

Suppliers facilities customer



$x_{S1a}^1 = 1, x_{S1c}^1 = 38, x_{S2b}^1 = 51$

$x_{bc}^1 = 32$

$x_{aC2}^1 = 1, x_{bC1}^1 = 26, x_{bC2}^1 = 25, d_{cC3}^1 = 38$

VI. Conclusions

In this paper, we introduce a green supply chain network design model with fuzzy demand which facility location is the main problem the main causes of cost in the green supply chain are the fixed costs to set up a facility, the transportation cost to move goods and the cost of emissions generated on the shipping lanes. The model is a multi-objective model which consists of minimizingtotal cost and environmental influence for solve this model we use of fuzzy method which consider Best and worst objective function value for two objectives then consider membership of them and solve, on the other hand, in this model we consider upper and lower bound for CO2 emission that these bounds depend on the government policy .We use normalized normal Constraint method to solve the model by general EXCEL solver2010. After that, we test the model by a eightnodeexample finally we observethat improving the capacity of the network and increasing the supplyto the facilities can decrease CO2 emission because more distributioncenters be opened to decrease vehicle travel distances.In the network and all of thatminimize the total cost. For The feature our model can be extend with many fuzzy variables with consideration of environmental element in the handling and transportation process, can solvethe uncertain demand with DE fuzzy method, and cansolve it with another solver,You can also considermachine downtime, customer satisfaction, consider the machinery space, consider the different types of machines for transport demand and ... Also be applied to objective functions and constraints.

References Références Referencias

1. Ates, M.A., Bloemhof, J., Van Raaij, E., Wynstra, F., in press. Proactive environmental strategy in a supply chain context; the ideating role of investments. International Journal of Production Research. doi:10.1080/00207543.2011.555426. Available online 5 July 2011.
2. Azapagic, A., Clift, R., 1999. Life cycle assessment and multi objective optimization .Journal of Cleaner Production 7, 135–143.
3. Bauer, J., Bektas, T., Crainic, T.G., 2010. Minimizing greenhouse gas emissions in intermodal freight transport: an application to rail service design. Journal of the Operational Research Society 61, 530–542, doi: org/CORMSIS-09-01.
4. Bektas_, T., Laporte, G., 2011. The pollution-routing problem. Transportation Research B: Methodological 45 (8), 1232–1250.
5. Benjaafar, S., Li, Y., Daskin, M., 2010. Carbon Footprint and the Management of Supply Chains: Insights from Simple Models. <http://www.ie.umn.edu/faculty/faculty/pdf/beyada-3-31-10.pdf> (accessed 24.05.10).
6. Cariou, P., 2011. Is slow steaming a sustainable means of reducing CO2 emissionsfrom container shipping? Transportation Research Part D 16, 260–264.
7. Chaabane, A., Ramudhin, A., Paquet, M., 2012.Design of sustainable supplies chainsunder the emission trading scheme. International Journal of Production Economics 135 (1), 37–49.
8. Diabat, A., Simchi-Levi, D., 2009. A carbon-capped supply chain network problem. In: Proceedings ofthe IEEE international conference of on industrial engineeringand engineering management, USA, pp. 532–527. doi: org/10.1109/IEEM.2009.5373289.
9. DDukic, G.,Cˇesnik, V., Opetuk, T., 2010. Order-picking methods and technologies forgreener warehousing. Strojarstvo 52, 23–31.EEA, 2011.EEA Greenhouse Gas Data (2008).<http://dataservice.eea.europa.eu/PivotApp/pivot.aspx?pivotid=475> (retrieved 12.02.11).
10. El-Wahed, W.F., Abo-Sinna, M.A., 2001. A hybrid fuzzy-goal programming approach to multiple objective decision making problems.Fuzzy Sets and Systems 119, 71–85.
11. Gonzalez-Torre, P.L., Adenso-Diaz, B., 2004. Environmental and reverse logisticspolicies in European bottling and packaging firms. International Journal of Green Logistics, 2010.Research into the Sustainability of Logistics Systems andsupply Chains.<http://greenlogistics.org/> (retrived 16.08.11).
12. Hannan, E.L., 1981. Some further comments on fuzzy priorities. Decision Science 13, 337–339.
13. Harris, I., Naim, M., Palmer, A., Potter, A., Mumford, C., 2011. Assessing the impact of cost optimization based on infrastructure modelling on CO2 emissions. International Journal of Production Economics 131 (1), 313–321.
14. Hervani, A.A., Helms, M.M., Sarkis, J., 2005. Performance measurement for green supply chain management. Benchmarking: An International Journal 12 (4), 330–352.
15. Huppes, G., Ishikawa, M., 2005. A frame work for quantified eco-efficiency analysis. Journal of Industrial Ecology 9 (4), 25–41.
16. Ignizio, J.P., 1982. On the rediscovery of fuzzy goal programming. Decision Science 13, 331–336.
17. Jabbour, A. B. L. S., & Jabbour, C. J. C. (2009). Are supplier selection criteria going green? Case studies of companies in Brazil. Industrial Management & Data Systems, 109, 477–495.
18. Lee, A. H. I., Kang, Y., Hsu, H. C-F., & Hung, H.-C. (2009). A green supplier selection model for high-tech industry. Expert Systems with Applications, 36, 7917–7927.
19. Li, F., Liu, T., Zhang, H., Cao, R., Ding, W., Fasano, J.P., 2008. Distribution center location for green supply chain. In: Proceedings of the IEEE International Conference on Service Operations and Logistics, and Informatics, Beijing, pp.2951–2956. doi: org/10.1109/soli.2008.4683040.
20. Listes, O., Dekker, R., 2005. A stochastic approach to a case study for product recovery network design. European Journ Methods and Applications of Interval Analysis al of Operational Research 160 (1), 268e287.
21. Listes, O., 2007. A genetic stochastic model for supply-and-return network design. Computers & Operations Research 34 (2), 417e442.
22. Macharis, C., Bontekoning, Y.M., 2004. Opportunities for OR in intermodal freighttransport research: a review. European Journal of Operational Research 153,400–416.
23. Mallidis, I., Dekker, R., Vlachos, D., 2010. Greening Supply Chains: Impact on Costsand Design. Retrieved from Erasmus University, Econometric Institute website :< http://repub.eur.nl/res/pub/20375/>.
24. Mohamed, R.H., 1997. The relationship between goal programming and fuzzy programming. Fuzzy Sets and Systems 89, 215–222.
25. Mohammed, W., 2000. Chance constrained fuzzy goal programming with right-hand side uniform random variable coefficients. Fuzzy Sets and Systems 109, 107–110.

26. Narasimhan, R., 1980. Goal programming in a fuzzy environment. Decision Science 11, 325–336.
27. Narasimhan, R., Rubin, P.A., 1984. Fuzzy goal programming with nested priorities. Fuzzy Sets and Systems 14, 115–129.
28. Ohta, H., Yamaguchi, T., 1996. Linear fractional goal programming in consideration of fuzzy solution. European Journal of Operational Research 92, 157–165.
29. QuariguasiFrotaNeto, J., Walther, G., Bloemhof, J., van Nunen, J., Spengler, T., 2009.A methodology for assessing eco-efficiency in logistic networks. European Journal of Operational Research 193, 647–914.
30. Ramudhin, A., Chaabane, A., 2010. Carbon market sensitive sustainable supply chainnetwork design. International Journal of Management Science and Engineering Management 5, 30–38.
31. Ramik, J., 2000. Fuzzy goals and fuzzy alternatives in goal programming problems. Fuzzy Sets and Systems 111, 81–86.
32. Rao, S.S., Tiwari, R.N., Mohanty, B.K., 1988. A preference structure on aspiration levels in a goal programming problem – a fuzzy approach. Fuzzy Sets and Systems 25, 175–182.
33. Salema, M.I.G., Barbosa-Povoa, A.P., Novais, A.Q., 2007. An optimization model for the design of a capacitated multi-product reverse logistics network with uncertainty. European Journal of Operational Research 179 (3), 1063e1077.
34. Tiwari, R.N., Dharmar, S., Rao, J.R., 1986. Priority structure in fuzzy goal programming. Fuzzy Sets and Systems 19, 251–259.
35. Tiwari, R.N., Dharmar, S., Rao, J.R., 1987. Fuzzy goal programming – an additive method. Fuzzy Sets and Systems 24, 27–34.
36. Wang, F., Lai, X., Shi, N., 2011. A multi-objective optimization for green supply chainnetwork design. Decision Support Systems 51 (2), 262–269.
37. Wang, J., Shu, Y.-F., 2005. Fuzzy decision modeling for supply chain management. Fuzzy Sets and Systems 150, 107–127.
38. Werners, B., 1988. Aggregation models in mathematical programming. In: Mitra, G., Greenberg, H.J., Lootsma, F.A., Rijckaert, M.J.,
39. Wang, H.-F., Fu, C.-C., 1997. A generalization of fuzzy goal programming with preemptive structure. Computers & Operations Research 24, 819–828.
40. Zadeh, L. A. (1965). Fuzzy sets. Information & Control, 8, 338–353.
41. Zimmermann, H.-J. (Eds.), Mathematical Models for Decision Support. Springer-Verlag, Heidelberg, pp. 295–305.