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Reverse SCM using Goal Programming

Computer Science

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Jyoti YMCA University of Science and Technology, Faridabad

Neetu Gupta YMCA University of Science and Technology, Faridabad

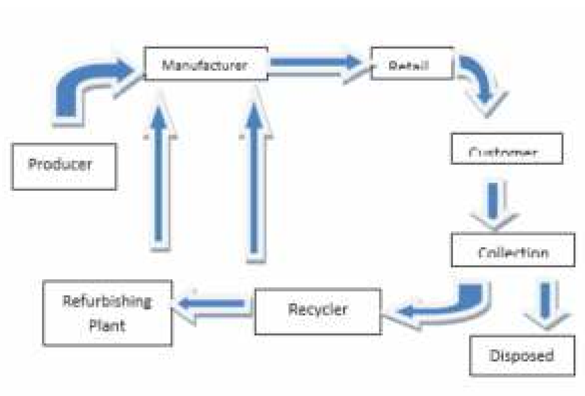
ABSTRACT

The term SCM is generally associated with the loop from producer to the customer but due to introduction of environmental stability and other laws by government the reverse loop i.e reverse logistics emerged. In the recent past the growth of environmental concerns have given 'reuse' increasing attention. The waste reduction efforts have promoted the idea of material cycles and brought in the importance of Reuse, Recycle, Reduce i.e.3R's.Goal programming is an efficient tool in solving various multi objective problems . All complex problems in real situations can be solved using this technique. We have tried to evolve a problem using MOGP technique for various goals (major as well as minor goals).

Introduction:

Supply Chain Management concerns mainly with procurement, production and sales but a company's supply chain doesn't end here. SCM can be applied to return product flows also known as Reverse SCM. It is gaining importance nowadays and moving with an idea of social sustainability. A company needs to consider its product disposal or return by the customers also re-use of products and materials is not a new phenomenon. Metal Scrap brokers, waster paper recyclers and soft drinks (bottle reuse) are all examples that have been around for a long time. In the recent past the growth of environmental concerns have given 'reuse' increasing attention. The waste reduction efforts have promoted the idea of material cycles and brought in the importance of Reuse, Recycle, Reduce i.e.3R's . Reverse Logistics can result in significant savings 'AT&T network systems division has saved nearly $ 100million in 19 months it has been operating a reverse logistics program for its telephone switching equipment.

The complete picture of reverse logistics network is



III.TYPES OF MOGP MODELS:

The basic concept of MOGP is whether goals are attainable or no, an objective may be stated in which optimization gives result as close as possible to the desired goal. Thus, based on definition of objective function MOGP is classified as follows:

A.Multi-goal with equal (no) priorities:

The multi-goal equal priority model is easy to deal with mathematically but is the least practical of all the formulations. Its general model can be stated as follows:

Objective function:

Min $z = \sum_i \; d_i^- + d_i^+$; $i = 1, 2, \ldots, m$

Subject To: $\sum_j \; a_{ij} + d_i^- - d_i^+ = b_i$; $i = 1, 2, , m,$

$j = 1, 2, \ldots., n$

and $x_j, d_i^-, d_i^+ \geq 0$; for all I, j

Here no weights and priorities are assigned in the objective function. Some actual cases may exist where all goals have equal priorities, but the output from an equal-priority model should be examined properly for compatibility.

B. Lexicographic (Pre-emptive) Goal Programming (LGP):

Lexicographic GP simultaneously satisfy various preferentially ordered goals according to the decision making situation through the use of priority coefficients (pi's). All goals (deviational variables) that have a top or first priority are assigned an objective function value of p1, the goals considered to be second in priority are assigned value p2 and the process goes on until all goals are ranked.

The general algebraic representation of LGP is given as:

Objective function:

Lexi min $z = \sum_i \; p_i (d_i^- + d_i^+)$

; $i = 1, 2, \ldots, m$

Subject To:

$\sum_j \; a_{ij} + d_i^- - d_i^+ = b_i$

; $i = 1, 2, \ldots, m,$

$j = 1, 2, \ldots., n$

and $x_j, d_i^-, d_i^+ \geq 0$; for all I, j

The coefficients p1, p2 ,..., are not variables or parameters. They do not assume a numerical value, they simply represent levels for priorities.

The LGP was introduced by Ijiri (1965) and developed by Lee (1972) [19] and Ignizio (1976).Later utilizing Orumie and Ebong (2011) initial table with modification, Orumie and Ebong (2013) discovered a new algorithm for LGP. The procedure considered goal constraints as both the objective function and constraints. The objective function becomes the prioritized deviational variables and solves sequentially starting from the highest priority level to the lowest [3].

C. Weighted Goal Programming (WGP):

In WGP, a differential weight is assigned to each of the objectives (deviational variables), used to reflect difference of importance within the same priority level.

The general algebraic representation of WGP as presented in Ken and Perushek [1],also mentioned in [4] Orumie and Ebong (2014), is given as:

Objective function:

Min $z = \sum_i \; (w_i^- d_i^- + w_i^+ d_i^+)$

; $i = 1, 2, \ldots, m$

Subject To $\sum_j \; a_{ij} + d_i^- - d_i^+ = b_i$

; $i = 1, 2, \ldots, m$,
$j = 1, 2, \ldots, n$
and $x_j, d_i^-, d_i^+ \geq 0$; for all I, j

Where wi- and wi+ are numerical weights associated with negative and positive deviational variables di- and di+ respectively which denotes how far the decision is from the goal and how much the decision has exceeded the goal respectively.

D. Prioritized (Weighted Pre-emptive) Goal Programming:
In this GP problem, both weights and priorities are assigned to the deviational variables in the objective function. Orumie and Ebong [4] explained that, this occurs when the goals can be categorized into groups where the goals within each group are of equal importance, but there are slight differences between the groups in their level of importance. Here, Weighted GP can be used within each group in-turn while Pre emptive GP deals with each group in order of importance.

Various other models have been introduced like:
- Fuzzy Goal Programming:

Apart from GP techniques discussed above, Fuzzy Logic is another technique for multi -objective optimization. The theory of Fuzzy sets is based on a multi-valued logic where in a statement can be partly true and partly false at the same time. In fuzzy logic, the degree of truthfulness of a statement is expressed by a membership function, m, in the range [0,1]. A value of m=0 indicates that the statement is false, while m=1 indicates that the statement is true. The fuzzy logic approach differs from binary logic , in that binary logic allows a statement to be either false or true.

In recent years the use of fuzzy logic for multi -objective optimization has gained momentum, with applications in various areas like forest planning [5] and resource allocation Liang.T-F (2009) [13] focuses on developing a two-phase fuzzy mathematical programming approach for solving the multi-objective project management decision problem in a fuzzy environment.

- Zero-One Goal Programming:

Zero-one GP is one of the GP techniques which is now a days being used in various optimization process. Ertugrul et al. (2002) presented a combined analytic network process (ANP) and a zero-one goal programming (ZOGP) approach in product planning in Quality Function Deployment (QFD) to incorporate customer's needs and the Product Technical Requirements (PTRs) systematically into the product design phase. Considering resource limitations and multi-objective nature of the problem (important levels of product technical requirement using ANP, cost budget, extendibility level and manufacturability level goals.

Literature Reviewed:
Fleischmann at al (1997)[4] have proposed quantitative models taking up changes in logistics environment into account. They discussed the implications of the emerging reuse efforts, review of various mathematical models proposed in the literature.

Schultmann et al (2003)[11] in their work prescribes the measures for collecting and recycling spent batteries that combines an optimization model for planning a reverse supply network and a flow sheeting process model that enables a simulation tailored to potential recycling options for spent batteries in steel making industry.

Maria Isabel et al(2007) have tried to give a generalized model, They designed a generic reverse logistics network where capacity limits, multi product management and uncertainty in product demands and returns are considered. A mixed integer formulation is developed whic is solved using B&B techniques.

Gyu and John (2000) [16] applied a goal programming model for project selection and resource planning. The decision model used is 0-1 goal programming model, which is validated by applying it to case study from the Woodward Governor Company.

Liang.T-F (2009) [14] focuses on developing a two-phase fuzzy mathematical programming approach for solving the multi-objective project management decision problem in a fuzzy environment.

Ertugrul et al. (2002) presented a combined analytic network process (ANP) and a zero-one goal programming (ZOGP) approach in product planning in Quality Function Deployment (QFD) to incorporate customer's needs and the Product Technical Requirements (PTRs) systematically into the product design phase. Considering resource limitations and multi-objective nature of the problem (important levels of product technical requirement using ANP, cost budget, extendibility level and manufacturability level goals. Suresh Chand Sharma et al. (2010) [15] proposed a goal programming model for tracking and tackling environmental risk production planning problem that includes minimization of damages and wastes in the milk production system.

Sheu et al (2005) have presented a linear multi objective programming model that optimizes the operations of both a manufacturing supply chain and reverse logistics chain. The composite multi objective function proposed in this research consists of two sub objectives namely, maximum of manufacturing chain based net profit and maximum of reverse chain based net profit.

The definition of consolidated forward and reverse supply chain profit objective used by Sheu et al (2005) seems unrealistic, as in reality each of the supply chain may have their own individual objectives and related constraints.

Aman Gupta et al (2009)[1] have modified the model and presented a realistic model then Sheu et al's model. They considered a multiple product model and developed a closed loop goal programming model in which the different members in closed loop supply chain come together and use the model to gain a competitive advantage over competitors and their supply chains, They tried to achieve a consolidated goal related to max. Of net profit for each members of forward supply chain and second set of goals is used to max. Of net profit for each of the members of reverse supply chain and minimize the waste that ends up in land fills.

In our study we have tried to develop a model for the reverse loop of supply chain.

Mathematical Model: Assumptions
- Multiple products have been considered in the model
- Parts commonality exists among the products
- The proportions of the quantity of used products returned from end customers in subsequent finite time interval are given.
- Capacity of each of the facilities associated with the chain members of the considered supply chain are known.

Indices for decision variables and parameters
a – Product types, a=1,2,3,...
s - Sub Assembly types, s=1,2,3,...
p - Part types, p=1,2,3,...
t – Time period, t=1,2,3,...
m – Members of supply chain

Customer, collection point, refurbishing plant, disassembly plant, testing plant, manufacturing plant, recycling plant, disposal site.

Decision Variables:
M_{amt} – No. of units of entity a produced, remanufactured, recycled or disassembled by member m in time period t.

N_{am1m2t} – No. of units of entity a transported from members m1 to

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member m2 in period t.

I_{gat} – No. of units of entity a stored by member m in time period t.

Parameters: The parameters considered in the model are
S_{amt} – The cost of storage per unit of entity a by member m in period t

P_{amt} – The cost of procurement per unit of entity a by member m in period t

T_{am1m2t} – Cost of transportation per unit of entity a transported from m1 to m2 in period t

C_{k2t} - Collection cost involved per unit of k by Collection point in period t

R_{k3t} - Cost of repair incurred by refurbishing plant per unit of k in period t

D_{a4t} – Cost of disassembling per unit of entity a by disassembly plant in period t

U_{a5t} - Testing cost per unit of entity a by testing plant in period t

Vr6t - Recycling cost per unit of raw material 'r' by recycling plant in period t

W_{a7t} – Cost of disposing off per unit of entity a at disposal site in period t

Major Goal:
$\sum_{a=1} B_a * (n_a + p_a)$, where Ba are the weights assigned to deviational variables

Z_{am1m2t} – Revenue per unit of entity a transported from m1to m2 in period t.

Minor Goal: Maximization of profit to collectors, repair/ refurbishing, disassembly, testing/remanufacturing, profit to recycler.

The goal can be formulated as:

$$\sum_{a=1}^{9} B_a * (n_a + p_a)$$

Such that $X_i + d_i - - d_i + = X_i'$, i = 1,2,...,9

$X_2 = N_{a12t} * (Z_{a12t} - C_{a2t} - P_{a2t}) - I_{a2t} * S_{a2t}$

$X_3 = N_{a23t} * (Z_{a23t} - R_{a3t} - T_{a23t} - P_{a3t}) - I_{a3t} * S_{a3t}$

$X_4 = N_{s34t} * (Z_{s34t} - D_{s4t} - T_{s34t} - P_{s4t}) - I_{s4t} * S_{s4t} + N_{p34t} * (Z_{p34t} - D_{p4t} - P_{p34t} - P_{p4t}) - I_{p4t} * S_{p4t}$

$X_5 = N_{s45t} * (Z_{s45t} - U_{s5t} - T_{s45t} - P_{s45t}) - N_{s57t} * T_{s57t} - I_{s5t} * S_{s5t} + N_{p45t} * (Z_{p45t} - U_{p5t} - T_{p45t} - P_{p45t}) -$

$N_{p57t} * T_{p57t} - I_{p5t} * S_{p5t}$

$X_6 = N_{s56t} * (Z_{s56t} - V_{s6t} - T_{s56t} - P_{s56t}) - N_{s67t} * T_{s67t} - I_{s6t} * S_{s6t} + N_{p56t} * (Z_{p56t} - V_{p6t} - T_{p56t} - P_{p56t}) -$

$N_{p67t} * T_{p67t} - I_{p6t} * S_{p6t}$

$X_7 = N_{s57t} * (Z_{s57t} - W_{s7t} - P_{s57t}) + N_{p57t} * (Z_{p57t} - W_{p7t} - P_{p57t}) + N_{s67t} * (Z_{s67t} - W_{s7t} - P_{s67t}) + N_{p67t} * (Z_{p67t} - W_{p7t} - P_{p67t})$

Various constraints observed:
$I_{a2t} = I_{a2(t-1)} + N_{a12t} - N_{a23t}$ (For collection point)

$I_{a2t} \le L_{a2t}$, a=1,2,3,... and t=1,2,3,...
$I_{a3t} = I_{a3(t-1)} + N_{a23t} - N_{a34t\ (For refurbishing plant)}$

$I_{a3t} \le L_{a3t}$, a=1,2,3,... and t=1,2,3,...

$I_{a4t} = I_{a4(t-1)} + N_{a34t} - M_{a4t}$ (For disassembly plant)

$I_{a4t} \le L_{a4t}$, a=1,2,3,... and t=1,2,3,...

$I_{s4t} = I_{s4(t-1)} - N_{s45t} - N_{s47t}$,

$I_{s4t} \le L_{s4t}$, s=1,2,3,... and t=1,2,3,...

$I_{p4t} = I_{p4(t-1)} - N_{p45t} - N_{p47t}$

$I_{p4t} \le L_{p4t}$, p=1,2,3,... and t=1,2,3,...

Testing plant :
$I_{s5t} = I_{s5(t-1)} + N_{s45t} - N_{s56t} - N_{s57t}$

$I_{s5t} \le L_{s5t}$, s=1,2,3,... and t=1,2,3,...

$I_{p5t} = I_{p5(t-1)} + N_{p45t} - N_{s56t} - N_{s57t}$

$I_{p5t} \le L_{p5t}$, p=1,2,3,... and t=1,2,3,...

Recycling plant :
$I_{s6t} = I_{s6(t-1)} + N_{s56t} - N_{s67t}$

$I_{s6t} \le L_{s6t}$, s=1,2,3,... and t=1,2,3,...

$I_{p6t} = I_{p6(t-1)} + N_{p56t} - N_{p67t}$

$I_{p6t} \le L_{p6t}$, p=1,2,3,... and t=1,2,3,...

Disposal Location :
$I_{s7t} = I_{s7(t-1)} + N_{s57t} + N_{s67t} + N_{s47t}$

$I_{s7t} \le L_{s7t}$, k=1,2,3,... and t=1,2,3,...

$I_{p7t} = I_{p7(t-1)} + N_{p57t} + N_{p67t} + N_{p47t}$

$I_{p7t} \le L_{p7t}$, p=1,2,3,... and t=1,2,3,...

Non-Negativity
I_{amt}, M_{amt} and $N_{am1m2t} \ge 0$

CONCLUSION:
Goal programming has received reputation of workhorse in the field of multi objective optimization field due to combination of simplicity of form and practicality of approach. In this work we have tried to formulate a model for supply chain network in closed loop. In future we are trying to develop a matlab program for this problem and solve it to get values of decision variables.

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