Research Journal of Applied Sciences, Engineering and Technology 8(6): 687-690, 2014
DOI:10.19026/rjaset.8.1023
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: June 22, 2013 Accepted: July 05, 2013 Published: August 15, 2014

Research Article

Implementation of Genetic Algorithm in Network Modelling of Multi-level Reverse Logistics for Single Product

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Abstract: In this study, a multi level reverse logistics network is developed for a single product. Reverse logistics is a logistic activity beginning from intake of products returned by customers to selling of remanufactured or new products in market; so, it is considered that reverse flow of used products is from various sources like customers, dealers, retailers, manufacturers, etc., to remanufacturer and followed by transportation to secondary market. Due to uncertainties, any traditional supply chain approach to identify potential manufacturing facilities in this situation cannot be employed. Hence, Genetic Algorithm (GA) is used for optimization and minimization of various costs involved in reverse logistics process. A sample numerical data is considered to test performance of the proposed model.

Keywords: Cost reduction, network model, optimization, reverse logistics

INTRODUCTION

Logistics is science of managing flow of goods, energy, information and other resources from source of production to the marketplace. It is difficult to establish any manufacturing and production processes without logistical support. It involves integration of information, transportation, inventory, warehousing, material handling and packaging.

Reverse logistics is movement of goods and products from a consumer towards a producer in a channel of distribution. It is the process of planning, implementing, controlling, cost effective flow of raw materials, in-process inventory, finished goods and related information from point of consumption to point of remanufacturing. Sources of reverse logistics may include returned merchandise, excess inventory, outdated products, return due to customer dissatisfaction, etc. It is being practiced in various industries where manufacturing of jet engine components, mobile phones, automotive parts, machine components and refillable containers is happening. The question is whether remanufactured product takes economical and environmental advantage than the disposal of the product.

Reverse Logistics are of various types based on product recovery options. They are Reuse, Recycle and Remanufacturing. In reuse, product is used once again rather than disposing it, after cleaning or repairing it. Recycling is the recovery of material without keeping product structure and properties. Different types of materials undergo different recycling processes considering its effects on the environment. Remanufacturing is a concept where used products are completely disassembled by various industrial processes and are resent into different remanufacturing processes. A completely new product might be obtained in this case. In a journal, Automotive remanufacturing: The challenges European remanufacturers are facing, it was reviewed that product take-back has been motivated in the automobile industries, then remanufacturing and redistribution of these products, in form of closed loop supply chain, in the recent years. This study has enumerated the difficulties that the manufacturers were facing and emphasizes on the importance of reducing wastes (Seitz, 2007). Authors of ‘GA model development for reverse logistics’, studied that managing reverse flow of products can be an important potential for winning consumers in future competitive markets. Best solutions are achieved when free space of distribution centers is used for collecting/inspecting used products, especially in cities without recycling/disposal center. GA has given most optimized solution but not the best solution for this problem (Mohammad and Mitra, 2010). A general method based on reverse logistics with aim of reducing aluminium scrap transported between certain productions units of aluminium manufacturing plant. Linear optimization model was used. It was found out that transported products and units that are being processed in-plant have a significant impression on the optimal transport model. The developed model showed that environmental and economic objectives are not always conflicting (Kladivij, 2006). The supply chain efficiency is important to bookstore due to low overall profit margin. A single period model was developed to

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study the buyback pricing decision under assumption of product substitution and random yield. A better supply could be entertained if buyback price is slightly reduced (Yuanjie and Abolhassan, 2011). Emphasizes was laid on the Green Supply Chain management by reviewing 84 stake-holders from various firms to develop a network for simultaneous location-allocation of facilities for cost effective and efficient reverse logistics (Samir, 2007). Concentration on the global optimization which provides decision on facilities planning, shipment and facilities capacity has emerged (Khajavi *et al*., 2011). A model was proposed based on supply model consisting of collection centers, customers, repair centers and re-manufacturing plants. This model showed a faster synthetic performance in computation and optimality in revere logistics (Qi and Fang, 2007). Emphasis on reverse logistics in product returns was laid and a mixed-integer linear model was developed to solve the problems of reverse logistics. Problems were addressed on the localization of collection centers. The scenario where used products are pushed to remanufacturing plant from the market place, this model was used to study the infinite horizon, continuous time (Li, 2004). The problems on inventory control on reverse logistics in dimensions of relationship between manufacturing and remanufacturing, production rate and production, cost structure and cost parameters etc., (Ying *et al*., 2005). The importance of taking decision whether to re-manufacture or dispose returned product has become an integral responsibility of the companies (Siva *et al*., 2012).

Single-product multi-level scenario suits any kind of industry, which follows reverse supply chain model with finite number of collection centers, re-manufacturing plants and secondary markets. Total supply of re-manufacturing plant depends upon demand at which returned products are collected at collection centers. Time factor and costs incurred in transporting returned products between collection centers and re-manufacturing plants varies according to logistics flow structure from collection center to re-manufacturing plant. These products after manufacturing are moved to inventory and then to market place which is referred as 'secondary market'. These operations happen in different stages as mentioned above hence referred as 'multi-level logistics'. The purpose of single product-multi level scenario in reverse logistics is to provide a nearer optimal production rate by minimizing total logistics of entire reverse supply chain

The approach in this study is based on genetic algorithm trying to interface both programs containing algorithms for generating initial solution and generating optimum priority order. The techniques used in GA are Selection, Crossover and Mutation to search population towards optimality. A random population is selected from search space and a solution is obtained from it. In this study a random population is taken from products and its fitness function is calculated, based on which next generation is created. Optimization is done based on cost reduction in different stages. Hence, an objective function is formulated with certain constraints.

METHODOLOGY

Problem statement: In this study, a single product is considered which passes through various levels, hence called multi-level, of reverse logistic process. The used or EOF (End of life) products are collected from various sources at various collection points, transported to re-manufacturing plants and finally transported to secondary markets. These processes involve inventory, transportation, manufacturing, merchandise, etc which incur heavy costs and payment. To reduce costs incurred in above levels, a network model is needed to be developed and optimized for best and economically advantageous logistics in this scenario. It also provides a nearer optimal production rate for re-manufacturing plant by reducing total cost of logistics for whole reverse supply chain.

Mathematical formulation:
Notation:

- C_U = Recruitment cost of product at collection center 'u'
- I_{UV} = Number of products flowing from collection center 'u' to remanufacturing plant 'v'
- I_{VW} = Number of products flowing from remanufacturing plant to secondary market 'w'
- β = Constant used in inventory cost
- T_{UV} = Transport cost from collection center to remanufacturing plant
- T_{VW} = Transport cost from remanufacturing plant to secondary market
- R_V = Remanufacturing cost at facility 'v'
- F_V = Fixed cost of running a remanufacturing facility 'v'
- N = Total number of products collected from collection centre
- RE = Remanufacturing capacities
- MC = Marketing facilties
- Objective Function = Retrieval Costs + Transportation Costs + Remanufacturing Costs + Inventory Costs + Fixed Costs

Therefore,

$$Z = \{\sum_{u=1}^{n}\sum_{v=1}^{n} C_{uv}I_{uv}\} + \{\sum_{u=1}^{n}\sum_{v=1}^{n} T_{uv}I_{uv} + \sum_{u=1}^{n}\sum_{w=1}^{n} T_{uw}I_{uw}\} + \{\sum_{v=1}^{n}\sum_{w=1}^{n} R_{vw}I_{vw}\} + \{\sum_{u=1}^{n}\sum_{v=1}^{n} \beta C_{uv}I_{uv}\} + \{\sum_{v=1}^{n}\sum_{w=1}^{n} \beta R_{vw}I_{vw}\}$$

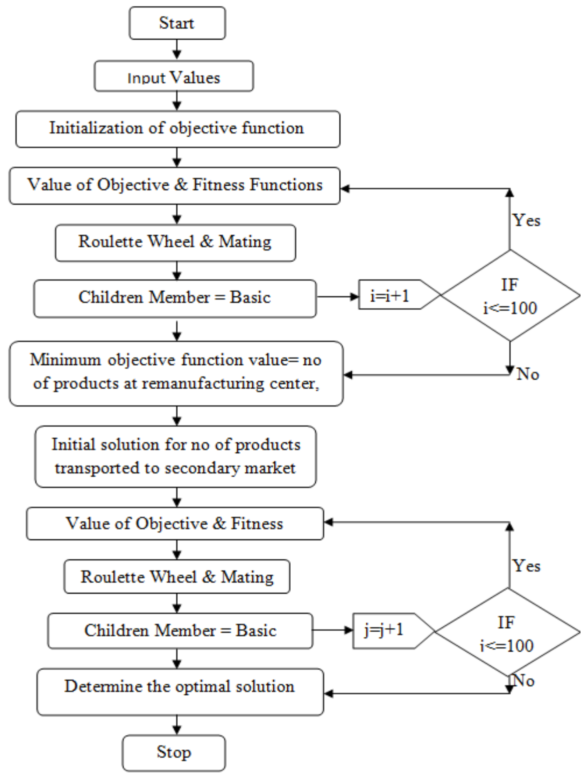

Fig. 1: Algorithm

Constraints: N = Input quantities near facilities: $\sum_{v=1}^{n}\sum_{w=1}^{n} I_{uv} = \sum_{v=1}^{n}\sum_{w=1}^{n} I_{vw}$:

$Y_V = \{0, 1\}$; for all u, v

$I_{uv} >= 0$ and $I_{vw} >= 0$; for all u, v, w

RE > = N and MC > = N

Expressions (A), (C), (D) are flow conservation. Expression (E) and (F) are capacity constraints. Expression (B) defines range of values for defined variables.

Assumptions: The model assumes return of used products. The capacity of collection centres should be less than or equal to total capacity of re-manufacturing plants and markets. The reproduction rate equals total demand at any moment. Time taken for transporting products is homogenous and not taken into considerations.

Algorithm steps of proposed GA: The proposed mathematical model contains linear and nonlinear equations which we incorporate in Genetic Algorithm, shown in Fig. 1, according to following algorithm to secure optimum results for problem solution. The diagram below explains steps involved in Genetic Algorithm mechanism used here.

The number of collection centres, remanufacturing centres and markets is entered and various capacities are defined. Then program is initialized and values of objective function are obtained. Then based on probabilities and cumulative values, roulette wheel concept is applied. Mate the pairs and children are obtained. If condition is satisfied, then continue with next step. Hence, the process is continued and the optimum values are obtained.

Initialization: Initialization is done through generation of random numbers based on criteria. Then this entry is

Table 1: Input and output values of problem statement

Various commodities	Plants	Product		
Collection cost at collection center (USD)	1	24		
	2	23		
	3	26.40		
Re-manufacturing cost at remanufacturing (USD)	1	19.60		
	2	18		
	3	20.60		
Number of products at collection center	1	240		
	2	220		
	3	230		
Capacity of remanufacturing plant	1	300	Capacity of remanufacturing plant	280
	2	250		320
	3	320		290
Transportation cost from collection centers to remanufacturing plant	1 to 1	25	Transportation cost from remanufacturing plant to secondary market (USD)	0.30
	1 to 2	30		0.40
	1 to 3	35		0.48
	2 to 1	20		0.46
	2 to 2	15		0.60
	2 to 3	25		0.56
	3 to 1	25		0.68
	3 to 2	12		0.64
	3 to 3	18		0.40
Fixed cost of remanufacturing plant (USD)	1	0.60		
	2	0.72		
	3	0.48		

Table 2: Flow of production from collection centers to remanufacturing plants

		Re-manufacturing plants		
		1	2	3
Collection centers	1	110	70	60
	2	57	116	47
	3	109	58	63

Table 3: Flow of production from re-manufacturing plants to secondary markets

		Secondary markets		
		1	2	3
Re-manufacturing plant	1	89	76	45
	2	77	83	10
	3	22	37	126

encoded in binary format for representation of chromosomes. Each chromosome contains binary strings, where each bit contains some characteristic.

Selection: To get best off-springs, best or fittest chromosomes are to be selected. The roulette wheel concept is used for selection process. The chromosomes are drafted according to their normalized fitness values on a pie chart following which a random number is generated to select a chromosome. Chromosomes with higher fitness values are selected and they occupy more space on pie.

Crossover: Crossover combines characteristics of parents to produce off-springs. It also provides a momentum for improvement.

Mutation: Mutation makes small local challenges of feasible solutions to provide diversity of population for wider search of feasible solutions.

RESULTS AND DISCUSSION

Considering a company, the study says 600,000 tons of products it produces are disposed off. These products are returned to various remanufacturing plants for remanufacturing to reduce effects on environment as well as increase profits of company. The reverse supply chain with 3 collection centres and 3 re-manufacturing plants and 3 secondary markets is taken into consideration after analysis.

This example problem is optimized by genetic algorithm by random generation of initial solution and then optimizing total cost taken. Operational method is encoded and executed using MATLAB. The program is tested with various randomly generated problems. The results were compared to those from literature.

Solution: The minimum total cost for retreading the product considering flow of product = 33,918.26 USD:

- The flow of product from collection centers to remanufacturing plants (Table 1).
- The flow of products from re-manufacturing plants to secondary markets (Table 2 and 3).

CONCLUSION

A network model for single product multi level scenario in reverse logistics has been developed using Genetic Algorithm considering various values from literature. This network is an attempt to correct shortcomings in an industry with single product in multi level scenario. It is aimed at reducing various costs incurred during reverse supply chain system starting from collection centres to remanufacturing plant, remanufacturing processes and finally transportation to secondary markets. The proposed genetic algorithm has been used to optimize solution using MATLAB software consuming less computation time. The results have shown that this optimized network has sufficiently reduced costs and saves time.

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