Optimization models in Supply Chain Management: A Critical Review

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***Abstract* - Improving the efficiency of supply chain has become the most important objective for different enterprises because of the increase in customer demand and competition among manufactures. Generally in a supply chain the main objective is to minimize cost and maximize production. For achieving this aim a set of approaches are available for managing the interrelationship with suppliers and customers to deliver high quality goods at right amount, at right location and at right time with minimum cost. Many non traditional methods are now a day used for optimization in supply chain management. Among these methods available, Genetic algorithm (GA)based methods are widely available.GA which is a direct search algorithm used as an appropriate solution to optimization and search problems in supply chain management. This paper critically reviews some of the literature thatuses genetic algorithm in supply chain optimization**

***keywords* - Genetic Algorithm, Supply chain management, Optimization Techniques, Evolutionary algorithm.**

I.INTRODUCTION

Supply chain management (SCM) is the management of the flow of goods and services in an organization.The main objectives of supply chain management include customer satisfaction, minimize cost and maximize profit and production. Supply chain includes a series of steps that transforms all raw materials into end products. Supply chain management in an enterprise generally consists of a series of steps such as obtaining raw materials, converting this raw material into end products and delivery of the end product to the retailers[1]. Supply chain management can be regarded as a set of approaches for managing the interrelationship with suppliers and customers to deliver high quality goods at right amount, at right location and at right time to reduce cost while retaining customer satisfaction [2].

In recent years, Supply chain has become the most important issue for different enterprises because of the increase in customer demand and competition among the manufactures. This increased global competition had forced the members of the supply chain to optimize their activities to achieve higher customer satisfaction levels [3]. Supply chain management consists of a series of steps from supplier to customer. The series of steps include internal supply chain and external supply chain. The internal supply chain includes the process carried out in a company such as purchasing, production and distribution.SCM is a set of process for managing the upstream and downstream interrelationship with suppliers and its consumers to deliver high quality products at lowest price as a whole supply chain. [4, 5]. As described by Hicks, 1999 [6] supply chains can be defined as "*...real world systems that transform raw materials and resources into end products that are consumed by customers. Supply chains encompass a series of steps that add value through time, place, and material transformation. Each manufacturer or distributor has some subset of the supply chain that it must manage and run profitably and efficiently to survive and grow."*The systems that can be utilized with the help of supply chain management include order management systems, transportation management systems, inventory management systems, replenishment systems, optimization tools, warehouse management system etc. Many methods are available for theoptimization of supply chain.

Supply chain management which comprises the flow of products and services from the beginning to the end. Supply chain management tries is to monitor and relate production, distribution and shipment of products from producer to the consumer. SCM basically merges the supply and demand management to maximize profit and minimize cost. The short term objective of SCM is to increase the productivity and reduce the entire inventory and the total cycle time, and the long term objective is to maximise customer satisfaction levels, market share and profit for all components in the supply chain: suppliers, manufacturers, distributors and customers [7]. Certain measures are put forward to achieve these objectives and to improve long term performance for companies. One such measure is applying efficient methods of optimization in supply chain

The paper is organized as follows: Section 2 Optimization methods are explained, Section 3 Evolutionary Algorithms are explained Section 4 Summary of traditional methods in optimization Section 5 describes about Genetic Algorithm. Section 6 gives the performance of GA.

II.OPTIMIZATION TECHNIQUES.

Optimization tries to improve the desirability and quality of a product or product concept.Optimization can be defined as the process of finding the maximum or minimum value of a function, where the function represents the desired benefit, or the effort required. In supply chain management the optimization techniques include nonlinear programming, geometric programming, dynamic programming, stochastic programming and evolutionary algorithms. This paper describes a literature review on differentmethodsof supply chain optimization which includes mathematical models, evolutionary algorithms etc. and here more emphasis is given to models based on genetic algorithms

From the literature many methods are available in the area of supply chain optimization. Traditional methods such as integer programming, geometric programming, stochastic dynamic programming, and nontraditional methods such as Ant colony algorithm, Differential Evolution, Dual phase Evolution, Genetic algorithm, Memetic algorithms, Neuro evolution, Particle swarm optimization, competitive learning, Swarm intelligence etc are seen in the literature. Some papers from the literature are narrated below.

Chen ke and Fu Qiang[8] uses a nonlinear integer programming for a supply chain network for fresh agricultural products. The agricultural products supply chain is generally constructed by subsystems such as production system, total distributed system and retail system. The main objective here is to reduce the total cost of the supply chain and also to maximize customer values and capacity utilization balance. For this model, non linear integer programming with bounded integer variables and a local minimizer is used to model the system.

Rabbani, M &Aliabadi, L [9] uses a signomial geometric programming approach for SCM optimization with demand rate which depends on the length of the credit period provided by the retailer totheir customers, marketing expenses and sales price. The main objective is to maximize retailers' total profit by taking into consideration the above stated factors. Here an approximation method is applied to simplify the profit function and convert the problem into constrained signomial geometric programming.

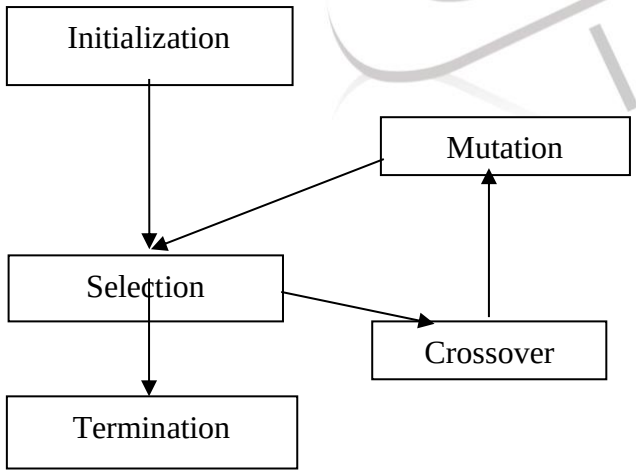
In Jaein Choietal[10] used an approach based on stochastic dynamic programming which generates a dynamic operating policy that incorporates the uncertainty in the problem at each sites. A novel stochastic optimization algorithmic framework called dynamic programming in a heuristically constrained state space is proposed by the authors. The state space is generated by simulating various potential scenarios under centralised dynamic inventory and production policy formed by combining static local inventory policy heuristics.

III.EVOLUTIONARY ALGORITHMS

Evolutionary Algorithms which is considered as a component of evolutionary computation in artificial intelligence is widely used nowadays in the area of optimizing supply chain networks. The algorithm functions through the reproduction process in which the least fit members of the population set are eliminated in successive iterations, whereas the fit members can survive and continue until better solutions are obtained. Many evolutionary algorithms are computer applications which mimic the biological processes for solving complex problems. Selection, crossover and mutation concepts in biology are used by the evolutionary algorithm. Initialization, selection, genetic operators and termination are the steps included in an evolutionary algorithm.Evolutionary algorithms depend on the concept of random sampling and have a population of candidate solutions. The components of an evolutionary algorithm consists of

- Representation (decision variables)
- Evaluation function (Fitness of solution)
- Population
- Parent selection method
- Offspring producing operators (recombination and mutation)
- Survivor selection method (replacement)

The steps can be represented with the help of a flowchart as



The evolutionary computing techniques mostly uses Metaheuristic optimization algorithms like Genetic algorithm Ant colony algorithm, Differential Evolution, Memetic algorithms, Simulated annealing, Particle swarm optimization, etc. Evolutionary Algorithmsare widely using in many complex problem solving applications due its advantages over classical search techniques and optimization techniques [11][12][13].

The following are some of the important articles seen in this area

IV.Table 1

Reference no	Year	Name of the Authors	Nature of the problem	Type of Model	Parameter considered	Methodology	Outcome of the paper
15	2004	C.A. Suva, I.M.C. Sousa, J.M.G. Sa da Costa , T.A. Runkler	Complex optimization problem	Distribution optimization problem	Based on the pheromone matrix of the ACO as a communication platform.	Ant colony optimization	Made a system with logistic, supplying and distribution sub-systems.
16	2008	Ruoving Sun, XingfenWabg, Gang Zhao	Multi objective optimization	Mathematical model	Measurement of cost, customer service fill rates and delivery flexibility	Ant colony algorithm	Made an optimal procurement policy
17	2010	LengKaijun , Cui Nanfang , Wang Yuxia	Two-echelon production-distribution supply chain system	Mathematical model	Transportation cost , approximate sales quantity , holding cost	Genetic algorithm	Made a system which has coordination mechanism decision making process through retailer selection.
18	2012	R.Jamshidi, S.M.T.FatemiGhomi , B.Karimi	Multi objective optimization	Mathematical and coding model	Environmental effects are considered	Memetic algorithm using the Taguchi method	Made a system with wide variety of problem size and structures.
19	2012	AndrásKirály, TamásVarga, JánosAbonyi	Stochastic optimization technique	Simulation model	Linear and non linear constraints are considered	Particle Swarm Optimization algorithm	Made a system flexible to handle complex situations and simple enough to be used for decision support.
20	2013	Sh. GholizadehTayyar ; D. Roy ; S. F. Ghaderi	Multi objective optimization	Mathematical model	Economic, environmental and social factors are considered	Differential Evolution algorithm	Dissatisfaction may cause more cost in the system
21	2013	S. MeysamMousavi, RezaTavakkoli-Moghaddam	Hybrid Simulated annealing	Mathematical model	Fixed costs, total transportation cost in the pickup and delivery processes, operational costs of vehicles and penalty cost	Two-stage hybrid simulated annealing (HSA) algorithm embedded with TS	Made a cross docking distribution on networks to avoid new location and scheduling problems.
22	2013	Lingjiang Zhao, Chen Li	Risk management multi-	Mathematical model	Risk probability, risk	Genetic algorithm	Made a system which can handle

			objective optimizatio n problem		management costs and expected loss.		decision-making of supply chain risk, and has high credibility

V.GENETIC ALGORITHM

Genetic algorithms (GA)is a class of evolutionary algorithms and is inspired by Darwin's theory about evolution, "Survival of the fittest". Genetic algorithm is considered as a multiple point search technique which examines a set of solutions and not just one solution. It starts with a population of solutionsGA which is robust and better than conventional AI, works well on mixed (continuous and discrete), and Combinatorial problems. Genetic Algorithms (GAs) are adaptive heuristic search algorithm based on the evolutionary methods of natural selection and genetic principles. GA is a derivative tree, direct search algorithm used to find exact or approximate solutions to optimization and search problems [14]

Genetic Algorithm works as an iterative optimization procedure. GA simulates natural evolution, mimicking processes the natural evolution process. The operators of GA are reproduction, crossover and mutation. The working principle of GA begins with a set of solutions called theinitial population.The working of GA can be explained below

1. Initialize a population with chromosomes
2. Evaluation of each string in the population using fitness function
3. Reproduction
4. Crossover
5. Mutation
6. Evaluation of the population
7. Repeat the steps until termination criteria is met

VI.ADVANTAGES OF USING GA

GA which uses crossover and mutation operators makes its population more diverse in nature. This diversity of solutions helps the algorithm to move faster to reach the global optima and that will allow the algorithm to search the solution space faster. GA which is a part of metaheuristic algorithms can is efficient in terms of computational time. In GA, the objective function should be known and make a smart representation of solutions using strings called chromosomes. The main critical thing in GA is the faster computation of objective function and for avoiding unfeasible solutions; a good crossover operation is needed It is seen from the literature that many models of supply chain are available in the literature using GA. Table 2 shows some of the supply chain models that uses GA as the solution methodology or for developing algorithms. Mostly GA is used as the solution methodology for mathematical models. In most of the cases the objective was to minimize various cost factors such as transportation cost, material handling cost, production cost etc. Some of the recent models are discussed below

TABLE 2

Reference no	Year	Name of the Author	Nature of the problem	Type of Model	Parameter considered	Methodology	Outcome of the paper
23	2006	FulyaAltiparmak , Mitsuo Gen, Lin Lin, TuranPaksoy	Multi objective optimization	Mathematical model	Cost of plants and distribution centres , inbound and outbound distribution cost, delivery time etc	Genetic algorithm	Made an efficient and effective system to minimize total cost
24	2006	Xiaobing Liu, Xiufei Li	Facility Layout Scheduling problem	Mathematical model	Material handling cost and total distance are considered	Genetic algorithm	Made a system which minimizes material handling cost and total distance that walk back and forth
25	2009	P Radhakrishnan, Dr V M Prasad, Dr M R Gopalan	Inventory optimization model	Novel efficient approach	Holding and shortage cost.	Genetic algorithm	Made a system to minimize cost by predicting stock levels and holding location

26	2014	Salah Alden Ghasimi , RizauddinRamli, NizaroyaniSaibani	Three-echelon defective goods supply chain network (DGSCN) using JIT logistics	Mathematical model	Cost of production, distribution, holding and back order	Genetic algorithm	Made a system to face problems occurred due to defective good
27	2016	Zahra AlizadehAfrouzy, SeyedHadiNasseri , IrajMahdavi	Multi echelon multi pro-duct multi period supply chain model	Mathematical model	Products are considered during the planning horizon	Genetic algorithm	Made a system to maximize total profit by optimizing launching time and phasing time during planning horizontal time.
28	2018	Amin Saghaeeian, Reza Ramezanian	Bi-Level programming model	Mathematical model	Location(strategic decisions), Production, Transportation and pricing decisions	Genetic algorithm	Made a system to reduce self price by improving the brand loyalty for their products
29	2019	Young-Bin Woo, ByungSoo Kim	Mixed integer nonlinear programming model	Mathematical model	Transportation cost and inventory cost are considered	Genetic algorithm	Made a hydrogen supply network chain to reduce inventory levels, transportation cost and inventory carrying costs

From the table, it is clearly specified that with the help of genetic algorithm the optimization of supply chain management system can be optimized efficiently. The recent papers regarding supply chain also specifying the above said optimization technique.

Ahmad Sayed Saif Eddine etal[30] used a mathematical approach to minimize the total supply chain cost. In this paper the Inventory Location Routing Problem is considered while adopting the Vendor managed Inventory Strategy. A mathematical model is formulated to minimize the total supply chain cost. Two instances are considered mainly vehicle per depot and vehicle capacity on the total supply chain cost. As the problem here is NP-hard, an improved genetic algorithm (IGA) is designed. The total cost decreases with the increase of vehicle capacity due to the usage of fewer depots. In this paper a model is developed to determine the depots used, customers served, the corresponding delivery quantity, vehicle dispatching times and routes for each period to attain optimal total supply chain cost. A real life modelling of holding cost within the periods is presented with the help of IGA and hence supply chain cost is reduced.

Salah Alden etal [31] used genetic algorithm for optimizing a novel mathematical model of the defective goods supply chain networks. All the imperfect-quality products are not repairable, where as those considered as scrap are directly sold to the customers at a low price. This model designs a most appropriate supply chain network (SCN) for reduction of total cost and wasted time. The two important factors in the market such as cost reduction and selection of the appropriate length of each period are considered here. The objective of the proposed model is to minimize the cost of production, distribution, holding and backorder. Other than cost minimization the model can determine the economic production quantity(EPQ), the appropriate length of each cycle and the quantities of defective products(ALOEP), scrap products and retailer shortages using lust in time logistics (JIT-L). Genetic Algorithms and Cplex solver with probability parameters and various dimensions are used to compare the outputs to demonstrate the performance of the model. We used the GAs and a Cplex solver with probability parameters and various dimensions for validation of the studied model in real-life situations, and we compared the outputs to demonstrate the

performance of the model. Hence a three-echelon defective goods supply chain network (DGSCN) using JIT logistics are proposed not only reduces the cost of production, holding, transport, defective goods, scrap products, retailer shortages and indirect costsbut also determines the EPQ and ALOEP according to the importance of customer lead time.

Dr NijuP.Joseph [32]finds that the total production cost can only be achieved when is carried out at each member of the production chain. For the planning of production, the variable production cost is to be determined which includes manufacturing costs, Labour cost, material cost, inventory holding cost and other relevant acquisition costs. The main issue in the implementation is the cost level is not static for every period. In this paper, a new and efficient approach that works on Genetic Algorithms to minimize production cost is developed. The work basically considers the uncertainty of cost in the production scenario.The Algorithm uses multiple crossover and mutation operators for removing uncertainty in production cost evaluation. This can lead to better forecasting of production cost and thereby achieve higher performance levels. The uncertainty variables can be controlled and hence the production cost can be reduced leading to lower supply chain cost.

Conclusion

Even though many computational algorithms are available GA found to be used as the major optimization algorithms for supply chain problems. GA has successfully used to develop algorithm based models or as solution to mathematical models and has shown getting good results are obtained. The reason for why GA is used many cases is because many supply chain models can be framed as combinatorial optimization problems. The literature review shows that the researchers used GA based models in almost all fields of supply chain management like manufacturing planning and control, logistics management, demand forecasting, analysis of bullwhip effect etc. Many supply chain situation can be converted into mathematical models so that GA can be efficiently used to find optimum or near optimum solutions. The research in this area can be further extendedby The rest of the research article is prepared asfollows:

Subsequent to the introduction in section 1, the genetic algorithms and supply chain management are briefly described insections 2 and 3 respectively. The methodology, section 4, describes the critical analysis of the literature and reviews of existing studies and section 5 briefed discussion part and future trends of the study. Finally, Summary drawn from the present study is provided

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