Use Of Genetic Algorithms in Supply Chain Management. Literature Review and Current Trends

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For the past few decades SCM has been one of the main objectives in research and practice. Since that time researchers have developed a lot of methods and procedures which optimized this process. To create an efficient supply chain network the resources and factories must be tightly integrated. The most supply chain network designs have multiple layers, members, periods, products, and comparative resources constraints exist between different layers. Supply chain networks design is related to the problems which are very popular in literature. The subject of this paper is to present the variants, configurations and parameters of genetic algorithm (GA) for solving supply chain network design problems. We focus on references from 2000 to 2011. Furthermore, current trends are introduced and discussed.

Keywords: supply chain management, genetic algorithm, optimization.

1. Introduction

Supply Chain Management (SCM) describes the discipline of optimizing the delivery of goods, services and information from supplier to customer. Standard supply chain management goals include transportation network design, production schedule streamlining, plant/DC location, and efforts to improve order response time[1]. The most important thing in supply chain management is coordinating distribution and production decisions. This coordination helps to achieve effective logistics scheduling[2].

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[1] M. Gen, F. Altiparmak, L. Lin, *A genetic algorithm for two-stage transportation problem using priority-based encoding*, "OR Spectrum" 2006, No. 28, pp. 338.

[2] M. Rostamian Delavar, M. Hajiaghaei-Keshteli, S. Molla-Alizadeh-Zavardehi, *Genetic algorithms for coordinated scheduling of production and air transportation*, "Expert Systems with Applications" 2010, No. 37, pp. 8255.

For the past few decades SCM has been one of the main objectives in research and practice. Since that time researchers have developed a lot of methods and procedures which optimized this process. To create an efficient supply chain network the resources and factories must be tightly integrated. The most supply chain network designs have multiple layers, members, periods, products, and comparative resources constraints exist between different layers. Supply chain networks design is related to the problems which are very popular in literature.

The supply chain networks design problem (SCNDP) is strongly NP-hard, and the computation times for exacting algorithms can be excessive even for moderately sized instances. Therefore the heuristics methods are used to solve this problem. For classification and performance evaluation of heuristics, Herroelen[3] divided them into heuristics focusing on *X-pass methods* (single pass methods, multi-pass methods, sampling procedures) and *metaheuristics* (simulated annealing, genetic algorithms and tabu search).

The subject of this paper is to present the variants, configurations and parameters of genetic algorithm (GA) for solving supply chain network design problems. The genetic algorithms were classified according to the objective function. Some objectives can be related to time, others – to cost. These two kinds usually represent conflicting objectives, since shortening the processing time results in increasing the resource consumption, and vice versa – decreasing the execution cost (in terms of the resources consumed) lengthens the process' duration[4].

This paper is organized as follows: Section 2 explains supply chain network design problem. In section 3 genetic algorithm review is presented. Section 4 describes current trends in solving SCNDP with genetic algorithm. Section 5 presents conclusions and suggestions.

2. Supply chain network design problem (SCNDP)

A definition of supply chain management provided by the SupplyChain.com (www.thesupplychain.com) is: "SCM is a strategy where business partners jointly commit to work closely together, to bring greater value to the consumer and/or their customers for the least possible overall supply cost. This coordination includes: order generation, order taking and order fulfillment/distribution of

[3] W. Herroelen, *Project scheduling – Theory and practice*, "Production and Operations Management" 2005, No. 14, pp. 1–35.

[4] J. Węglarz, J. Józefowska, M. Mika, G. Waligóra, *Project scheduling with finite or infinite number of activity processing modes – A survey*, "European Journal of Operational Research" 2011, No. 208, pp. 182.

products, services or information. Effective supply chain management enables business to make informative decisions along the entire supply chain, from acquiring raw materials to manufacturing products and distributing finished goods to the consumers. At each link, businesses need to make the best choices about what their customers need and how they can meet those requirements at the lowest possible cost".

Because of the large size of the physical supply network and constant variability of environment, management of supply chain is a very complicated task. Effective management should take place both at the operational and strategic levels and should be considered in a wide long-term horizon.

From the logistics point of view, the management of supply chain consists of many problems (e.g. delivery of materials, transportation routing, etc.). Each of these problems can be very combinatorial complex, even if it is considered in isolation from other problems. Therefore, there is a need to find methods that will be able to solve these problems in a relatively short time[5].

Supply chain network design problem (SCNDP) determines the optimal network infrastructure, which defines how to efficiently use the resources of production, distribution and storage in the supply chain. This optimization should be as a response to demand and, consequently, should lead to increase an economic efficiency[6].

3. Genetic algorithm in solving SCNDP – a review

In this section we introduce a review of articles concerned with theory and practice of application of genetic algorithm in supply chain network design problem. This literature review has been drawn from the journal articles from across a broad range of disciplines, but we focus on GA usage in SCNDP. Generally books and conferences have not been included. If several papers are available for a concept, we focus on references from 2000 to 2011.

The considered articles are divided according to the objective function, which was implemented by the genetic algorithm. In this article we identify three categories of objective functions: time objective, cost objective and complex objective.

[5] D. Naso, M. Surico, B. Turchiano, U. Kaymak, *Genetic algorithms for supply-chain scheduling: A case study in the distribution of ready-mixed concrete*, "European Journal Of Operational Research" 2007, No. 177, pp. 2069.

[6] L. G. Papageorgiou, *Supply chain optimisation for the process industries: Advances and opportunities*, "Computers and Chemical Engineering" 2009, No. 33, pp. 1932.

3.1. Time objective

A time-based objective is a minimized function of activity completion times. The most natural performance measure in this group is the makespan (project duration)[7]. Minimizing the project duration is one of the most common objectives used in supply chain management.

Moon *et al.*[8] proposed a new adaptive genetic algorithm (AGA) based on a heuristic approach. The authors introduced a solution, which automatically runs the local search, and adjust the value of mutation and crossover operators in a GA. The objective function was the makespan (which consisted of processing, setup and transportation time) minimization. In proposed GA the initial population was randomly generated by preparation of feasible solutions. GA was hybridized with the local search technique which was responsible for movement of generated offspring to a local optimum before injecting it into the new population. In the evolutionary process the authors used the one-point crossover[9], swap mutation[10] and neighbour search mutation. As the selection mechanism the roulette wheel selection[11] was applied. The GA stopped when a fixed number of generations was reached. Proposed AGA was compared with Moon–Kim–Gen's[12] approach that used the same data. Based on the run-tests the AGA was more efficient.

Lim *et al.*[13] presented a hybrid approach involving a genetic algorithm and simulation to establish optimal distribution planning in the supply chain. The GA was used to generate fast feasible distribution sequences and the objective

[7] J. Węglarz *et al.*, *Project scheduling...*, op. cit., pp. 182.

[8] C. Moon, Y. Seo, Y. Yun, M. Gen, *Adaptive genetic algorithm for advanced planning in manufacturing supply chain*, "Journal of Intelligent Manufacturing" 2006, No. 17, pp. 509–522.

[9] In one-point-crossover one crossover point is selected, binary string from beginning of chromosome to the crossover point is copied from one parent, the rest is copied from the second parent.

[10] In the swap (exchange) mutation two positions of the genes are randomly selected and chose genes are exchanged. This operator picks two genes at random and swaps their positions.

[11] The roulette wheel selection is one of proportional selection mechanisms. The basic idea on it is to determine selection probability or survival probability for each chromosome proportional to the fitness value. The selection process is based on spinning the wheel the number of times equal to population size, each time selecting a single chromosome for the new population.

[12] C. Moon, J. Kim, M. Gen, *Advanced planning and scheduling based on precedence and resource constraints for e-plant chains*, "International Journal of Production Research" 2004, No. 42, pp. 2941–2955.

[13] S. J. Lim, S. J. Jeong, K. S. Kim, M. W. Park, *Hybrid approach to distribution planning reflecting a stochastic supply chain*, "The International Journal of Advanced Manufacturing Technology" 2006, No. 28, pp. 618–625.

function minimized transportation time with the minimal amount of completion time. The authors used the real number coding representation; the chromosome consisted of the gene which presented the relationship of the product, the distribution center and the customer; the chromosome was represented by the matrix. For the crossover the order operator[14] was used and in mutation phase the swapping operator was applied. As the selection method the ranking approach was chosen. To demonstrate the effectiveness and viability of the proposed solution a few computational experiments were developed. In the numerical experiments there was no comparison with other method.

The multi-factory production scheduling problem was considered by Chung *et al.*[15] In each factory there were a various machines. Some factories might produce final product and the other might produce intermediate product and send it to other factories. The objective function was to minimize the makespan (in this problem it was processing time, transportation time between resources, and machine set-up time) of set of jobs which were processed on different machines in each factory. In this paper two genetic algorithms were proposed: simple genetic algorithm (SGA) and modified genetic algorithm (MGA). In SGA the chromosome was composed of genes where each gene consisted of 2 parameters, representing order and machine. The initial population was generated randomly. In the evolutionary process the order crossover and two types of mutation operators were proposed. As a selection mechanism the elitist[16] strategy was applied. In MGA each gene in chromosome was built from three parameters: order, machine and domination parameter. In this GA the crossover operator was similar to SGA, but also the domination parameter was taken into account in each gene. The mutation operator was similar to the one mentioned in SGA. To demonstrate the performance of the optimization reliability of the SGA and the MGA, a numerical example of multi-factory problem was considered. The comparison with the other methods was made and it appeared that AGA and MGA were more effective.

[14] Order crossover produces offspring by transferring a randomly chosen subsequence of random length and position from one parent, and filling the remaining positions according to the order from the other parent.

[15] S. H. Chung, H. C. W. Lau, K. L. Choy, G. T. S. Ho, Y. K. Tse, *Application of genetic approach for advanced planning in multi-factory environment*, "International Journal of Production Economics" 2010, No. 127, pp. 300–308.

[16] Elitist selection is generally used as supplementary to proportional selection to preserve the best chromosome in the new generation if it is not selected through a proportional selection process (Gen *et al.*, 2006).

The scheduling of products and vehicles in a two-stage supply chain environment (SCE) was considered by Zegordi *et al*.[17] The first stage included suppliers with different production speeds, and the second stage consisted of vehicles (each of them might have a different speed and different transport capacity). The authors proposed a gendered genetic algorithm (GGA) where each of two genders had a different chromosome structure. Two types of chromosomes were considered. The first type was composed of a string of genes that represented each supplier and each vehicle. In the second type of chromosomes there were two different strings; the first string indicated the job priority from a supplier perspective and the second string represented job priority from a vehicle perspective. The objective function of considered problem was to minimize over all throughputs in order to minimize the worst-case maximum completion time for all jobs. The initial population was generated randomly and composed of both types of chromosomes. The authors employed a parameterized uniform crossover[18] operation. For crossover, two parents with different chromosome type were selected randomly. Then special procedures were developed, each of them was dedicated to the different type of the selected parents. In the mutation procedure, a random chromosome was first selected, then for each type of chromosome a different mutation operator was used. Best chromosomes were selected for the next generation and all of the remaining chromosomes were selected according to the roulette wheel approach. If the computational time exceeded 20 min or if no improvement occurred in the fitness function of the best chromosome over multiple successive generations, then the genetic algorithm was terminated. To evaluate the GGA performance, the researchers compared it with an the adapted algorithm proposed in the literature. Their experimental results showed that GGA outperforms adapted algorithm in all cases with respect to the objective value.

3.2. Cost objective

The cost minimization objective is a measure which is based on financial flow in supply chain. Cash outflows are usually caused by the execution of projects activities and resources usage. Cash incomes are usually due at the end

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[17] S. H. Zegordi, I. N. K. Abadi, M. A. B. Nia, *A novel genetic algorithm for solving production and transportation scheduling in a two-stage supply chain*, "Computers & Industrial Engineering" 2010, No. 58, pp. 373–381.

[18] Uniform crossover is a dynamic and nondeterministic method where a set of positions, called a mask, is chosen for each of the chromosomes and their alleles are exchanged with each other based on the generated positions.

of some parts of the project[19]. The costs in the supply chain may depend on costs of production and distribution, costs of the transportation of raw materials from suppliers to plants, the transportation of the finished products from plants to DCs and from DCs to the customers[20].

In genetic algorithm proposed by Gen *et al.*[21] the objective was to find the way of transporting homogeneous product from several sources to several destinations so that the total cost could be minimized. In this problem a chromosome consisted of priorities of sources and depots. Then the transportation tree corresponding with a given chromosome was generated by the sequential arc appending between sources and depots. Each chromosome consisted of two parts. The first part represented transportation tree between plants and distribution centers and the second part represented transportation tree between distribution centers and customers. In this study, researchers proposed a new crossover operator called as weight mapping crossover (WMX) and investigated the effects of four different crossover operators on the performance of GA. Authors also studied the effects of two different mutation operators on the performance of GA. Insert[22] and swap mutations were used for this purpose. As selection mechanism the roulette wheel selection with elitist strategy was employed. Termination of genetic algorithm was a fixed number of generations. The proposed genetic algorithm was compared with other GA. Statistical analysis based on seven problems showed that while proposed GA gave better heuristic solutions than the compared GA, its computation time was bigger.

A solution procedure based on steady-state genetic algorithms for the design of a single-source, multi-product, multi-stage SCN was presented by Altiparmak[23]. The objective function minimized the total cost of the supply chain. It consisted of the fixed cost of operating and opening plants and DCs, the variable costs of production and distribution, costs of the transportation of raw materials from suppliers to plants, the transportation of the final products from plants to DCs and from DCs to customers. A chromosome consisted of priorities of sources and depots to obtain a transportation tree and its length

[19] J. Węglarz *et al.*, *Project scheduling…*, op. cit., pp. 183.

[20] F. Altiparmak, M. Gen, L. Lin, I. Karaoglan, *A steady-state genetic algorithm for multi-product supply chain network design*, "Computers & Industrial Engineering" 2009, No. 56, pp. 525.

[21] M. Gen *et al.*, *A genetic algorithm…*, op. cit., pp. 337–354.

[22] In the insert mutation a position of the gene in the chromosome is randomly selected and a chosen gen is inserted in a new position then all the genes are shifted to the right by one position.

[23] F. Altiparmak *et al.*, *A steady-state genetic algorithm…*, op. cit., pp. 521–537.

equaled to the total number of sources and depots. A transportation tree for the corresponding product was built basing on each part of the chromosome. The authors proposed seven greedy heuristics (GH) to obtain the good solutions for the initial population. As a selection mechanism the binary tournament procedure[24] was used. A segment-based crossover operator based on previous work[25] was employed. In the mutation phase segment-based mutation operator was applied. To investigate the effectiveness of the proposed GA, the researchers utilized three heuristic approaches (Lagrangean heuristic, hybrid GA with linear programming, simulated annealing algorithm). Experimental study showed that developed GA found better heuristic solutions than the other heuristic approaches and reached faster the good heuristic solutions.

Yao and Hsu[26] proposed a spanning tree-based GA for solving the optimal locations of the hubs and the optimal transportation routes. The objective function was minimization of the total costs in the whole supply chain. In proposed solution each chromosome consisted of five ordered sub-strings. The first sub-string represented the decisions if the sites of plants should be opened. The second sub-string figured the decisions if the sites of DCs should be opened. The last three sub-strings represented the transportation patterns between the suppliers and the plants or between the plants and the DCs or between the DCs and the customers. Some chromosomes in the initial population were randomly generated, and the other were built with greedy procedure. The authors used two-point[27] and uniform operators for crossover. For mutation the insertion and swap (exchange) operators were used. Numerical experiment was divided into three parts. In first part authors compared the proposed GA with solution developed by Syarif *et al.*[28] In this part of the experiment developed algorithm outperformed the solution proposed by Syarif *et al.*, but it had longer run time.

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[24] In binary tournament selection two individuals are chosen from the population randomly. The one with the better fitness value is chosen as the first parent. The process is repeated to obtain a second parent.

[25] F. Altiparmak, M. Gen, L. Lin, T. Paksoy, *A genetic algorithm approach for multi-objective optimization of supply chain networks*, "Computers & Industrial Engineering" 2006, No. 51, pp. 196–215.

[26] M. Yao, H. Hsu, *A new spanning tree-based genetic algorithm for the design of multi-stage supply chain networks with nonlinear transportation costs*, "Optimization and Engineering" 2009, No. 10, pp. 219–237.

[27] Two-point crossover generated two random positions, head and tail. The alleles of the first chromosome from the head position to the tail are exchanged with the second chromosome in the same range.

[28] A. Syarif, Y. S. Yun, M. Gen, *Study on multi-stage logistic chain network: a spanning tree-based genetic algorithm approach*, "Computers and Industrial Engineering" 2002, No. 43, pp. 299–314.

In the second part the tests were made to find the best combination of genetic operators for the proposed GA. The authors compared three operators for crossover: one-point, two-point and uniform operators, and three operators for mutation: inversion-displacement, insertion and exchange operators. They observed that the combination of the two-point operator for crossover and the exchange operator for mutation brought the best solution for most of the cases. The third part conducted further comparison between the proposed solution and solution developed by Syarif *et al*. using larger number of instances. After comparing different combinations of genetic operators (part 2 of the experiment), researchers concluded that the proposed approach outperformed the approach of Syarif *et al*. in both aspects: the solution quality and the run time.

Yimer and Demirli[29] proposed a two-phase mixed integer linear programming (MILP) model for material procurement, components fabrication, product assembly and distribution scheduling of a build-to-order supply chain system. In the proposed model, the problem was divided into two subsystems (a production-subsystem and a distribution-subsystem) and evaluated sequentially. The objective was to minimize the aggregate costs associated with each subsystem, while meeting customer service requirements. The search space for presented problem is very large, so for the fast exploration the genetic algorithm was used. In proposed GA each chromosome consisted of 8 genes. The first gene represented the index number of a product. The second gene was the total volume of product assembled by plant in period (both at regular time and overtime). The third gene was the inventory level of the same product in period at distribution center. Given the quantity of products delivered to DC in period, the fourth gene was the proportion of those assembled by plant. The fifth gene referred to the fraction that came from distributor. The customer satisfaction level at retailer in period was given by the sixth gene. The seventh gene represented the fitness value assigned to the particular chromosome based on its objective value-aggregate production–distribution cost. The last gene of the solution structure (status) was a binary variable representing the feasibility of the chromosome. The initial population was generated randomly. In evolutionary stage three crossover operators were applied: averaging crossover, convex crossover, uniform crossover. In proposed GA the five mutation operators were implemented: flip mutation, swap mutation, combine mutation, border mutation, random mutation. As a selection mechanism a combination of

[29] A. D. Yimer, K. Demirli, *A genetic approach to two-phase optimization of dynamic supply chain scheduling*, "Computers & Industrial Engineering" 2010, No. 58, pp. 411–422.

roulette wheel and elitism was applied. The algorithm terminated when there was no significant improvement during the specified number of iterations or if the maximum generation was reached. Proposed GA was compared with commercial software called LINGO 8.0. The GA results indicated that the range of gaps with respect to the solution quality was in the order of 99.17–99.92% of its lower bounds. In addition, the proposed GA approach solved all the test problems within a very short period of computational time, mostly in less than 3 h.

Ying-Hua[30] developed a genetic algorithm combined with the co-evolutionary mode (considering multiple criteria, search speed and avoiding converge before the right time) and the constraint satisfaction mode to establish supply chain system for all manufacturing branches. Minimization of the cost of a supply chain network was an objective function. The chromosome consisted of three sections which represented the relationship between the four levels: raw material supplier, manufacturer, distribution center and retailer. In evolutionary process the roulette wheel selection was applied. The two-point crossover operator was employed. Furthermore, after crossover execution the single point mutation[31] was used. Termination condition was defined as follows: the genetic algorithm stopped when fitness values of chromosomes in a population were the same or when the number of generations exceeded 100 000. Proposed GA was compared with LINGO software (version 9.0) in mathematical programming mode. The experimental result was compared with the algorithmic result to determine the difference in cost and calculation time. The study analyzed the time and solution search cost for large and small-scale cases. The comparison of solution search efficiency and quality for large and small cases indicated that although costs by the genetic algorithms were slightly greater than those for LINGO, time cost for the genetic algorithms was smaller than for LINGO.

Radhakrishnan and Jeyanthi[32] proposed a genetic algorithm for reducing the total supply chain cost. In this paper the supply chain inventory optimization analysis was considered without raw material lead time. In proposed GA each gene of the chromosome represented the stock level of the product and each member was presented by the positive values representing excess stock level of

[30] C. Ying-Hua, *Adopting co-evolution and constraint-satisfaction concept on genetic algorithms to solve supply chain network design problems*, "Expert Systems with Applications" 2010, No. 37, pp. 6919–6930.

[31] In the single point mutation a gen is chosen randomly and then the random value is added to the chosen gen.

[32] P. Radhakrishnan, N. Jeyanthi, *Genetic Algorithm Model for Multi-factory Supply Chain Inventory Optimization involving Lead Time*, "International Journal of Computational Engineering & Management" 2011, No. 14, pp. 142–150.

the product and the negative values representing shortage level of the product. The initial population was generated randomly. The selection operation was the initial genetic operation which was responsible for the selection of the fittest chromosome for further genetic operations. This was done by assigning ranks based on the calculated fitness value to each of the prevailing chromosomes. On the basis of this ranking, the best chromosome was selected for further processing. In the evolutionary process the authors chose two-point crossover and swap mutation. The GA stopped when the fixed number of generations was reached or till convergence criteria were satisfied. In the numerical experiments the simulation was run on a large database of past records. Basing on the obtained results, it was noted that the solutions obtained by GA were better than decisions made in the past.

3.3. Complex objective (Balance between facilities)

Besides time objectives and cost objectives, there are a lot of other optimization objectives which are considered in supply chain. The most popular approach is to create the complex objective functions, which are a combination of several variants.

Chan and Chung[33] developed a multi-criterion genetic optimization for solving distribution network problems in supply chain management. In the proposed solution each chromosome represented the allocation of demands between the customers, warehouses, and manufacturers. The chromosome was divided into two regions. In the first region, the value of the gene represented the number of warehouse and the position of the gene represented the customer number. In the second region, the value of a gene represented the manufacturing plant number, and the location of the gene represents the customer number. The initial population was generated randomly. The authors adopted the multi-point crossover method where the number of cut point equaled the rounded integer value of the chromosome length divided by 4. The mutation operator was applied when a pair of chromosomes with similar genes structure came over to crossover. Both of them were mutated instead of crossover. Termination of genetic algorithm was a fixed number of generations. In numerical experiments there were considered some different variants of supply chain. The optimization results showed that GA was reliable and robust. The results also illustrated the

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[33] F. T. S. Chan, S. H. Chung, *Multi-criteria genetic optimization for distribution network problems*, "The International Journal of Advanced Manufacturing Technology" 2004, No. 24, pp. 517–532.

effect of optimizing a particular factor on the other factors, and indicated the influencing changes from structure to structure. By changing the weightings of criteria, GA was capable to determine the optimal solutions according to the changes made.

Altiparmak *et al.*[34] proposed a new solution procedure based on genetic algorithms to find the set of Pareto-optimal solutions for multi-objective SCN design problem. The problem was a single-product, multi-stage SCN design problem. The objectives were minimization of the total cost of supply chain, maximization of customer services that could be rendered to customers in terms of acceptable delivery time and maximization of capacity utilization balance for DCs. In the proposed solution each chromosome consisted of three segments. Each of the segments was used to obtain a transportation tree of a stage on the supply chain. In the proposed GA, initial population was random. In the evolutionary process a segment-based crossover operator, which was based on uniform crossover, was employed. In the mutation a swap operator was used for the first two segments. In the last segment, mutation operator randomly selected a gene and replaced the value with new one which was selected between 1 and number of DCs except to its current value. The selection mechanism consisted of two, modified stages: tournament selection and elitist strategy. To investigate the effectiveness of the proposed GA the comparison with other method was made. The results showed that proposed GA produced better solutions, but the computation times were approximately two times higher on each problem.

Naso *et al.*[35] developed a genetic algorithm to solve a problem where the supply chain consisted of a network of independent and distributed production centers serving a set of customers distributed across a predefined geographical area surrounding the nodes of the supply chain. In proposed genetic algorithm the objective was to find optimal assignment of demands to depots. In GA each chromosome consisted of two parts. The first part defined the assignment of demands (requests) to the depots. The second part established the order in which the requests would be considered in the construction of the complete schedule of the production chain. The initial population was generated randomly. For evolutionary process the tournament selection was used. Then they applied two kinds of crossover (one-point and order) and mutation (single point and swap) operators. The termination condition of the GA was a fixed number of generations. The proposed scheduling algorithm was compared with other four constructive heuristics. The obtained results illustrated the

[34] F. Altiparmak *et al.*, *A genetic algorithm approach…*, op. cit., pp. 196–215.
[35] D. Naso *et al.*, *Genetic algorithms…*, op. cit., pp. 2069–2099.

interesting potential of the proposed approach. Firstly, in the solutions found by the GA the number of requests that were redirected to external companies was very small in comparison with the other scheduling strategies. Secondly, the proposed model allowed the definition of safety margins for minimizing the effects of transportation delays.

Farahan and Elahipanah[36] developed and solved a model for just-in-time (JIT) distribution in the context of supply-chain management. For the distribution network a bi-objective model was set up with two objective functions: minimizing costs, and minimizing the sum of backorders as well as surpluses of products in all periods. A chromosome was represented as a binary string. Initial population was generated by special procedure, which produced near feasible chromosome. For the evolutionary process, parents were selected using the binary tournament method, and were copied into the mating pool as well. A multiple-point crossover[37] was applied here. After the crossover, each parent in the mating pool was mutated with established probability. The termination condition of the GA was a fixed number of generation. For the small-size problems solutions received from developed GA were compared with solutions obtained from LINGO 8.00 optimization software. Some larger-size real-world problems which could not be solved by LINGO or other commercial software were only solved by the proposed GA.

Jung and Lee[38] proposed a new supply chain synchronizing approach that synchronized each timing point found between a supplier and a buyer in the serial structure of the supply chain with one in two timing points. The aim of the considered case was to find the optimal solution for the production quantity in the production lot and the job sequence with the minimum supply chain total cost taking into account the time limits. The authors proposed two genetic algorithms, GA1 and GA2. Since GA2 was an expanded version of GA1, the details of GA1 were described below first. Each chromosome was divided into two sections. The first section (on the left side of the chromosome) represented a job sequence. The second section (on the right side of the chromosome) represented the integer solutions for the production quantity in each production lot. For the first chromosome in a population, the initial job sequence was randomly

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[36] R. Z. Farahan, M. Elahipanah, *A genetic algorithm to optimize the total cost and service level for just-in-time distribution in a supply chain*, "International Journal of Production Economics" 2008, No. 111, pp. 229–243.

[37] Multi-point croossover is an extension of two-point crossover.

[38] J. W. Jung, Y. H. Lee, *Heuristic algorithms for production and transportation planning through synchronization of a serial supply chain*, "International Journal of Production Economics" 2010, No. 124, pp. 433–447.

generated and the initial production quantity was determined. Crossover and mutation operators were divided into sections for the job sequence and the production quantity. As a selection mechanism the roulette wheel method was used. Two types of termination conditions were used. The search procedure was terminated when either the number of generations exceeded the fixed number of generations, or if an improved solution was not found within a fixed number of search generations. GA2 differed from GA1 in the way that it also applied an elitist selection method. In the numerical experiment three simulated annealing algorithms were compared with G1 and G2. To compare the performance of 5 algorithms, the mean and the standard deviation of the absolute error was used as the standard of judgment. The experiment was replicated 30 times for each problem, and thus the various parameters were randomly generated 30 times for each problem. GA2 proved to be the most robust heuristic algorithm, because it produced the minimum mean absolute error and the smallest lead time in all cases.

4. Current trends

Research papers related to the genetic algorithm are constantly presenting innovative approaches. It can be noted that increasingly few classical genetic algorithms are used. Hybrid approaches become increasingly popular. Basing on the analyzed literature it can be said that scientists are increasingly introducing extensions to the classical genetic algorithm. They combine genetic algorithms with other methods, for example with simulated annealing, local search methods[39]. This type of extensions should be justified, why they are better than others, why they fit to the problem formulation.

Researchers are trying to improve the performance of genetic algorithms, e.g., by creating new genetic operators, introducing new method for generating initial population and so on. Experiments performed by Józefowska and Zimniak[40] for two well known multicriteria combinatorial problems, showed that the reduction of the search space reduced computational time of the algorithm with the little impact on the quality of solutions.

[39] Compare with Moon *et al.*, *Advanced planning…*, op. cit.; Lim *et al.*, *Hybrid approach…*, op. cit.

[40] J. Józefowska, A. Zimniak, *A multiple criteria genetic algorithm operating on a reduce search space*, in: E DS. S. Domek, R. Kaszyński, Proceedings of the 10th IEEE Conference on Methods and Models in Automation and Robotics. Międzyzdroje 2004, pp. 1379–1384.

Traditionally, research focused on planning for simple supply chain with a few layers (e. g. suppliers, manufacturers, distribution centers, retailers). In supply chain management practice, there are very often more than four layers. There is a need to find a more general solution, which will take into account the complexity of supply chains occurring in reality.

Nowadays the environment is very dynamic, so there is a need to develop an algorithm that will react to dynamically changing elements in the supply chain. Supply chain redesign in the context of the new requirements will be a great challenge for scientists, especially if this process have to be made in a short time.

In many cases, descriptions of the genetic algorithms are too poor to be able to make a comparison of their performance with other solutions. Therefore, there is a need to develop standards for conducting experiments with the use of genetic algorithms. As noted by Węglarz *et al.*[41] "The current state is that no common standard has been elaborated indicating how computational experiments should be performed, which data sets should be used, which measures should be considered, which other results and how should be used for comparison, etc.". Such standard is much needed to create a mechanism that allows to compare the another implementation and reproduce studies of other researchers. Many types of these recommendations can be found in Aytug *et al.*[42] and Węglarz *et al.*[43].

Conclusion

In this paper we have reviewed a literature concerning the use of genetic algorithm for supply chain network design problem. We have also introduced an overview of the genetic algorithm elements such as: chromosome representations, objective functions, selections, crossover and mutation operators, replacement scheme and termination conditions.

According to this survey, many papers present an accurate description of the genetic algorithm elements, for example they explain how crossover operator works, what is "step-by-step" encoding procedure. Furthermore in this case, researchers describe own elaboration by introducing a pseudo-code

[41] J. Węglarz *et al.*, *Project scheduling…*, op. cit., pp. 201.

[42] H. Aytug, M. Khouja, F. E. Vergara, *Use of genetic algorithm to solve production and operations management problems: a review*, "International Journal in Production Research" 2003, No. 41, pp. 3955–4009.

[43] J. Węglarz *et al.*, *Project scheduling…*, op. cit.

for procedures and function (e.g., “how crossover operator works”). It is very important for other researchers, who will base on past papers. On the other hand, there are a lot of works which have several shortcomings. Firstly, there is the omission of one or more basic elements of GA. This fact complicates analyses and comparisons with other variants proposed by other researchers. Secondly, when a new method is presented it should be described accurately; it helps to implement this method in order to compare with others.

Finally, the review has also presented the current trends in the literature related to the genetic algorithms for supply chain network design problem. According to the author, these trends should be the benchmark for researchers involved in the use of genetic algorithms in that process.

References

Altiparmak F., Gen M., Lin L., Karaoglan I., *A steady-state genetic algorithm for multi-product supply chain network design*, ”Computers & Industrial Engineering” 2009, No. 56.

Altiparmak F., Gen M., Lin L., Paksoy T., *A genetic algorithm approach for multi-objective optimization of supply chain networks*, ”Computers & Industrial Engineering” 2006, No. 51.

Aytug H., Khouja M., Vergara F. E., *Use of genetic algorithm to solve production and operations management problems: a review*, “International Journal in Production Research” 2003, No. 41.

Chan F. T. S., Chung S. H., *Multi-criteria genetic optimization for distribution network problems*, ”The International Journal of Advanced Manufacturing Technology” 2004, No. 24.

Chung S. H., Lau H. C. W., Choy K. L., Ho G. T. S., Tse Y. K., *Application of genetic approach for advanced planning in multi-factory environment*, ”International Journal of Production Economics” 2010, No. 127.

Farahan R. Z., Elahipanah M., *A genetic algorithm to optimize the total cost and service level for just-in-time distribution in a supply chain*, ”International Journal of Production Economics” 2008, No. 111.

Gen M., Altiparmak F., Lin L., *A genetic algorithm for two-stage transportation problem using priority-based encoding*, ”OR Spectrum” 2006, No. 28.

Goldberg D. E., *Algorytmy genetyczne i ich zastosowania*, Wydawnictwo Naukowo-Techniczne, Warszawa 2003.

Herroelen W., *Project scheduling – Theory and practice*, ”Production and Operations Management” 2005, No. 14.

Józefowska J., Zimniak A., *A multiple criteria genetic algorithm operating on a reduce search space*, in: Eds. S. Domek, R. Kaszyński, Proceedings of the 10th IEEE Conference on Methods and Models in Automation and Robotics. Międzyzdroje 2004.

Jung J. W., Lee Y. H., *Heuristic algorithms for production and transportation planning through synchronization of a serial supply chain,* "International Journal of Production Economics" 2010, No. 124.

Lim S. J., Jeong S. J., Kim K. S., Park M. W., *Hybrid approach to distribution planning reflecting a stochastic supply chain,* "The International Journal of Advanced Manufacturing Technology" 2006, No. 28.

Moon C., Kim J., Gen M., *Advanced planning and scheduling based on precedence and resource constraints for e-plant chains,* "International Journal of Production Research" 2004, No. 42.

Moon C., Seo Y., Yun Y., Gen M., *Adaptive genetic algorithm for advanced planning in manufacturing supply chain,* "Journal of Intelligent Manufacturing" 2006, No. 17.

Naso D., Surico M., Turchiano B., Kaymak U., *Genetic algorithms for supply-chain scheduling: A case study in the distribution of ready-mixed concrete,* "European Journal Of Operational Research" 2007, No. 177.

Papageorgiou L. G., *Supply chain optimisation for the process industries: Advances and opportunities,* "Computers and Chemical Engineering" 2009, No. 33.

Radhakrishnan P., Jeyanthi N., *Genetic Algorithm Model for Multi-factory Supply Chain Inventory Optimization involving Lead Time,* "International Journal of Computational Engineering & Management" 2011, No. 14.

Rostamian Delavar M., Hajiaghaei-Keshteli M., Molla-Alizadeh-Zavardehi S., *Genetic algorithms for coordinated scheduling of production and air transportation,* "Expert Systems with Applications" 2010, No. 37.

Syarif A., Yun Y. S., Gen M., *Study on multi-stage logistic chain network: a spanning tree-based genetic algorithm approach,* "Computers and Industrial Engineering" 2002, No. 43.

Węglarz J., Józefowska J., Mika M., Waligóra G., *Project scheduling with finite or infinite number of activity processing modes – A survey,* "European Journal of Operational Research" 2011, No. 208.

Yao M., Hsu H., *A new spanning tree-based genetic algorithm for the design of multi-stage supply chain networks with nonlinear transportation costs,* "Optimization and Engineering" 2009, No. 10.

Yimer A. D., Demirli K., *A genetic approach to two-phase optimization of dynamic supply chain scheduling,* "Computers & Industrial Engineering" 2010, No. 58.

Ying-Hua C., *Adopting co-evolution and constraint-satisfaction concept on genetic algorithms to solve supply chain network design problems,* "Expert Systems with Applications" 2010, No. 37.

Zegordi S. H., Abadi I. N. K., Nia M. A. B., *A novel genetic algorithm for solving production and transportation scheduling in a two-stage supply chain,* "Computers & Industrial Engineering" 2010, No. 58.

Резюме

Использование генетических алгоритмов в управлении цепью поставок. Обзор литературы, актуальные тренды

Уже несколько десятилетий управление цепью поставок (SCM) является одним из главных направлений исследований и практики. За это время были разработаны многие методы и процедуры оптимизации этого процесса. Чтобы создать эффективную сеть цепи поставок ресурсы и фабрики должны быть тесно интегрированы. SCM обращается к проблемам, которые очень популярны в литературе. Предметом настоящей работы является презентация вариантов конфигурации и параметров генетического алгоритма (GA), используемого для решения проблем с цепью поставок. В настоящей статье представлен обзор литературы за 2000–2011 гг. Креме того обсуждены здесь тренды, касающиеся проблематики SCM.

Ключевые слова: управление цепью поставок, генетический алгоритм, оптимизация.

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