Vehicle Routing in a Multi-product Supply Chain using Populated Simulated Annealing Algorithm

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Abstract: This paper aims to examine the scheduling of vehicles in a multi-product supply chain regarding to the mutual relationship between the transportation and the manufacturing units. The integration level in the supply chain consists of a manufacturer and its first tier suppliers, which are linked by a transportation fleet. The problem is determining orders allocation to the suppliers, orders production sequence at the suppliers, orders allocation to the vehicles, and orders transportation priority, in order to minimize the sum of orders delivery time. This issue has not been discussed in the literature, so far. At first, the mathematical model of the problem is presented, then the NP-Hardness of the problem is demonstrated. For solving the problem, a new combination of genetic algorithm and simulated annealing algorithm, named as Populated Simulated Annealing algorithm (PSA) is proposed. For verifying the PSA, its results are compared to results of simulated annealing algorithm (SA) and developed version of DGA algorithm, proposed for the nearest problem in the literature to our problem. Furthermore, relaxing some hypothesis, the results of PSA are compared to DGA results. All of the comparisons show that PSA is more efficient than the other algorithms. Finally, comparison of PSA with exact solution for small size problems demonstrates its proper efficiency.

Keywords: Routing, Genetic Algorithm, Simulated Annealing, Scheduling.

Introduction: The vehicle routing problem (VRP) is one of the most important issues in the world's industry, which, today, is highly regarded because of its practical applications in industries.

We examined the scheduling of production and transportation in a multi-product supply chain considering the interaction between the transportation and the manufacturing units. The supply chain consists of two parts.The first part is suppliers which are located in different geographical locations handling specific orders. The second part consists of several vehicles that collect the orders processed by suppliers and deliver them to the company. The considered transportation system is similar to vehicle routing problem (VRP). The difference between VRP and the problem in this research is that in VRP the amount of goods that should be transported, and is known. However, as it is assumed in this research, the allocation of orders and sequencing of their manufacturing are the decisive variables. Problem objectives are determining the allocation of orders to suppliers, orders production sequence, orders allocation to the vehicles, and transportation sequence, in order to minimize the summation of the orders completion time. Innovation of this paper is as follows:

- A combination of production scheduling problem in suppliers and VRP in a supply chain when the supplier can't process all orders.
- Developing a new mathematical model for solving the problem.
- Three algorithms have been proposed to solve this problem, including: developed DGA, simulated annealing algorithm (SA), and a new combination of these two algorithms, which is named populated simulated annealing algorithm (PSA).

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A supply chain consists of a set of suppliers, producers and distributors that cooperate with each other in order to satisfy customers' need. A supply chain determines all levels in which the value is added to a product. VRP has several versions. In this study, it is considered that a number of heterogeneous vehicles are collecting orders from suppliers located in different geographical locations.

With considering the integration level of companies in the supply chain, researches can be divided into four categories:

1) Researches that examine the relationship between manufacturers and suppliers;
2) Researches that examine the relationship between manufacturers and distributors or customers;
3) Researches that focus on the relationship between some manufacturers together (Outsourcing);
4) Researches that consider combination of the above scenarios.
5)

Considering the examination level of supply chain, researches have been divided in two categories: 1) Researches that have a macro planning and coordinating in the completion chain; 2) Researches that have an operational scheduling and coordinating in the supply chain.

The literature shows that the combination of VRP with scheduling problem in supply chains possessing constraint on allocating the orders to suppliers has not been studied.

Materials and Methods: Step 1) Developing a new mathematical model for this problem.
Step 2) Developing the PSA algorithm to solve the problem.
Step 3) Validating PSA algorithm as follows:
Step 3-1) Producing random samples with different structures.
Step 3-2) Comparing PSA with SA and developing DGA.
Step 3-3) Comparing PSA with DGA after adding a relaxation assumption.
Step 3-4) Solving small samples with PSA and comparing with exact solution.
Step 4) Doing sensitivity analysis on the three main parameters. (Number of orders, Number of suppliers, and Number of vehicles)

Results and Discussion: The results of the comparison demonstrate that the populated simulated annealing algorithm shows better results than the other two. This method shows that the combination of genetic algorithm and simulated annealing in this specific way can adapt advantages of both methods. The results show that the mean of answers is increased by increasing number of orders,. With increasing suppliers, the objective function is improved because the orders allocate to different suppliers and the delivery time is decreased. By increasing orders processing time, the objective function value gets worse because the waiting time for processing orders is increased. By increasing transport times, the average solution is increased. It's because vehicles should spend more time along the way.

Conclusion

This issue has not been discussed in the literature. At first, the mathematical model is presented and then it is shown that the problem is NP-Hard. Three algorithms have been proposed to solve this problem: Developed DGA, Simulated Annealing Algorithm, and a new combination of these two algorithms, which is named Populated Simulated Annealing Algorithm. Random samples with different structures is created and solved by these three algorithms. Also, relaxation of distance assumption between suppliers that are in the same location has been discussed at Zegordi and Beheshti Nia (2009) and is compared with PSA which shows that PSA is more efficient than the other algorithms. Finally, the comparison of PSA with exact solution for small size problems demonstrates its proper efficiency.

References

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