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Integrated process planning and scheduling in a supply chain ☆

Chiung Moon [a], Young Hae Lee [b,*], Chan Seok Jeong [c], YoungSu Yun [d]

[a] Department of Information and Industrial Engineering, Yonsei University, Seoul, Republic of Korea
[b] Department of Information and Industrial Engineering, Hanyang University, Ansan, Gyeonggi-do, Republic of Korea
[c] Korea Army, Seoul, Republic of Korea
[d] Department of Business Administration, Chosun University, Gwangju, Republic of Korea

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Abstract

This paper deals with the integration of process planning and scheduling, which is one of the most important functions in a supply chain to achieve high quality products at lower cost, lower inventory, and high level of performance. Solving the problem is essential for the generation of flexible process sequences with resource selection and for the decision of the operation schedules that can minimize makespan. We formulate a mixed integer programming model to solve this problem of integration. This model considers alternative resources: sequences and precedence constraints. To solve the model, we develop a new evolutionary search approach based on a topological sort. We use the topological sort to generate a set of feasible sequences in the model within a reasonable computing time. Since precedence constraints between operations are handled by the topological sort, the developed evolutionary search approach produces only feasible solutions. The experimental results using various sizes of problems provide a way to demonstrate the efficiency of the developed evolutionary search approach.

Keywords: Process planning; Scheduling; Evolutionary search approach; Supply chain; Topological sort

1. Introduction

Supply chain is an integrated business process where various business entities work together in an effort to (a) acquire raw materials, (b) convert these raw materials into specified final products, and (c) deliver these final products to retailers (Beamon, 1998). A global chain covers multiple manufacturing sites and consists of suppliers, fabrication and assembly shops, as well as outsourcing entities. These supply chains' planning and scheduling activities are very complex and have to take place within the enterprise and across the entire supply chain in order to achieve high quality products at lower cost, lower inventory, and high levels of performance. As a result, to efficiently provide global optimal solutions, enterprises are migrating from separated planning processes toward more coordinated and integrated planning processes.

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* Corresponding author. Tel.: +82 31 400 5262; fax: +82 31 602 7730.
E-mail address: yhlee@hanyang.ac.kr (Y.H. Lee).

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Recently, researchers have placed increasing attention on integrated models for supply chain planning. Process planning and scheduling are possibly the most important functions in a supply chain system. This is because these functions are essential for inventory to be available-to-promise for customers. Process planning determines how an item will be manufactured; it acts as a bridge between design, manufacturing, and scheduling. Process planning considers alternative resources.

In practice, any customer order, assigned to a site for processing, can be scheduled on various resources and may have a flexible process sequence. If some orders have certain process sequences, they should be considered for an integrated model using alternative resources. Hankins, Wysk, and Fox (1984) showed that using alternative resources reduces lead-time and improves overall resource utilization. Nasr and Elsayed (1990) presented two heuristics to determine an efficient schedule for the n orders and the m resources problem with alternative routings allowed for each operation. Brandimarte and Calderini (1995) developed a two-phase hierarchical Tabu search for planning and scheduling. Palmer (1996) developed a method based on simulated annealing to solve integrated problems.

However, the researchers mentioned above did not consider the precedence rule for an operation sequence; they only considered the time aspect with a non-constraint operational sequence. Tan (2000) presented a review of various research efforts considering the process planning and scheduling area and discussed the extent of applicability of various approaches in solving process planning and scheduling. Guinet (2001) proposed a primal-dual approach to solve a production planning model with a network.

More recently, Moon, Kim, and Hur (2002) proposed an integrated model for flexible process sequencing and scheduling to minimize total tardiness. This model considered resource selection and precedence constraints. They developed an evolutionary algorithm approach to solve the model. Cochran, Horng, and Fowler (2003) solved parallel resource scheduling problems using a two-stage multi-population evolutionary algorithm. Tan and Khoshnevis (2004) presented a mixed integer programming model to solve process planning and scheduling problems.

The main focus of our work is not only the formulation of a mathematical model that incorporates the process planning of resource selection and operation sequencing and the determination of their schedules so that the total processing time is optimized, but also the development of an efficient evolutionary search approach with a topological sort (TS) technique (Horowitz & Sahni, 1984) .This technique is to determine a set of operation sequences for orders. The evolutionary search approach has been successfully applied to a number of combinatorial optimization problems (Cochran et al., 2003; Gen & Cheng, 2000; Moon et al., 2002).

An evolutionary search approach based on a TS can generate a good solution to the model within a reasonable amount of computation time. Since precedence relations between operations are handled by the TS, an evolutionary search approach produces only feasible solutions.

2. Problem definition

The manufacturing process for a customer order is made up of various processes used for converting raw materials or semi-finished products, or assembly parts into finished products. The set of processes can be constrained by the precedence relations. These relations are imposed by the technological requirements of the product. Process planning contains the determination of operations and their sequences considering precedence relations and alternative resources for effectively producing a customer order. Scheduling involves allocating resources over time to produce a set of orders. The integrated process planning and scheduling problem is to determine optimal schedules with process plans considering precedence relations between operations, processing time, and the set of alternative resources. The schematic diagram of the problem is shown in Fig. 1.

In Fig. 1, a set of n orders are to be processed using m resources with alternative operation sequences. Since the orders that should be manufactured have a typical operational structure constrained by sequentially related operations or machining functions, a process plan representation should have the capability to represent all possible precedence constraints that occur among the planning and processing decisions.