A biased-randomized simheuristic for the distributed assembly permutation flowshop problem with stochastic processing times

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A R T I C L E   I N F O
Article history:
Received 4 May 2017
Revised 11 September 2017
Accepted 12 September 2017

Keywords:
Distributed assembly flowshop
Stochastic optimization
Simulation-optimization
Metaheuristics
Biased randomization

A B S T R A C T
Modern manufacturing systems are composed of several stages. We consider a manufacturing environment in which different parts of a product are completed in a first stage by a set of distributed flowshop lines, and then assembled in a second stage. This is known as the distributed assembly permutation flowshop problem (DAPFSP). This paper studies the stochastic version of the DAPFSP, in which processing and assembly times are random variables. Besides minimizing the expected makespan, we also discuss the need for considering other measures of statistical dispersion in order to account for risk. A hybrid algorithm is proposed for solving this N/P-hard and stochastic problem. Our approach integrates biased randomization and simulation techniques inside a metaheuristic framework. A series of computational experiments contribute to illustrate the effectiveness of our approach.

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1. Introduction

Scheduling optimization deals with allocating, in a specified period of time, limited resources to tasks in order to achieve one or more goals determined by the decision maker [85]. One of the scheduling optimization problems that has been extensively studied during the last decades is the flowshop problem (FSP) [83,94]. The FSP has applications in different industry sectors, among others: the metallurgical, chemical, textile, iron and steel making, etc. [65,97]. In a FSP, a set of $m$ machines have to process a set of $n$ jobs, which are available at time zero. Each job requires to pass through all the machines. The processing time of job $j$ in machine $i$ is denoted by $p_{ij}$. Typically, at any given time each machine is able to process just one job, and each job can only be processed by one machine. Notice that there are $n!$ possible job sequences per machine. Therefore the total number of possible job sequences adds up to $(n!)^m$. Usually, it is assumed that the job sequence of the first machine is kept for all the remaining machines. Thus, the number of feasible job sequences is reduced from $(n!)^m$ to $n!$. This FSP variant is known as the permutation flowshop problem (PFSP). The PFSP is one of the most studied problems in scheduling optimization [23,60,102].

In the scheduling literature, it has been usual to assume that processing times are deterministic and known in advance. However, in real life these times are frequently subject to certain degree of uncertainty, which can be due to different fac-

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http://dx.doi.org/10.1016/j.simpat.2017.09.001
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The processing with the assigned; parts This concept computer applications of customized problem might be seen as an assembly problem –i.e., a job–, and that different parts of the same product can be generated in different factories. The assembly operation of product \( h \) can begin only once all its \( |N_h| \) parts have been completed at the production stage. The assembly time of product \( h \) at the assembly machine is denoted by \( pp_h \). In this environment two decisions are taken: (i) to which factory a job \( j \in N \) has to be assigned; and (ii), in which sequential order should the assigned jobs be processed at each factory. A schematic diagram of the DAPFSP is shown in Fig. 1.

To the best of our knowledge, only two conference papers have addressed stochastic versions of the DAPFSP (SDAPFSP) with random processing and assembly times. In the first one, Ji et al. [49] considered also a no-wait constraint in the processing stage. These authors used the PSOSAHT algorithm [71], which combines particle swarm optimization with simulated annealing concepts. In the second work, Du et al. [22] considered stochastic sequence-dependent setup times as well as stochastic job release times. Again, the PSOSAHT algorithm was used to solve the problem. Both papers employed a hypothesis-testing approach to evaluate and compare the stochastic results. As a contribution to the emerging interest in the SDAPFSP, we propose a simheuristic algorithm [56] to minimize the expected makespan. Our approach integrates biased

![Fig. 1. A schematic representation of the DAPFSP.](image-url)
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