Multi-factory parallel machine problems: Improved mathematical models and artificial bee colony algorithm

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A B S T R A C T

This paper considers the problem of multi factory parallel machine problems. This problem is already studied in the literature and there is a mathematical model and a genetic algorithm for the problem. We analyzed the model and algorithm, and showed that they suffer from serious shortcomings. Then, we propose three mathematical models for makespan and total completion time objectives. The proposed models are compared with the available model in both size and computational complexities. The available model is significantly outperformed. Moreover, we propose three effective metaheuristics based on artificial bee colony algorithms. The proposed metaheuristics are compared against the four available algorithms on both small and large instances. The proposed metaheuristics perform much more effectively.

1. Introduction

In today’s world, the centralized manufacturing seems deficient to respond to the market requirements. Therefore, many organizations are showing increasing interest for utilizing a decentralized structure in manufacturing. Hence, a new concept called distributed manufacturing has been introduced in which several factories are integratedly planned in order to gain competitive advantages in the international economic area (Alvarez, 2007). Kanyalkar and Adil (2005) state that the single- and multi-factory production systems have some basic differences. In the single-factory production, products are manufactured by a single entity and then delivered to the market. However, in the multi-factory production, products are manufactured in several factories, maybe located in different geographical places. Therefore, some might be closer to customers and some might be far away. Moreover, not all factories are able to carry out all job types. In other words, there is the factory eligibility.

According to Kreipl and Pinedo (2004), a multi-factory model schedules all the jobs in different factories and at the same time satisfies the precedence constraints and sometimes time windows. Thoney, Hodgson, King, Taner, and Wilson (2002) considered scheduling of multi-factory supply chains and studied a model of batch processing with internal and external bulk transportation and solved industrial-sized problems. Moon, Seo, Yun, and Gen (2006) proposed a scheduling model and an advanced process planning for the multi-factory production to minimize the makespan and operation sequences with machine selections considering the precedence constraints, flexible sequences, and alternative machines.


More recently, Behnamian and Fatemi Chomi (2013) consider a multi-factory model where each factory has multiple identical
The number of jobs, \( n \), the base processing time of job \( pj \), the processing time of job \( 37 \), is independent of sequence of jobs in set \( f \). The speed of machines in factory \( v \) is the set of jobs assigned to machine \( f \) of factory \( k \). We know \( C_{max} = \max_{j} \{ F_{ik} \} \)

We have

\[ F_{ik} = \sum_{j=1}^{n} p_{jik} \]

where \( j_{ik} \) is the set of jobs assigned to machine \( i \) of factory \( k \). Therefore, \( F_{ik} \) is independent of sequence of jobs in set \( j_{ik} \). □

The available model proposed by Behnamian and Fatemi Ghomi (2013), although for makespan minimization, is developed so as to consider both assigning and sequencing. In this case, the model consists of many unnecessary binary variables and constraints for sequencing decision. This fact makes the model and their algorithm completely ineffective. The available model solves the makespan problem, although the problem is easier, at expense of both assignment and sequencing decisions.

We now present the mathematical model of makespan minimization. The variables applied in the first model are as follows.

- \( X_{jki} \) binary variable taking value 1 if job \( j \) is processed at factory \( f \) on machine \( i \); and 0 otherwise
- \( C_{max} \) continuous variable for the makespan

As can be seen, the decision variables merely express the assignment part. The model is as follows.

Objective:

\[
\text{Min } C_{max} \tag{1}
\]

Subject to:

\[
\sum_{k=1}^{f} \sum_{j=1}^{n} X_{jki} = 1 \quad \forall j \tag{2}
\]

\[
C_{max} \geq \sum_{j=1}^{n} p_{j} \cdot X_{jki} \quad \forall k, i \tag{3}
\]

\[
X_{jki} \in \{0, 1\} \quad \forall j, k, i \tag{4}
\]

Eq. (1) is the objective. Constraint set (2) assures that job \( j \) is assigned to exactly one machine of one factory. Constraint set (3) calculates the makespan which is equal to maximum finishing time of all machines. Constraint set (4) defines the decision variables.

2.2. Total completion time minimization

Note that the objective in the problem of MFPM with total completion time minimization depends on both decisions of assigning and sequencing. This fact causes that this problem with makespan minimization differs from the problem with total completion time minimization. Since the available model and genetic algorithm determine both assigning and sequencing, they can solve problem with total completion time. Even for this problem, we believe that
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