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Full Length Article

# Coordinating order acceptance and integrated production-distribution scheduling with batch delivery considering Third Party Logistics distribution

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A B S T R A C T

The present study proposes two mixed integer linear programming model for two important aspects of integrated production-distribution scheduling: order acceptance and batch direct delivery. Moreover, as many companies are unable to provide sufficient transportation facilities to deliver the customer orders due to high costs of initial investment, transportation is outsourced to a third-party logistics provider in which the transportation cost is dependent on the batch. The aim of this paper is trading off among the revenue of accepted orders, costs of delivery, and penalties for tardiness incurred in an integrated production-distribution in a supply chain to maximize the total of benefit. In addition, since the problem in this study is strongly NP-hard, an adaptive genetic algorithm is used to solve large-scale instances in this regard that use the adaptive search approach.

A representation procedure is introduced based on two optimal properties of the problem. For the initial population, four heuristics are developed. To explore and locate the algorithm in a better neighborhood, a local search is made use of. Taguchi experimental design was applied to set the appropriate parameters of the algorithms. Moreover, to verify the developed model and evaluate the performance of algorithm against the exact solution, a commercial solver is used. The obtained results on generated random instances reveal the appropriate performance of heuristics, the adaptive approach and local search on the genetic algorithm. Furthermore, the effect of different parameters and factors of the proposed model on the profit shows that the order acceptance and the more vehicles of the company improve the profit.



## 1. Introduction

Supply chain refers to the flow of goods and services through the functions such as production and distribution. Due to be time-sensitive of products and many applications of Make-To-Order (MTO) supply chains, companies now tend to a closer interaction and coordination between these functions in an integrated manner. To achieve the optimal operational performance of a supply chain, it is critical to integrate production and distribution of a supply chain [1] which has been recently attention to both practice as well as academic research [2–5]. In this regard, Chen [1] and Fahimnia et al. [6] reviewed and classified existing integrated production and distribution literature. However, classical scheduling researches just focused on determination of the schedules for production orders such that one or more performance measures were optimized without taking into account distribution costs.

Besides, Vroblefski et al. [7] have highlighted that one of the main costs in any distribution network is the transportation cost, which is extremely dependent on the volume of orders being transported. Batch delivery can be regarded as one of the most important approaches that can decrease transportation costs in many industries such as food and beverage, chemicals and pharmaceutical, and iron and steel industries. Batch delivery is defined as the process of batching the orders and delivering the batches using transporters (vehicles), pallets, boxes, or carts [4,8,9]. A good number of studies conducted by Ahmadizar and Farhadi [8], Rasti-Barzoki and Hejazi [10], Mazdeh et al. [11], and Gao et al. [4] have been devoted to address the batch delivery problem. In the mentioned

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studies, it was assumed that the orders occupied the same physical space. Thus, the vehicle capacity could be defined as the maximum number or volume of orders that could be simultaneously carried. Furthermore, these studies focused on a single customer's orders. However, in real cases, there are several customers who may have numerous orders. On the other hand, another group of authors such as Wang and Cheng [12], Yin et al. [13], Steiner and Zhang [14], Gong et al. [15] and Gao et al. [4] have addressed the batch delivery problem with multiple customers, in which all the orders occupied the same amount of space. The above-mentioned batch delivery models only focused on minimization of time-based (service) and/or cost-based objective functions without considering the orders revenue.

Moreover, as many companies are unable to provide sufficient transportation facilities to deliver the customer orders due to high costs of initial investment, transportation is outsourced to the third-party logistics (3PL) providers in many practical cases [16–18]. A proper outsourcing plan can improve reduce total costs, lead times, and make a company more competitive [19]. Aguezzoul [20] has presented a literature review on 3PL. In addition, Li et al. [21] have studied the coordinated scheduling of parallel machine and 3PL transportation in a make-to-order electronic supply chain. Zhong et al. [22] have studied the mentioned problem with a single machine, in which various shipping times for different vehicles are specified by the 3PL. Koc et al. [23] have analyzed a problem, in which the manufacturer can use vehicles with unlimited numbers and relatively low costs in their setting. The related literature review indicates that only Agnetis et al. [18] have considered the integrated production and interstate batch delivery scheduling problems. In their study, the batches of semi-finished products are delivered from one manufacturing location to another one belonging to the same manufacturer using 3PL companies.

All the studies mentioned in the previous section have assumed that the orders are accepted without taking into account the production and distribution capacity. Guerrero and Kern [24] have stated "accepting orders without considering their possible costly impact on capacity can mean the firm is paying for the privilege or profitability of accepting an order". In fact, there must be a trade-off between the revenue provided by a particular order and all of its associated processing and delivering costs.

Furthermore, these costs may include delay costs for orders and any penalties incurred if the order is delivered after its agreed-upon due date [25]. In fact, an important step to remain competitive is to attend a coordinated decision making: the order acceptance and scheduling (OAS) [26] that determines which orders should be accepted and how they should be scheduled. Besides, literature indicates that the OAS studies have only focused on production function of a supply chain, and distribution is not addressed in the literature. Slotnick [25] has presented the taxonomy and a review of OAS literature. Considering classical scheduling in the production environment, Reisi-Nafchi and Moslehi [27] have developed the OAS addressing two agents with the weighted number of tardy orders and the total weighted lateness scheduling criteria in a single machine environment. For the same problem, Reisi-Nafchi and Moslehi [28] have developed a pseudo-polynomial dynamic programming algorithm. Og et al. [29] have addressed the problem where the orders have release dates, due dates, deadlines, processing times, sequence-dependent setup times, and revenues. Their study aimed to maximize the total profit in a single machine environment. Cesaret et al. [30] have solved the OAS problem in a single machine environment with release dates and sequence-dependent setup times. Nobibon and Leus [31] have studied the OAS problem in a single machine environment, in which a pool of orders consists of two disjoint subsets, firm planned orders, and the orders that can still be rejected. A permutation flow shop and a parallel machine scheduling problems with the OAS and weighted tardiness were considered by Lin and Ying [32] and Emami et al. [33], respectively.

As can be seen from the description above, recently, the scheduling has been developed in two distinct fields: the scheduling and order acceptance, and integrated production and distribution scheduling with batch delivery. To the best of our knowledge, so far, no study has been made on the coordinated decisions of order acceptance and scheduling in an integrated production and distribution. Table 1 summarizes the assumptions and features of the studies reviewed in this paper.

The present study develops an OAS problem for integration of production and distribution in a supply chain. Recently, Noroozi et al. [60] presented the first study of batch delivery considering simultaneous order acceptance and third party logistics. However, in their work, they considered batch delivery due to round trip transportation and batch independent transportation cost. They presented a mixed integer nonlinear programming and a hybrid meta heuristic algorithm in which elapses a lot of time. In addition, their paper did not study the optimal structures for a solution.

To the best of researchers' knowledge, in the current study, this is the first time that a coordinated order acceptance, batch direct delivery, and third-party logistics optimization of a supply chain scheduling considering the revenues, tardiness costs, and batch dependent transportation costs has been addressed. The very aim of this study is to provide two comprehensive mixed integer linear programming models, one develops the [60] and other is a novel model, to maximize the total net profit with consideration of the following points: 1) there are several customers who may have numerous orders, 2) the orders occupy different amount of space, 3) the vehicle capacity is defined as the maximum occupied space by the orders that can be carried simultaneously, 4) the transportation can be outsourced to a third-party logistics, and 5) the orders may not be accepted. An overview of the considered problem is demonstrated in Fig. 1. The considered problem is strongly NP-hard. To offer the optimal solution of the proposed optimization model, an adaptive genetic algorithm was applied [61]. Furthermore, in contrary to Noroozi et al. [60], a direct encoding scheme was proposed based on two optimal structures for a solution. Moreover, a local search was proposed for quick exploration around a solution. Taguchi experimental design was applied to set the appropriate parameters of the algorithms. A number of test problems were generated to evaluate the performance of the proposed algorithm against the exact methods. Sensitivity analysis was also conducted to discuss the effects of different parameters of the model.

The rest of the paper is organized as follows. In Section 2, a mixed integer programming model is proposed after describing the problem in detail. Section 3 presents different parts of the developed algorithm. Section 4 examines the performance of algorithms and sensitivity analysis and describes Taguchi optimization technique. Factors of the problem, data generation, and parameter calibration are described in Section 5, and then Section 6 compares different variants of the algorithms. Finally, Section 7 presents the conclusion.

## 2. Problem statement and mathematical programing

The important notations used throughout this paper are defined as follows:

*Index list*

| | |
|---|---|
| $k, k'$ | The customer number ($k = 1, \ldots, K$) |
| $j, j'$ | The order index ($j,j'=1,\ldots,n_k$) |
| $i$ | The position of the order in the sequence ($i = 1, \ldots, N$) |
| $b$ | Batch number ($b = 1, \ldots, N$) |
| $M$ | A large positive number |