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# Addressing lot sizing and warehousing scheduling problem in manufacturing environment

N. Mishra [a], V. Kumar [b,*], N. Kumar [c], M. Kumar [d], M.K. Tiwari [e]

[a] School of Computer Science and Information Technology, University of Nottingham, NG8 1BB, UK
[b] DCU Business School, Dublin City University, Dublin 9, Ireland
[c] School of Management, University of Bath, BA2 7AY, UK
[d] School of Management and Law, Edinburgh Napier University, EH14 1DJ, UK
[e] Department of Industrial Engineering and Management, Indian Institute of Technology, Kharagpur-721302, India

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ABSTRACT

In recent years, lot sizing issues have gained attention of researchers worldwide. Previous studies devoted on lot sizing scheduling problems were primarily focused within the production unit in a manufacturing plant. In this article lot sizing concept is explored in the context of warehouse management. The proposed formulation helps manufacturer to decide the effective lot-size in order to meet the due dates while transferring the product from manufacturer to retailer through warehouse. A constrained based fast simulated annealing (CBFSA) algorithm is used to effectively handle the problem. CBFSA algorithm encapsulates the salient features of both genetic algorithm (GA) and simulated annealing (SA) algorithms. This hybrid solution approach possesses the mixed characteristics of both of the algorithms and determines the optimal/near optimal sequence while taking into consideration the lot-size. Results obtained after implementing the proposed approach reveals the efficacy of the model over various problem dimensions and shows its superiority over other approaches (GA and SA).

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## 1. Introduction

Uncertain demand pattern and customized product design are some of the key challenges for companies in current competitive market scenario. Moreover, providing best customer service and growing the customer base are increasingly becoming tougher for manufacturing enterprises. In order to meet these challenges warehouse management plays a key role in the manufacturing supply chain. The competitive warehousing scenario compels the manufacturing firms to deal with the issues such as selection of appropriate warehouses and its efficient management. The product delivery from the manufacturing to warehouse and then from warehouse to retailer is a very crucial issue. This is a complex decision making process, therefore, to ease the complexity nowadays lot-sizing of the product in warehouse scheduling is becoming more common. Sometimes manufacturing companies strive hard to find a place for a complete lot in warehouses. In such circumstances the lot-sizing helps to deal with the availability issues in the warehouse. The lot-size concept also helps the firms to meet the due-date of the retailers. Proper management and efficient use of warehouses are critical for manufacturing industries to performance well in current competitive business scenario. An inefficient warehouse can lead to excess inventory and deadlock of manufacturing order while transferring products from manufacturers to customers.

In this research, warehouse scheduling problem has been considered with the prime objective to search for an optimal schedule, such that the total tardiness and number of tardy orders are minimized. The paper also addresses lot sizing scheduling issues in warehousing environment where the shipment of goods from the manufacturers to warehouses and then to retailers has been considered. The paper also assumes that the number of vehicles in the warehouse is fixed for the time period. The present research also considers the precedence relationship among the products along with non-uniform starting time of warehouse to match the real-life scenario as closely as possible. This non-uniform starting time of warehouse arises due to the non-uniform ending time of previous customer order. Subsequently, a mathematical model is developed to address the dynamic nature of this problem. Warehouse scheduling problem is well known for its computational complexities (Byung-In, Heragu, Graves, & Onge, 2003). Since complexities grow exponentially searching an effective solution is difficult even with the help of a state-of-art optimization tools.

* Corresponding author. Tel.: +353 1 700 8062.
*E-mail addresses:* nxm@cs.nott.ac.uk (N. Mishra), vikas.kumar@dcu.ie (V. Kumar), N.Kumar@bath.ac.uk (N. Kumar), m.kumar@napier.ac.uk (M. Kumar), mkt09@hotmail.com (M.K. Tiwari).

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Nevertheless, the need of coping up with increasingly higher computational complexity has stimulated research in optimization algorithms. This is particularly true in context of evolutionary algorithms, particularly in case of genetic algorithm (GA) and simulated annealing (SA) which showed better performance than their predecessors in solving complex optimization problems (Xu, Wei, & Wang, 2009). Therefore, this paper focuses on the hybrid form of both the approaches and termed as, constraint based fast simulated annealing (CBFSA) algorithm (Tiwari, Kumar, Prakash, Kumar, & Shankar, 2006) to address the warehouse scheduling problem. This algorithm addresses the possible synergy between GA and SA and converges quickly toward better solutions in minimum number of generations.

Rest of the paper is organized as follows: Section 2 discusses the literature in warehouse management together with highlighting lot-sizing aspects. Section 3 presents the problem environment with detailed mathematical modeling for the generation of alternative warehouse sequence as well as lot sizing. Section 4 covers the background of constraint based fast-simulated annealing (CBFSA) algorithm. Section 5 puts forward the solution approach based on CBFSA algorithm pertaining to warehouse scheduling problems. In Section 6 illustrative examples are presented to demonstrate the efficiency of proposed CBFSA algorithm and the corresponding results are discussed in Section 7. Finally, Section 8 summarizes the paper with a note about the future scope of this paper.

## 2. Background and motivation

### 2.1. Warehousing

Warehousing is an integral part of the supply chain which contributes in efficient delivery of goods to the customer. The research in the area of manufacturing technology primarily deals with the scheduling of the manufacturing processes that aims at reducing lead time for product developments and supply chain processes. However, a warehouse management issue has not received much attention in literature. In past few decades, production management has been widely discussed in literature, but later effective management of the supply chain gained more attention. Warehouse is an integral part of a supply chain and its effective management helps in reducing the inventory cost and delivery lead time (Chan & Kumar, 2009a, 2009b). Researchers have realized the significance of warehousing in supply chain management and emphasized that it should be given same importance as the manufacturing process. Consequently, Richard, Jeffrey, and Robert (1996) developed a model for warehouse order picking problem and they considered the assignment of inventory to an order and the associated sequence to reduce the cost.

Further, Byung-In et al. (2003) proposed a hybrid intelligent agent-based scheduling and control system architecture for an actual industrial warehouse order-picking problem, Their architecture includes a higher level optimizer, a middle level guide agent, and lower level agents. Moreover, the performance of different search algorithms in case of warehouse scheduling problem was studied by Watson, Rana, Whitley, and Howe (1999). Van der Berg and Zijm (1999) explained various types of warehousing systems, and discussed multiple decision problems encountered in setting up the warehousing system. They further identified the need for intelligent warehousing for better performance. Transchela and Minner (2009) studied the dynamic pricing and replenishment issues in the warehouse scheduling problem. They aimed to maximize the profit by choosing the optimal pricing strategy, optimal lot-sizes, and the optimal staggering of the order releases. However, their study was more marketing oriented rather than engineering focused as they concluded that achieving operational efficiency through dynamic pricing in the warehouse scheduling is more beneficial. Furthermore, Daniels, Rummel, and Schantz (1998) discussed different aspects of warehouse picking problem and formulated a model for simultaneously determining the assignment and sequencing decisions. Later he compared it with the previous models for the order picking problem and applied Tabu search based heuristic to tackle the complexity. Rubrico, Ota, Higashi, and Tamura (2008) also developed a schedule for multiple picking agents in a warehouse management and used Tabu search to solve the scheduling problem.

Koester, Van der Poort, and Wolters (1999) applied two heuristic algorithms; (a) seed algorithm and (b) time saving algorithm and evaluated the performance using S-shape and L-shape strategies to investigate the over-batching problem in warehouses. Further, Macro and Salmi (2002) generated a simulation model tool to determine the warehouse efficiency and storage allocation. However, they argued that their model was scale-able and can be modified to simulate any warehouse configuration including selective racks, bulk floor storage, push-back flow through drive in and drive through racks. Cormier and Gunn (1992) reviewed various types of warehouse design models especially the throughput capacity models and the storage capacity models. Rosenthal and Ratliff (1983), Goetschalckx and Ratliff (1988) and Bozer and White (1990) have developed different warehousing models assuming that all stocks of a particular part are stored in one location within the warehouse. The warehouse location problems under continuous economies of scale were studied by Feldman, Lehrer, and Ray (1966), Martel and Vankatadri (1999), Ozsen, Coullard, and Daskin (2008). Perl and Daskin (1985) and Burkard, Fruhwirthy, and Rote (1995) discussed the warehouse location-routing problem (WLRP) and analyzed the vehicle routing in an automated warehouse. Moreover, Ildefonso, Ruberico, and Ota (2004) discussed the route generation problem in warehouse management using fast heuristics approach. They studied a warehouse scheduling sub-problem involving routing of intelligent agents as a preliminary step in optimizing the total schedule. This problem involved the generation of routes for automated agents with the transfer of items within a warehouse from the storage pallets to a common loading shed. The aim was to minimize the distance and number of routes generated. Kumar, Kumar, Tiwari, and Chan (2008) studied the vehicle routing problem in flexible manufacturing environment, however, their concept can be well applied in warehousing environment when dealing with order loading and unloading. Chan and Kumar (2009a, 2009b) studied the warehouse management system with the aim to reduce the overall tardiness while transferring the product from arrival to delivery end. They considered the AGV loading and unloading time and applied hybrid Tabu SA to reduce the tardiness. This paper addresses the lot-sizing scheduling along with the scheduling of the vehicles used in the warehousing system.

The consolidated shipment of goods from manufacturers to warehouses has been discussed in past literatures in supply chain and logistics and the shipment scheduling has gained much attention (Cetinkaya & Bookbinder, 2003; Pooley & Stenger, 1992). Cetinkaya and Lee (2003) discussed the importance of shipment consolidation and scheduling in the context of supplier managed inventory. However, Bramel and Simchi-Levi (1997) emphasized more on the integrated inventory and transportation policies and argued that it remained an important area of research. Lee, Cetinkaya, and Wagelmans (2001) discussed the dynamic lot-sizing model with the consideration of demand time windows. They presented polynomial time algorithms for cases with the backorders and without backorders. Discussion on dynamic lot sizing with inventory constraints can also be found in Erenguc and Aksoy (1990), Sandbothe and Thompson (1993) and Toczylowski (1995).

Some of the researchers (Gupta, 1992; Eijs, 1994) stressed more on the impact of inbound transportation decisions on inventory

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