



A modified Pareto genetic algorithm for multi-objective build-to-order supply chain planning with product assembly

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ABSTRACT

The build-to-order supply chain (BOSC) model is a key operation model for providing services/products at present. This study focuses on performing the supply chain planning for the BOSC network. The planning is designed to integrate supplier selection, product assembly, as well as the logistic distribution system of the supply chain in order to meet market demands. With multiple suppliers and multiple customer needs, the assembly model can be divided into several sub-assembly steps by applicable sequence. Considering three evaluation criteria, namely costs, delivery time, and quality, a multi-objective optimization mathematical model is established for the BOSC planning in this study. The multi-objective problems usually have no unique optimal solution, and the Pareto genetic algorithm (PaGA) can find good trade-offs among all the objectives. Therefore, the PaGA is applied to find solutions for the mathematical model. In addition, regarding BOSC problems solving, this study proposes a modified Pareto genetic algorithm (mPaGA) to improve the solution quality through revision of crossover and mutation operations. After application and analysis of cases, mPaGA is found to be superior to traditional PaGA (tPaGA) in solution performance.

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1. Introduction

In 21st century, supply chain management (SCM) is a key strategy to improve competitive edge. In particular, due to the success of several high-tech corporations such as Dell, BMW, Compaq, and Gateway, BOSC has received more attention in recent years. Some auto makers have also proceeded to adopt BOSC [14]. In BOSC model, production activities are not executed until receiving orders from customers, that can effectively reduce the costs of demand prediction and inventory and credibly reflect market demands.

As BOSC is started, supplier selection becomes the priority. After a proper part supplier is selected, product assembly begins. Consequently, we should select suitable assembly planning and a qualified assembly factory, and distribute the assembled products in accordance with customer requirements.

Among previous supply chain studies, there were quite a few researches involving the argument of supplier selection [4,10,15], product assembly [26,35,21], and logistic distribution issues [1,3,34]. However, most of the issues were examined separately in earlier studies. To be consistent with the BOSC model, these issues should be further explored in an integrated manner, lest the overall benefits of supply chain should not be increased.

In terms of supplier selection, Dickson [6] proposed 23 criteria for supplier selection in his research and identified quality, delivery, and performance history as the three major criteria. Weber et al. [32], Weber et al. [33], Liao and Rittscherb [22], and Wadhwa and Ravindran [31] used cost, quality, and time for evaluation criteria. For this reason, this study also applies these three criteria for supplier selection and extends them to production and distribution of the entire supply chain to form a multi-objective programming issue. Moreover, this study additionally considers the quantity discount in cost.

Gen and Cheng [9] indicated that multi-stage logistic problems can be treated as the combination of the multiple-choice knapsack problem with the capacitated location allocation problem as an NP-hard problem. Goossens et al. [11] indicated when various goods should be procured from multiple suppliers with considering the quantity discount, and these problems refer to the total quantity discount problems. They argued that it is NP-hard, and also there exists no polynomial-time approximation algorithm with a constant ratio (unless $P = NP$). In this study, the BOSC planning problem has considering multi-stage logistic system, quantity discount, and assembly problem, that thus it becomes even more complex. Simaria and Vilarinho [29] argued that the genetic algorithm (GA) can be used to effectively solve the assembly line balancing problem. Sha and Che [28], Altıparmak et al. [1], and Xu et al. [34] had applied GA to deal with supply chain problems. In addition, Poulos et al. [24] and Hosung et al. [16] have successfully

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Nomenclature

Parameters

i	part index, $i = 1, 2, 3, \dots, I$
I	total number of parts
x	supplier index, $x = 1, 2, 3, \dots, X_i$
X_i	total number of suppliers for part i
$U_{i,x}$	upper limit of production capacity of supplier x for part i
p	assembly scheme index, $p = 1, 2, 3, \dots, P$
P	total number of assembly schemes
n	index of assembly stage, $n = 1, 2, 3, \dots, N^p$
N^p	total number of assembly stages for assembly scheme p
a, b	assembly factory a/b in assembly stage, $a = 1, 2, 3, \dots, A_n^p, b = 1, 2, 3, \dots, B_n^p$
A_n^p, B_n^p	total number of assembly factories for assembly stage n in assembly scheme p
k	customer index, $k = 1, 2, 3, \dots, K$
K	total number of customers
D_k	demand of customer k
$OC_{i,x}$	order cost of part i of supplier x
$PC_{i,x}$	purchase cost of part i of supplier x
$TC_{i,x,a}$	transport cost of part i from supplier x to factory a in initial assembly stage
$TC_{n,a,n+1,b}$	transport cost from factory a in assembly stage n to factory b in assembly stage $n + 1$
$TC_{a,k}$	transport cost from factory a in final assembly stage to customer k
$TT_{i,x,a}$	transport time from supplier x of part i to factory a in initial assembly stage

$TT_{n,a,n+1,b}$	transport time from factory a in assembly stage n to factory b in assembly stage $n + 1$, $n = 1, 2, 3, \dots, N^p - 1$
$TT_{n-1,b,n,a}$	transport time from factory b in assembly stage $n - 1$ to factory a in assembly stage n , $n = 2, 3, 4, \dots, N^p$
$TT_{a,k}$	transport time from factory a to customer k in final assembly stage
$Q_{i,x}$	quality of part i of supplier x

Variables

$S_{i,x}^p$	1: order part i from supplier x in assembly scheme p ; 0: otherwise
$W_{i,x,a}^p$	quantity of part i ordered and transported from supplier x to factory a in initial assembly stage in assembly scheme p
$W_{n,a,n+1,b}^p$	quantity of semi-finished products transported from factory a in assembly stage n to factory b in assembly stage $n + 1$ in assembly scheme p , $n = 1, 2, 3, \dots, N^p - 1$
$W_{n-1,b,n,a}^p$	quantity of semi-finished products from factory b in assembly stage $n - 1$ to factory a in assembly stage n in assembly scheme p , $n = 2, 3, 4, \dots, N^p$
$W_{a,k}^p$	quantity of finished products in factory a in final assembly stage to customer k in assembly scheme p
$M_{n,a}^p$	maximum transport time of parts or semi-finished products to factory a in assembly stage n in assembly scheme p
M_k^p	maximum transport time of product to customer k in assembly scheme p

employed PaGA for dealing with the multi-objective optimization problems. Hence, this study present the mPaGA based on PaGA for solving the multi-objective optimization mathematical model of BOSC planning.

The main purposes of the study are described as follows: (1) Establish a multi-objective optimization mathematical model for BOSC problems. This model integrates supplier selection, product assembly, and the logistic distribution system. As far as we are concerned, the mathematical model for integrated multi-objective BOSC problems has not been developed up till now. (2) Propose the mPaGA model for solving the optimization mathematical model. Principally, mPaGA based on PaGA is intended to improve the crossover and mutation operators for higher solving efficiency. In addition, after the crossover and mutation operators have been used, the equilibrium and feasibility-adjustment mechanisms proposed for maintaining the feasibility of each individual, that can reduce the computational time for searching the feasible individuals. (3) Compare the solving efficiency between mPaGA and tPaGA to verify that mPaGA is superior in calculation capabilities. The tPaGA based on PaGA employs one-point crossover and one-point mutation operators for finding the new individuals.

The framework of the study is as described in the following. Literature review for BOSC and PaGA is provided in Section 2. Section 3 provides the optimization mathematical model for BOSC problems. The proposed mPaGA model is described in Section 4. Section 5 provides an illustrative example to illustrate the application of mPaGA for obtaining the optimal plans. Results thus obtained are also compared with those of tPaGA to validate the efficiency of the proposed mPaGA. Conclusions, limitations of the proposed model, and the future research are drawn in Section 6.

2. Literature review

This section addresses literature review for BOSC and PaGA.

2.1. BOSC

The concept of supply chain management (SCM), first developed by Houlihan [17], is a key development in logistics. In the initial development, it only dealt with physical distribution and transportation operations with industrial dynamic technology. Jones and Riley [19] defined SCM as an integrative approach to deal with the planning and control of the materials flow from suppliers to end-users. Gunasekaran et al. [13] pointed out that SCM is the most important business strategy for increasing organizational competence in the 21st century.

Prasad et al. [25] argued that today's supply chains are increasingly moving towards a build-to-order (BTO) environment from a Made to Stock (MTS) one as a way to gain competitive edge. They examined the differences of SCM in BTO and MTS, and suggested that MTS was transformed into BTO must focus on three dimensions: information complexity, operational independence, and supplier integration. The BTO strategies have pure customization, and in order to meet the particular customer needs that the total quantity needs to be on hand. Gunasekaran [12] figured that a successful business should not only avoid production activities lacking economic benefits, but also create marketing capabilities that are not imitable. In particular, BOSC is a supply chain model designed for various industries and can be used to address market demands and offer cost-effectiveness.

According to Krajewski et al. [20], the production model has already shifted from mass production to mass customization over a wide spectrum of products, ranging from personal computers, bikes, to automobiles, which are made in the BOSC model, where customers may select parts assembly depending on their preference. Howard et al. [18] proposed that build-to-order (BTO) has been hailed as a production strategy that fits the demands of the 21st century, where a considerable challenge for the industry is addressed. Based on the findings of these literatures, BOSC is a successful supply chain model that is currently widely in use.

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