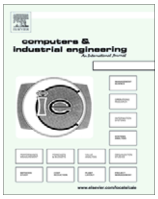
Computers & Industrial Engineering 58 (2010) 411–422

Contents lists available at ScienceDirect

Computers & Industrial Engineering

journal homepage: www.elsevier.com/locate/caie



A genetic approach to two-phase optimization of dynamic supply chain scheduling

Alebachew D. Yimer *, Kudret Demirli

Fuzzy Systems Research Lab., Department of Mechanical and Industrial Engineering, Concordia University, 1515 St-Catherine W., Montreal, QC, Canada

ARTICLE INFO

Article history:
Available online 22 January 2009

Keywords:
Genetic algorithm
Build-to-order
Supply chain scheduling
Agile manufacturing
Mixed integer programming

ABSTRACT

In today's competitive environment, *agility* and *leanness* have become two crucial strategic concerns for many manufacturing firms in their efforts to broaden market share. Recently, the build-to-order (BTO) manufacturing strategy is becoming a popular operation strategy to achieve both in a mass-scale customization process. BTO system combines the characteristics of make-to-order strategy with a forecast driven make-to-stock strategy. As a means to improve customer responsiveness, customized products are assembled according to specific orders while standard components are pre-manufactured based on short-term forecasts. Planning of the two subsystems using a two-phase sequential approach offers both operational and modeling incentives. In this paper, we formulate a two-phase mixed integer linear programming (MILP) model for material procurement, components fabrication, product assembly and distribution scheduling of a BTO supply chain system. In the proposed approach, the entire problem is first decomposed into two subsystems and evaluated sequentially. The first phase deals with assembling and distribution scheduling of customizable products, while the second phase addresses fabrication and procurement planning of components and raw-materials. The objective of both models is to minimize the aggregate costs associated with each subsystem, while meeting customer service requirements. The search space for the first phase problem involves a complex landscape with too many candidate solutions. A genetic algorithm based solution procedure is proposed to solve the sub-problem efficiently.

1. Introduction

The build-to-order (BTO) manufacturing system is a pull system in which materials are pulled downstream of the supply chain driven by customer orders. It basically incorporates the characteristics of both lean and agile manufacturing strategies. Unlike the traditional make to stock supply chain, BTO strategy reduces the dependency of the system on demand forecasts, hence diminishing the requirement of high inventory buffers in the supply chain as pointed out in Gunasekaran and Ngai (2005). BTO systems combine the characteristics of both make-to-stock (forecast driven) and make-to-order (demand driven) strategies. Standard component parts and non-customizable subassemblies are acquired or build in-house based on short-term forecasts, while schedules for the few customizable parts and the final assembly are executed after detailed product specifications have been derived from booked customer orders, see Demirli and Yimer (2008).

Customization of products can only be achieved if there is some form of postponent strategy either in the assembly state, assembly area, delivery or at the design phase. As described by Li, Cheng, and Wang (2007), postponent refers to delaying some product differentiation or process as late as possible until the supply chain becomes cost effective. Customer's input in BTO manufacturing environment would involve postponent in downstream decisions with some speculation on the upstream manufacturing and supplies, see Prasad, Tata, and Madan (2005). Manufacturing plants operating under BTO supply chain use one of the three form postponent strategies in their functions: finished goods, work-in-process parts and purchased items or raw-materials as shown in Krajewski, Wei, and Tang (2005). Sharma and LaPlaca (2005) study the long-term impact of adopting a BTO manufacturing system on the marketing function and identify the marketing strategies used by successful BTO companies. A BTO strategy positively affects market performance through its influence on the supply chain application knowledge downstream with customers, while a JIT strategy does the upstream application with suppliers, see Christensen, Germain, and Birou (2005).

If we consider the upholstered furniture business, it is characterized by a wide range of product styles and a diversified customer demand. A variety of basic frame styles, fabrics, colors and other special options would generate a wide range of custom-built products. Therefore, a lean production system along with an agile strategy must be implemented to keep the units moving through the plant and to the customer smoothly as shown in Lyons, Coronado-Mondragon, and Kehoe (2004). As a result, firms such as Pella, Herman Miller and Norwalk have shifted to a BTO manufacturing strategy and assemble different customized products, see Gunasekaran and Ngai (2005), Sharma and LaPlaca (2005), Yao and

---

* Corresponding author. Tel.: +1 702 353 6038.
E-mail addresses: alebachew@ie.mie.conocrdia.ca (A.D. Yimer), demirli@encs.conocrdia.ca (K. Demirli).

0360-8352/$ - see front matter © 2010 Published by Elsevier Ltd.
doi:10.1016/j.cie.2009.01.010

Nomenclature

Sets and indices

Ω_f	set of component fabricating plants
Ω_a	set of assembling plants
Ω_d	set of distribution centers
Ω_r	set of product retailers (dealers)
i	product type index, $i = 1, 2, \cdots, I$,
j	component part or subassembly index, $j = 1, 2, \cdots, J$,
l	raw-material index, $l = 1, 2, \cdots, L$,
t	period index, $t = 1, 2, \cdots, T$,
k	fabrication plant index, $k \in \Omega_f$,
p	assembly plant index, $p \in \Omega_a$,
q	distribution center index, $q \in \Omega_d$,
r	retailer index, $r \in \Omega_r$,

Input parameters

ψ_{kpj}	1 if k supplies p with component j; or 0 otherwise
χ_{pq}	1 if p can supply to q with products; or 0 otherwise
χ_{qr}	1 if q can deliver products to r; or 0 otherwise
ρ_{kl}	holding cost of raw-material l by fabricator k
s_{kl}	order setup cost of raw-material l by fabricator k
η_{kl}	unit purchasing cost of r.m. l by fabricator k
σ_{kpj}	fixed cost of p to acquire j from fabricator k
ϑ_{kpj}	unit variable cost of p to procure j from k
λ_{pj}	holding cost of plant p per unit of part j
c_{pij}	unit customization cost of j in assembling i by p
γ_{pi}	fixed cost of plant p to assemble i
β_{pi}	unit regular time assembling cost of i at plant p
ω_{pi}	unit overtime assembling cost of i at plant p
h_{qi}	inventory holding cost per unit of i at distributor q
τ_{pqi}	unit transport cost of i from plant p to distributor q
τ_{qri}	unit transport cost of i from distributor q to dealer r
a_{ri}	setup cost of dealer r per order of product i
π_{ri}	penalty cost of r per unit backordered of i
δ_{lj}	proportion of r.m. l required per unit of part j
u_{ij}	units of j required per unit of product type i
ℓ_k	expected raw-material procurement lead-time at k
ℓ_{pq}	transportation lead-time from p to q
ℓ_{qr}	delivery lead-time from q to r
ℓ_r	expected production–distribution lead-time at r
T	planning horizon
M^{∞}	very big positive integer
D_{rit}	demand volume of i at r in period t; equal to O_{rit} if $t \leqslant \ell_r$; or $max(O_{rit}, F_{rit})$ otherwise,
SL_{min}	min. customer service level requirement in % demand
MDC_{kpj}	capacity of k to supply p with component j per period
MRC_{pi}	regular time capacity of p to assemble product i per period
MOC_{pi}	overtime capacity of p to assemble product i per period
MLC_{kl}	capacity of k to stock r.m. l per period
MJC_{pj}	inventory capacity of plant p to carry part j
MIC_{qi}	storage capacity of q to carry i per period
MTC_{pqi}	capacity of p to deliver q with product i
MTC_{qri}	capacity limit to ship i from q to r

Decision variables

DM_{klt}	demand volume of r.m. l by fabricator k in period t
DC_{pjt}	demand of component j by assembler p in period t
F_{pjt}	anticipated demand for component j by p in period t
L_{klt}	inventory level of r.m. l at the end of period t
J_{pjt}	inventory status of j at the beginning of period t
I_{qit}	on hand balance of product i at q in period t
Qin_{qit}	quantity of i delivered to q by all plants in period t
$Qout_{qit}$	quantity of i shipped from q to all retailers in period t
QL_{klt}	scheduled receipt of r.m. l by k in period t
QC_{kpjt}	quantity of j procured by p from k in period t
QR_{pit}	regular time assembled volume of i in period t
QO_{pit}	overtime assembled volume of i in period t
QA_{pit}	total volume of product i assembled in period t
QT_{pqit}	volume of i shipped from p to q in period t
QT_{qrit}	volume of i transported from q to r in period t
SL_{rit}	demand satisfaction level of i at retailer r in period t
QN_{rit}	quantity of i backordered by r in period t
Q_{rit}	quantity of i delivered to r in period t
Z_{RM}	aggregate raw-materials cost
Z_{CF}	aggregate components fabrication cost
Z_{AS}	aggregate products assembling cost
Z_{DC}	aggregate distribution cost
Z_{RT}	aggregate retailers cost
$\mathbf{Z_{PD}}$	total cost of production and distribution (*phase-1*)
$\mathbf{Z_{CR}}$	total cost of components and raw-materials(*phase-2*)
θ_{klt}	1 if k places order to procure l in period t, or 0 otherwise;
ϕ_{kpjt}	1 if p procures part j from k in period t, or 0 otherwise;
α_{pit}	1 if p is setup to assemble i in period t, or 0 otherwise;
φ_{rit}	1 if r places assembly order of i in period t, or 0 otherwise;

Carlson (2003). Agile manufacturing facility can cope with changes in customer requirements including price, quality, customization, and promised delivery dates as indicated by Christian and Zimmers (1999). In most cases, furniture products consume large amounts of space during production, storage and shipment. A lean production system is thus important to curb large space requirements. A lean furniture production system uses its skilled work force and flexible handling equipment to quickly move small batch of material units from one workstation to the next thereby minimizing WIP. To enhance both agility and leanness, constructing a recommended cluster of fabrics available in different styles and colors would help limit the degree of customization.

The overwhelming majority of the literature in the area of supply chain modeling consider the traditional make-to-stock demand satisfying strategy. Production–distribution planning and scheduling is one important issue in multi-plant supply chain modeling. Scheduling models in multi-stage supply chains usually involve trade-offs among different conflicting objectives such as minimization of overall operating cost and safe inventory levels, while maximizing customer service performance and total profit with fair distribution among all partners, see Aghezzaf, Raa, and Landeghem (2006), Ertogral, Darwish, and Ben-Daya (2006), Guillen, Badell, and Puigjaner (2006), Neiro and Pinto (2004), Selvarajah and Steiner (2005). LP models to minimize total tardiness or total operation costs and considering capacity constraints, alternative machines sequences, sequence-dependent setup, and distinct due dates are also proposed in Ertogral et al. (2006), Liang (2006), Moon, Kim, and Hur (2002), Spitter, Hurkens, Kok, Lenstra, and Negenman (2005). Lakhal, Martel, Kettani, and Oral (2001) Perea-Lopèz, Ydstie, and Grossmann (2003) formulate a mixed integer linear programming (MILP) model to optimize strategic networking issues in multi-echelon supply chains. Multi-objective approaches for production and distribution scheduling scheme in multi-echelon supply chain networks are shown in Chen and Lee (2004), Sabri and Beamon (2000), Sakawa, Kato, and Nishizaki (2003). Talluri and Baker (2002) develop a multi-phase mathematical programming model with a combination of multi-criteria efficiency measures based on game theory concepts, and mixed integer linear programming methods. Amiri (2006), Ding, Benyoucef, and Xie (2005), Jayaraman and Prkul (2001) and Ross