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Simultaneous optimization of process operations and financial decisions to enhance the integrated planning/scheduling of chemical supply chains

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Abstract

This paper addresses the integrated planning/scheduling of chemical supply chains (SC) with multi-product, multi-echelon distribution networks taking into account financial management issues and suggests a novel approach for enterprise wide management. In order to tackle this problem, it is derived a mathematical formulation combining a scheduling/planning model with a cash flow and budgeting formulation. To motivate the use of such integrated model, a sequential scheme representing traditional enterprise practices is firstly applied. Within this strategy, scheduling and planning decisions are taken firstly, and finances are fitted afterwards considering the cash flows associated to the scheduling/planning decisions previously computed as input parameters. The comparison between the results of the sequential approach and those of the integrated model highlight the advantages of the latter option, in which scheduling/planning and cash management decisions are optimized in unison with a common objective of maximizing the change in equity achieved by the company. The modeling approach developed in this paper and the obtained results suggest that a new conceptual strategy in enterprise management systems consisting of the integration of the financial models of the enterprise with those dealing with the operative area is a must to improve the firm's performance and its overall earnings and ensuring also healthy cash flow management.

Keywords: Optimisation; Supply chain management; Financial management

1. Introduction

The concept of the supply chain (SC), which first appeared in the early 1990s, has recently been the focus of much interest, as the possibility of providing an integrated management of an SC can reduce the propagation of unexpected/undesirable events throughout the network and can markedly improve the profitability of all the parties involved.

Supply Chain Management (SCM) aims to integrate plants with their suppliers and customers so that they can be managed as a single entity and to coordinate all input/output flows (of materials, information and funds) so that products are produced and distributed in the right quantities, to the right locations, and at the right time (Simchi-Levi, Kamisky, & Simchi-Levi, 2000). Therefore, SCM implies the handling of flows throughout the entire SC, from suppliers to customers while encompassing warehouses and distribution centres (DCs), and usually including after-sales services, returns, and recycling (Silver, Pyke, & Peterson, 1998). The main objective is to achieve acceptable financial returns together with the desired consumer satisfaction levels.

The SCM problem may be considered at different levels depending on the strategic, tactical and operational variables involved in decision-making (Fox, Barbuceanu, & Teigen, 2000). Therefore, a large spectrum of a firm's strategic, tactical and operational activities are encompassed by SCM:

- The strategic level concerns those decisions that will have a long-lasting effect on the firm. It is focused on SC design, and entails determining the optimal configuration for an entire SC network, including the design of the embedded plants.
- The tactical level encompasses long/medium term management decisions, which are typically updated at a rate ranging between once every quarter and once every year. These include overall purchasing and production decisions, inventory policies, and transport strategies.
- The operational level refers to day-to-day decisions such as scheduling, lead-time quotations, routing, and lorry loading.

Therefore, in the SC models time is multifaceted in the hierarchical planning: the long strategic, the medium tactical and

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Nomenclature

Indices

c	copies
i	tasks
j	equipments
s	states
t	scheduling intervals
t^*	planning periods
u	utilities

Sets

C_{it^*}	set of copies of task i that can be performed in period t^*
FP	set of states corresponding to final products
I_j	set of tasks that can be performed in equipment j
IP	set of states corresponding to intermediate products
NTR	set of non transport tasks (production tasks)
SI_s	set of tasks receiving material from state s
SI'_i	set of states consumed by task i
SO_s	set of tasks producing material for state s
SO'_i	set of states produced by task i
RM	set of states corresponding to raw materials
RMSup_e	set of raw materials provided by external supplier e
TR	set of transport tasks
TSO_s	set of states s' coming from state s
USup_e	set of utilities provided by external supplier e

Parameters

B_i^{MAX}	maximum batch size of task i
B_i^{MIN}	minimum batch size of task i
C_s	maximum storage for material in state s
$C_{it^*}^{\mathrm{MAX}}$	maximum number of copies of task i that can be performed in period t^*
$\mathrm{Coef}_{et^*,t^{*\prime}}$	technical discount coefficient for payments to external supplier e executed in period t^* on accounts incurred in period $t^{*\prime}$
$D_{t^*,t^{*\prime}}^{\mathrm{MS}}$	technical coefficient for investments in marketable securities
Dem_{st}	demand of material in state s in time interval t
Demp_{st^*}	demand of material in state s in period t^*
dep	amount depreciated
Div_{t^*}	dividends in period t^*
$E_{t^*,t^{*\prime}}^{\mathrm{MS}}$	technical coefficient for sales of marketable securities
FCost	fixed cost
H	time horizon
$H1$	length of one planning period
$H2$	length of one scheduling interval
ir	interest rate
MaxCLine	upper bound of the credit line
MinCash	minimum cash
Others_{t^*}	other expected outflows or inflows of cash in period t^*
Price_{st}	price of material in state s in time interval t
Pricep_{st^*}	price of material in state s in period t^*
pt_i	processing time of task i
$E_{t^*,t^{*\prime}}^{\mathrm{MS}}$	technical coefficient for sales of marketable securities
$S_{t^*}^{\mathrm{MS}}$	marketable securities of the initial portfolio maturing in period t^*
SPrice_{st^*}	stock price of material in state s in period t^*
trate	taxes rate
$U_u^{\max}$	maximum consumption of utility u in scheduling periods
$\mathrm{Up}_u^{\max}$	maximum consumption of utility u in planning periods
UCost_{ue}	amount of money payable to external supplier e due to the consumption of one unit of utility u

Variables

ARec_{t^*}	accounts receivable in period t^*
B_{it}	batch size of task i started in time interval t
B_{ist}^I	amount of material in state s consumed by task i started in time interval t
B_{ist}^O	amount of material in state s produced by task i started in time interval t
Borrow_{t^*}	total amount borrowed to the credit line in period t^*
Bp_{cit^*}	batch size of copy c of task i performed in period t^*
$\mathrm{Bp}_{cist^*}^I$	amount of material in state s consumed by copy c of task i performed in period t^*
$\mathrm{Bp}_{cist^*}^O$	amount of material in state s produced by copy c of task i performed in period t^*
Cash_{t^*}	cash in period t^*
CLine_{t^*}	debt in period t^*
EPurch_{et^*}	purchases to external supplier e in period t^*
ECash_{t^*}	exogenous cash in period t^*
$\mathrm{Net}_{t^*}^{\mathrm{CLine}}$	total amount of money borrowed or repaid to the credit line in period t^*
$\mathrm{Net}_{t^*}^{\mathrm{MS}}$	total amount received or paid in securities transactions in period t^*
$\mathrm{Pay}_{et^*t^{*\prime}}$	payments to external supplier e executed in period t^* on accounts payable incurred in period $t^{*\prime}$
$\mathrm{Pled}_{t^*,t^{*\prime}}$	amount pledged within period $t^{*\prime}$ on accounts receivable incurred in period t^*
Profit	profit
Purch_{st}	amount of material in state s purchased in time interval t
Purchp_{st^*}	amount of material in state s purchased in period t^*
Repay_{t^*}	total amount repaid to the credit line in period t^*
S_{st}	amount of material in state s at the end of time interval t
Sales_{st}	amount of material in state s sold in time interval t