Computers and Chemical Engineering 33 (2009) 1999–2011

Contents lists available at ScienceDirect

Computers and Chemical Engineering

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

Financial and financial engineering considerations in supply chain and product development pipeline management

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ARTICLE INFO

Article history:
Received 30 October 2008
Received in revised form 11 June 2009
Accepted 22 June 2009
Available online 1 July 2009

Keywords:
Supply chain management
Product portfolio management
Supplier–customer relationships
Corporate value
Inventory management
Risk management
Flexibility

ABSTRACT

Enterprise-wide decision problems are receiving increasing attention in the process systems engineering literature. In particular, the supply chain and product development pipeline management components of this general class of problems have been subjects of intensive research in both their deterministic and their stochastic forms. The supply chain management (SCM) problem has seen work largely focused on the process operations and logistics components while for the product development pipeline management (PDPM) problem much of the attention has been on MILP formulations addressing the consequences of product failure during its development. In their full realization, both are recognized as challenging stochastic multi-stage decision problems. In this paper we discuss three important aspects of these problems that require further research: the realistic representation of the financial components and appropriate criteria for this class of problems, strategic management of supplier and customer relationships through inventory management and option contracts, and innovative approaches to suitably value and integrate a broader range of decisions available to management. We highlight and extend relevant contributions and case examples drawn from the recent literature that are emerging on these topics and use this work to point out further challenges.

1. Introduction

Enterprise-wide decision problems have increasingly become the focus of research and application for the process systems engineering (PSE) community. This expansion in the traditional scope of PSE research has been driven in part by the availability of information systems that allow ready access to up-to-date information across the enterprise, in part by our ability to develop, solve and maintain large-scale models, and partly because of a recognition that the globalization of enterprises requires that organizational decisions must take into account impact on a wider scale, both temporally and geographically. Additionally, the recognition of collective responsibility for the global environment has pushed into the forefront the issue of sustainability and thus consideration of all aspects of the life cycle of products and processes. Two enterprise-wide decision problems that have received the most intense attention have been supply chain management (SCM) and product development pipeline management (PDPM). The former addresses the design and operational issues associated with the supplier, manufacturer, customer and logistics network by means of which an enterprise delivers its products to the market place. The latter addresses the set of decisions and network of tasks associated with turning a new discovery into a product and introducing it into the corporation's supply chain (Varma, Reklaitis, Blau, & Pekny, 2007). In this paper we will discuss several aspects of these two problems that deserve further attention.

Both of these enterprise-wide problems are resource intensive, involve large cash flows and thus their successful solution has a direct bearing on the viability of the enterprise. Both are large-scale in terms of the number of state and decision variables that must be considered, involve activities at multiple time scales, are dynamic in nature, and are subject to a large number of exogenous and endogenous uncertainties. They, at root, constitute large-scale, multi-stage stochastic optimization problems. Given their importance to the viability of the enterprise, the quality of solutions to these decision problems must be measured in terms of enterprise-wide metrics such as cash flow, corporate value preservation and growth. Evaluation of these metrics in turn requires capture of the relevant financial flows and accounting details. However, there are substantive differences between the two. SCM encompasses the portion of the life cycle of a company's products from market launch to withdrawal, includes consideration of logistical functions associated with the movement of material through the supply chain and thus necessarily must include the management of feedstock supplier/producer and producer/customer relationships. PDPM covers only the development and launch portion of

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doi:10.1016/j.compchemeng.2009.06.025

Nomenclature

APS	advanced planning and scheduling
CV	corporate value
DC	distribution center
DCC	warehouse locations for illustrative example in Section 3.2
DFCF	discounted-free-cash-flow
E[NPV]	expected net present value
KPI	key performance indicator
MoMINLP	multiobjective mixed-integer nonlinear programming
NPV	net present value
PDPM	product development pipeline management
PSE	process system engineering
QF	quantity flexibility contract
SC	supply chain
SCM	supply chain management
WACC	weighted average capital cost

Parameters

I_i^{LB}	inventory lower bound for product i
$NetDebt_0$	net debt at the beginning of the planning horizon
$trate$	tax rate
$WACC_t$	cost of capital for period t
α	quantity flexible contract parameters
q_{ij}	safety stock set point for product i at facility j

Variables

CV	corporate value
D_{it}	demand for product i in period t
FCF_t	cash flow in period t
FEx_t	any other financial expenses or incomes in period t
I_{it}	safety stock for product i in period t
$NetInvest_t$	net change in investments in period t
P_{it}	product i production in period t
$Profit_t$	profit obtained in period t
$\Delta APay_t$	change in account payable in period t
$\Delta ARec_t$	change in account receivable in period t
ΔInv_t	change in inventory in period t
ΔNWC_t	change in net working capital in period t
π_{ij}	service level or expected on hand inventory level for product i at facility j

the product life cycle and involves the critical decision of selection of product candidates that will constitute the development portfolio. One of the defining aspects of PDPM is that product candidates are likely to fail during development. When this occurs not only is the investment in the development of the failed product lost but also the company incurs the opportunity cost of not having developed one of the alternate potential product candidates in its portfolio. Indeed studies have shown that the US industry average is only one commercial success per seven new product concepts in which development is invested. As a result as much as 50% of new product development resources are spent on failed or cancelled products. The success rate in the development of pharmaceutical products is even less than that and the investment per successful product is now reaching $2 Billion (Hynes, 2008). It is thus no surprise that the management of pharmaceutical product development has been receiving special attention in the PSE literature in recent years. Given the high failure rate and large potential investment loss, the challenge is the valuation of product portfolios that properly takes into account not only the uncertainties and risks but also the decision flexibility that management can exercise during the course of the development path.

Since these two decision problems comprise complementary segments of the product life cycle, they do have areas of overlap. Specifically, in both cases the forecasting of uncertain demand, which may include forecasting of competitor action, is an important decision input. In both, capacity planning decisions are important, that is, whether to produce a new product for launch in an existing facility (and in which one) or whether to plan for new capacity. Moreover, the two are interdependent in that typically the cash flow from effective SCM provides all or a significant portion of the investment funding required for PDPM while SCM relies on a steady flow of new products from PDPM to drive supply chain growth or at least to sustain the enterprise in the face of competitor's product innovations.

The PSE related research on the SCM problem has largely focused on issues related to process operations: assignment of physical resources and the scheduling and routing of material flows through the network. The supply and pricing of feedstocks are typically treated as deterministic and uncertain product demand is accommodated through production planning/scheduling and suitable allocation of inventory. Product pricing is usually assumed to be given. The work on the PDPM, which has almost exclusively concentrated on the pharmaceutical product domain, has focused on portfolio selection in the face of uncertainty due to product failure during development and to resource reassignment in response to termination of a product candidate. The variety of managerial actions, which can be taken at a tactical and operational level to mitigate risk by corrective action when uncertainties are realized, have not been fully exploited. In practice this may mean that the impacts of risks are over-estimated, performance metrics underestimated and thus poor strategic decisions advanced. Additionally, the treatment of financial factors is restricted to primary operating and fixed investment costs and, typically, some form of net present value with interest rate fixed over the time horizon is used as performance metric. The intent of this paper is to call attention to the need and potential for augmenting the research in these decision problems in three areas:

1. Realistic representation of the financial aspects of enterprise-wide decision problems, including the choice of appropriate performance criteria.
2. Strategic management of supplier and customer relations.
3. Capturing and suitably valuating a broader range of decisions available to management in solving these enterprise-wide problems.

2. Integration of financial aspects

The effective control of cash is one of the most important requirements of financial management, and its steady and healthy circulation throughout the entire business operation has repeatedly been shown to be the basis of business solvency (Howard & Upton, 1953). In fact, the availability of cash governs the production decisions made in a company. For this reason, operational models should not consider cash as an infinite resource. A production plan cannot be implemented if it violates the minimum cash constraints imposed by the firm.

There is an increasing awareness of the impact that chemical process production systems have on firms' finances, which has led to enterprise-wide management strategies that aim to provide a holistic view of the system. In fact, the need to extend the studies and analysis of process operations to incorporate financial considerations has been widely recognized in the literature.

A number of budgeting models started to appear in the late 1950s, when linear programming computation methods also