企業資源規劃系統協同生產銷售決策模式之研究

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摘要

企業資源規劃(ERP)系統可做爲整合企業資源配置、規劃與管理的平台。目前時下所提供的 ERP 系統都過於簡化，以致在實務上存有嚴重的缺點。例如，在 ERP 系統的規劃參數不是固定就是隨意選取，造成參數的設定很少是有效；而且在一般的系統設定上生產產能都被假設爲無限。本研究發展一套 ERP 系統附加決策模式，以改善生產規劃之靜態參數設定與市場之動態特性間的差距。本研究所發展之模式同時考量動態環境下生產時程、批量與價格，使後端生產決策更能反映前端市場變化。再者，本模式考量到產能的有限性，以彌補傳統 ERP 系統設定上的不足。本研究最後根據推導出的模型作數值分析，深入探討各重要參數與獲利間之關係。

關鍵字：定期存貨系統、動態定價、協同規劃、企業資源規劃

Developing an Add-in Decision Model for Collaborated Production Planning in Enterprise Resource Planning Systems

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Abstract

ERP systems can provide a platform for the integration of plant and enterprise resource allocation, planning, and management. Currently available systems in the market are yet fairly simplistic that results in serious inherent weaknesses in practice. For example, the planning parameters are arbitrarily selected, fixed, and rarely validated, and production capacity is assumed unlimited in typical system settings and implementation of ERP systems. In this paper, an add-in decision model is developed that closes the gap between the static parameter settings in production planning and dynamic nature in the marketplace. The proposed model jointly considers the production schedule, lot-size and the periodic pricing in a dynamic environment that makes the back-end production decision more responsive to the front-end changing market. Further, the model takes limited capacity into account which remedies the traditional ERP system settings.

Keywords: periodic inventory system, dynamic pricing, collaborative planning, ERP

1. Introduction

The latest manufacturing technologies enhance cross-functional interaction between manufacturing and marketing such as flexible manufacturing system (FMS), just-in-time (JIT), quick response (QR), manufacturing resources planning (MRP II), and enterprise resource planning (ERP). In spite of increasingly emphasizing on the aspect of customer demands, many production decision-making processes still do not take marketing's dynamic nature into account. For example, the classical economic order quantity (EOQ) model assumes a constant demand that is time-invariant, exogenous, and uncontrollable. The lately evolved MRP II and ERP systems can optimize the lot-size scheduling problem with time-varying demand over finite planning horizon, yet the dynamic aspects of pricing and other marketing related variables tend to be ignored in the highly computerized manufacturing control systems. This paper is an attempt to fill the gap between marketing and manufacturing decision making with the objective of developing an add-in model like the advanced planning and scheduling (APS) within an ERP system.

A historical survey of manufacturing control practices including MRP is provided in Mckay (2003). The basic architecture of an MRP II/ERP system builds upon one database and a unified interface across the entire enterprise providing integrated business solutions for the core processes and the main administrative functions of an enterprise (see Figure 1). In addition to increasing operational efficiencies, the highly integrated system can strengthen strategic advantages and generate related benefits that have been well documented in the literature (Langenwalter 2000, Stefanou 2001, Mandal and Gunasekaran 2002, Gattiker and Goodhue 2000, and Robinson and Dilts 1999). However, ERP benefits cannot be fully realized without a finely tuned alignment and reconciliation between system configurations, organizational imperatives, and core business processes (Al-Mashari et al. 2003). Further, the fundamental basis of planning and scheduling in an MRP II/ERP system is based on the fixed and static parameter settings (e.g., lead time, lot size, safety stock, and costs) with infinite capacity (Hsiang 2001 and Petty et al. 2000). As a result, the system generates suboptimal solutions to the production lot-size scheduling problem.

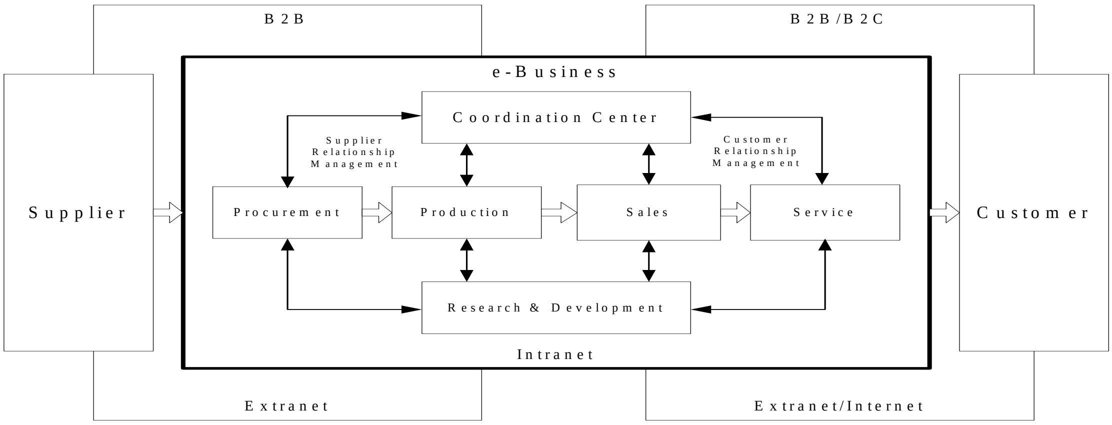

Figure 1 Value chain model in enterprise logistics.

To remedy these drawbacks, considerable research works have been devoted to methodology development that adds “intelligence” into the current MRP II/ERP systems. For examples, Petty et al. proposed a hybrid approach that offers finite capacity scheduling (FCS) scheme incorporated into MRP II packages. Such hybrid claims to give the benefits of FCS to established MRP II users. Kim and Hosni (1998) formulated a multi-level capacitated optimization model and developed a relative efficient heuristic working under MRP II environment, which considers work center capacities and interrelationship between levels in lot-sizing computation. Vandaele and De Boeck (2003) proposed an advanced resource planning scheme explicitly capturing the stochastic nature of manufacturing systems. It is an ideal high-level tuning and planning tool and can be used in a variety of planning environments like JIT, MRP, ERP, and Theory of Constraints (TOC). Hu and Munson (2002) proposed an incremental quantity discount scheme rectifying the unrealistic assumption of fixed prices for MRP lot-sizing planning. In a comparative study, Liberopoulos and Dallery (2003) proposed a unified modeling framework based on queuing network representation for describing, comparing, and contrasting classical multi-stage production-inventory control policies with lot sizing, including reorder point policy (RPP), JIT, MRP, and MRP II.

In this paper, we develop a mathematical model that solves optimally the production lot-size/scheduling problem taking into account the dynamic nature of customer’s demand which is partially controllable through pricing schemes. In addition, the deteriorating property of manufactured items and capacitated constraint are also incorporated into the model. The proposed scheme can be used as an add-in optimizer like an APS system that coordinates marketing and production planning in an ERP system (Chapter 5, Langenwalter 2000). APS systems use operations research and management science techniques to optimize production planning and scheduling at varying levels within an enterprise. In this paper, we restrict our research scope within a single plant which produces and sells a deteriorated item in the market with the objective of maximizing total profit and minimizing inventory investment over finite planning horizon.

In a traditional approach, the marketing and production functions within a firm are managed by entirely separate units. The marketing department sets the price, the market responds with a specific demand, and the production department makes the lot-sizing and scheduling decision that minimizes the total production cost while satisfying demand. As opposed to the sequential process, the cooperative process such as the one treated in this paper determines the price and lot-size/scheduling at a time. It is well documented (see, for examples, Eliashberg and Steinberg 1993, Federgruen and Heching 1999) that the cooperative approach is superior to the sequential (decentralized) approach in many dimensions such as minimizing cost or maximizing profit.

2. The problem context

In this section, we describe the underlying problem and settings, including assumptions and necessary notation. We consider a manufacture firm who produces and sells a single product that is subject to continuous decay over lifetime, faces a price-dependent and time-varying demand function $D(p,t)$, and has the objective of determining production lot size and scheduling so as to maximize the total profit stream over multi-period planning horizon. The reason of using time-varying demand under multi-period setting is twofold: to reflect sales fluctuation over time and to reflect sales trend in different phases of product life cycle in the market. For example, the demand increases over time in the growth phase and decreases in the decline phase. Wagner and Whitin (1958) and Donaldson (1977) are two of the earliest works that consider the discrete and the continuous time-varying demands, respectively.

The demand function considered in this paper satisfies the following mild and realistic assumptions (see Rajan et al. 1992 for further discussions): i) $D(p,t) > 0$ and is continuous for $p \geq 0$, $t \geq 0$; ii) $D(p,t)$ is nonincreasing in *p*; iii) $D(0,t) < +\infty$ and $\lim_{p\to\infty} pD(P,T) = 0$ for $t \geq 0$; and iv) $D(p,t) > 0$ for $p \in (p_{\min}, p_{\max})$, $t \geq 0$. A reasonable assumption on the selling price is to let $p_{\min}$ equal the variable production cost and $p_{\max}$ be the maximal acceptable price by the customers. The function is a generalized form of the demand model used in Rajan et al. who assumed $D(p,t)$ is nonincreasing in *p* and *t*, separately. Their specific demand function captures the property of diminishing effect toward the end of product lifetime in single period setting; ours can reflect sales trend, upward or downward, over multi-period horizon.

To incorporate the multi-period setting in a typical MRP II/ERP environment, we assume the inventory and selling price are reviewed periodically at time *t*, *t* = 0, 1, 2,…, *H*, where *H* is the planning horizon. At the beginning of each period, a joint decision is made regarding the lot-size of a new production run (if any) and its associated selling price. The problem is equivalent to determining the optimal sequence of times z_{i-1}, *i* = 1, 2,…, *n*, at which a new production is scheduled, the selling price *p* is reset, and the lot-size $Q(p)$ is specified simultaneously so that the total profit stream over [0, *H*] is maximized. Since demand is a function of price, the production quantity is accordingly dependent on the price. It is worthy noting that $n \leq H$, $z_0 = 0$, $z_n = H$, z_{i-1} is integer and $z_{i-1} \in [0, H)$, and *n* is the total number of productions to be scheduled over the planning horizon. To simplify the study, we assume no shortages are allowed that is not uncommon in an ERP system. Consequently, each new production at z_{i-1} is for the selling period over $[z_{i-1}, z_i]$. In the dynamic system, no inventory is held at the beginning and at the end of the time horizon. If the initial inventory level is positive in the system, no action will be taken until the depletion of inventory. Figure 2 graphically illustrates the production system in which the maximal accumulated inventory level over $[z_{i-1}, z_i]$ is at time epoch *s* after which production stops until next run to be scheduled at z_i.

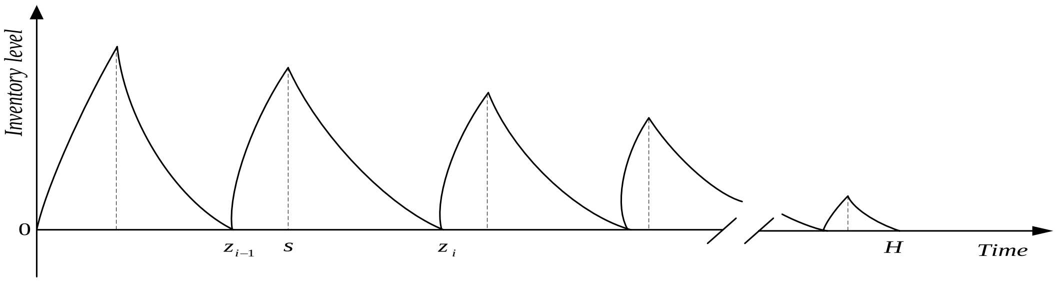

Figure 2 The production lot-size and scheduling for a deteriorating item with time-decreasing demand over multi-period planning horizon.

3. The model

We first derive the optimal lot-size and price joint decisions over an arbitrary production period [z_{i-1}, z_i], then prove the uniqueness of the solutions, and finally determine the optimal production schedule z^*_{i-1} and associated price p^*_{i-1} and lot-size $Q^*_{z_{i-1}}$ for i = 1, 2,…, n, using dynamic programming technique.

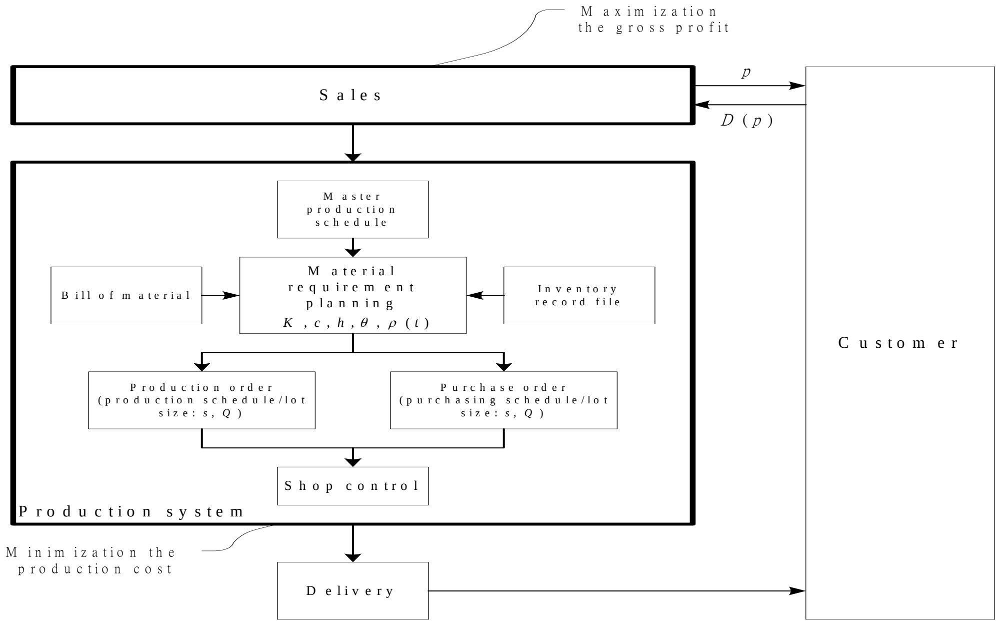

Figure 3a Production/sales logic in decentralized system

The developed profit model (the detail is omitted) is a function of the selling price p which can be determined either by the decentralized policy or by the centralized (coordinated) policy. In the decentralized decision process (see Figure 3a), the marketing department sets the price by maximizing its gross profit function disregarding the production cost, the market responds with a specific demand, and the production department makes the lot-sizing and scheduling decision with the objective of minimizing the total production cost while satisfying the demand.

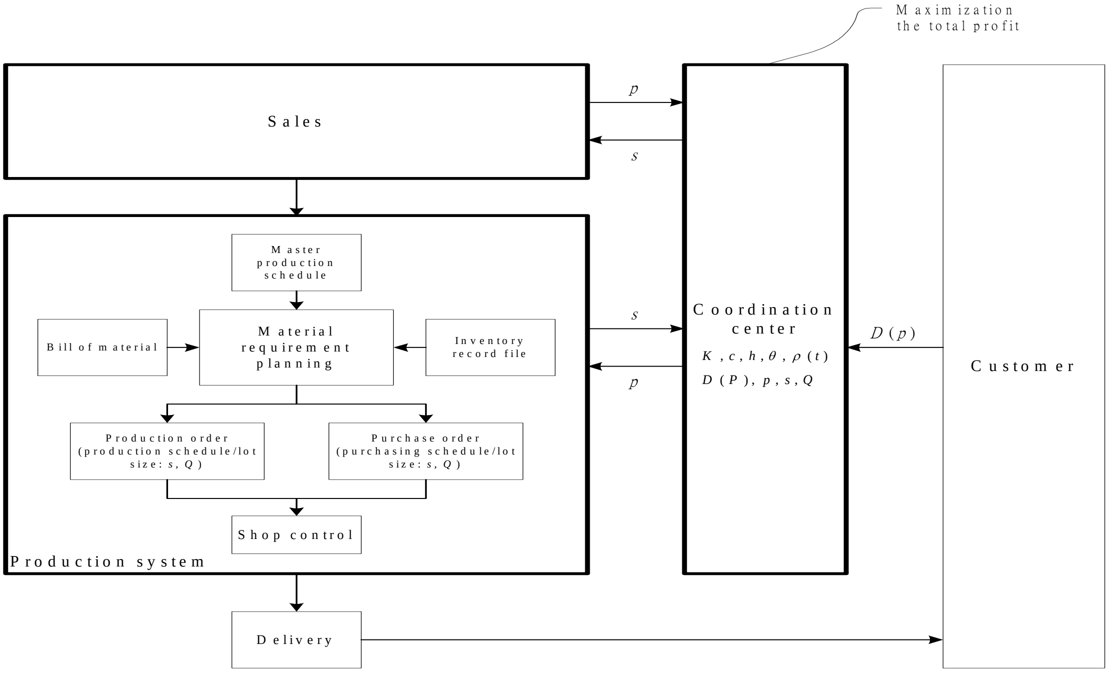

Figure 3b. Production/sales logic in coordinated system.

As contrast to the sequential process, the coordinated policy makes the pricing and production decisions at a time (see Figure 3b).

4. Numerical study

The dynamic solution procedure for both policies was implemented on a personal computer with Pentium CPU at 1.8 GHz under Windows XP operating system using Mathematica version 4.1. In our experiments, we first verified the concavity of the gross profit model, and then determined the optimal price p* or p** and associated lot size $Q(p^*)$ or $Q(p^{**})$, and the production schedule z^*_{i-1} or z^{**}_{i-1}, i = 1, 2,…, n. For the iterative procedure, the process continued until the absolute value of relative error between consecutive iterates was less than or equal to 10^{-4}. The process took less than 3 iterations to converge in all experiments being studied. The computer time required for the dynamic programming was about 3 seconds on average.

Several numerical studies were conducted to attend qualitative insights into the structures of the proposed policies and their sensitivity with respect to major parameters. We focused in particular on investigating the solution property as well as the benefit of the coordinated policy compared to the decentralized policy in settings with time-decreasing demand ($\lambda < 0$). Further, we explored the impacts of price-sensitivity coefficient and production rate on the profits generated by the two policies.

Comparing the solutions generated by the two policies, the coordinated policy generates higher price and more profit. Intuitively, the higher price yields less quantity demanded in the market as well as smaller production lot-size and less amount of deteriorating units. One additional performance measure is introduced in the study: the maximal inventory level over the planning horizon for the decentralized and the coordinated policies. The coordinated policy produces smaller value of inventory which implies less storage capacity required and, as a result, less investment needed in warehousing and material handling system.

Using the settings in the illustrative example above, we analyzed the sensitivity of the solutions generated by the two policies with respect to major parameters. We investigate the impact of different price elasticity on such measurable dimensions as the net profit, lot-size, and deteriorating quantity. We changed the price-sensitivity coefficient *b* in demand function from 7.5 to 12.5 with step size of 0.5 in order to represent different price elasticity. Numerical results show that the percentage of profit difference between the two policies increases in *b* significantly, i.e., the higher price-sensitivity of demand, the more profit improvement can be made by the coordinated policy over the decentralized.

Next, we investigate the impact of production rate $\rho(t)$ on the solutions generated by the two policies. We changed the production rates from 50 to 550 with step size of 50. Numerical results show that the percentage of profit difference between the two policies increases in $\rho(t)$, but not as significant as in *b*.

5. Conclusions

This paper has proposed two decision-making policies, coordinated and decentralized, that determine the optimal price and production lot-size/scheduling for a deteriorating item over finite planning horizon. We have presented the necessary and sufficient conditions to the maximization problem, formulated the problem as a dynamic programming model, and provided the solution procedure. An extensive numerical study has been conducted to attend qualitative insights into the structures of the proposed policies and their sensitivity with respect to major parameters such as price-sensitivity coefficient and production rate. The numerical results have shown that the solution generated by the coordinated policy outperforms that by the decentralized in maximizing the net profit and other quantifiable measures such as minimizing inventory investment and storage capacity. Further, we have shown that the percentage of profit difference between the two policies increases significantly in price elasticity of the demand function.

The proposed model is based on a periodic review policy which makes it applicable in many manufacturing planning and control practices. It can be used as an add-in optimizer like the advanced planning and scheduling in an ERP system. The main restriction for the practical implementation of the model is subject to its dynamic pricing mechanism which may be unacceptable by the contract-based customers. A nature extension of this research is to consider more complicated and practical demand and deterioration functions in the model, such as the stochastic demand and the fuzzy-modeling deterioration. In addition, the value drop effect considered by Rajan et al. (1992) and the effect of diminishing arrival rate and decreasing reservation price considered by Bitran and Mondschein (1997) can possibly be incorporated into the model.

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