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CUSTOMER INTEGRATED PRODUCTION SYSTEMS ANALYSIS

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ABSTRACT

This paper addresses the increasingly prevalent phenomenon of customer integrated production systems. In particular, it examines the operation of systems where customer integration has been enabled by the implementation of EDI and where supply chain uncertainty exists. A simulation model of such a system was employed to analyze four different production systems operating under different batch procedures and cost scenarios. Numerous experiments were conducted and the results obtained were analyzed. Several conclusions relating to customer behavior pattern and supply chain uncertainty were drawn from this analysis.

INTRODUCTION

A significant number of companies have incorporated closer integration of their customers with their production systems as a key part of their quest for competitiveness. To this end, companies are implementing various systems such as electronic data interchange (EDI). EDI is the inter-company computer-to-computer exchange of business documents (such as purchase orders, invoices and shipping notices) in standard format [6]. Unlike other electronic means such as electronic mail which provides computer to computer exchange of free-formatted text, EDI is strictly formatted into pre-determined standards [8].

With advances in communications techniques, software engineering and hardware technology, it has become easier and more cost effective for companies to implement EDI. Apart from localized improvements, systems such as EDI, offer companies the opportunity to expand their scope of operations to the global arena. Notwithstanding the many benefits which can accrue from the implementation of EDI, the operation of a customer integrated production system raises new issues which need addressing. The most critical of these issues is the uncertainty which is created within the production system. This uncertainty arises due to the exposure of the system to a variety of customer behavior patterns. This results in an unstable master production schedule (MPS). Coping with this instability may be exacerbated by the presence of uncertainties in the process and supply chain.

Hence, there is a need to develop models of production systems that incorporate the elements of uncertainty facing

them. Since, the way the system behaves in a deterministic environment is very different from the way the system behaves in an uncertain environment, it is necessary to develop and study models of production systems under uncertainty [9]. The potential benefits of studying such models have been underlined by Bahl et al [1].

Some studies have been carried out with a view to understand the determinants of production system's behavior. The focus of these studies has tended to be on material requirements planning (MRP) (e.g. see [3][4][7][10]). None of these studies has been concerned with an integrated production system subject to supply and process uncertainties and with customer access via EDI. This paper attempts to address the operation of this type of production system in such an environment.

OBJECTIVES

The general objective of this paper is to study the behavior of a customer integrated production system. The integration of customers and the production system is enabled by means of EDI. Specifically, an understanding of the effect on the production system performance of a variety of customer demand behavior patterns is sought given the presence of supply and process uncertainties. An understanding of this behavior can lead to the development of strategies to maximize system performance in such circumstances.

METHODOLOGY

A simulation model incorporating integration of the production planning and control system and shop floor elements and with EDI linkage to the customer, was developed by the authors [2]. The simulation model consists of three modules, viz., input module, MRP/Shop Floor module and an output module. The input module is concerned with providing the basic information for the formation of the MPS. It should be noted that part of this information is obtained via EDI. The MRP/Shop Floor module mimics the operation of the MRP system and the performance of the shop floor control functions. The output module calculates and reports period by period statistics and end of simulation run statistics. These statistics cover service level, average backorder and inventory levels, maximum and minimum backorder and inventory levels, and the number of periods backorders are

experienced during the simulation run. Finally, the total cost is calculated based on the number of setups, the average inventory levels and average shortage levels.

This simulation model was used to study the influence of different customer behavior patterns on the customer integrated production system. This was studied in conjunction with a variety of multi-stage processing configurations, batch sizing procedures, process and supply uncertainties and costs (including setup costs, inventory charges and backorder costs). The paper concludes with several recommendations to improve the responsiveness of such production systems.

EXPERIMENTATION

To model different customer behavior patterns, three types of customers were considered. These three types were chosen because they constitute a representative range of customer behavior and customer-producer interaction modes. Type A represents an environment in which the customer orders are received sufficiently well in advance so that the producer has time to complete the entire order by the proposed due date. Type B customers are given the right to increase or decrease the order quantities by up to 60% of the agreed amount. Type C customers can increase the order quantity up to a level which is two and a half times the original quantity ordered or decrease it to any level including complete cancellation of the order.

Among the factors considered in conjunction with customer behavior was processing configuration. This is concerned with the distribution of processing and assembly operations from the start to the finish of the product. Four cases were considered and they all had an equal number of manufacturing operations, but their configurations varied. A further factor considered was the unit requirements. This represents the quantity of each item which is required for a subsequent manufacturing or assembly operation. In this study, two levels of unit requirements were considered, viz. single and multiple. For the purpose of this study, unit requirements at the multiple level were restricted to two.

Another factor considered was the ratio of setup cost to inventory charges. Here, setup cost represents the cost incurred in preparing a processor to produce a batch of a particular item. In this study, three such ratios were considered. The values chosen were designated as low, medium and high.

The size of a batch is determined by one of ten well known lot sizing procedures normally used in conjunction with

MRP, viz. Economic Order Quantity (EOQ), Lot For Lot (LFL), Least Total Cost (LTC), Least Unit Cost (LUC), Period Order Quantity (POQ), Part Period Algorithm (PPA), Silver-Meal Algorithm (S-M), Economic Order Quantity with Shortages (EQS), Gupta-Brennan Algorithm (G-B) and Wagner-Whitin (W-W) [5].

Supply chain uncertainty occurs at both the supplier and process levels. Six levels of uncertainty were modeled. For each level of uncertainty, 50% of items were always supplied/processed on time. Thus the uncertainty was associated with the remaining 50% of the items. This could vary from "all early" to "all late" and various combinations in between. In addition to these six levels of uncertainty, a deterministic supply chain was also considered.

To investigate the impact of customer behavior patterns in a multi-stage processing environment, a total of 5,040 scenarios were investigated. These scenarios arose from the combination of different factor levels described above, viz., three levels of the customer behavior factor, seven levels of the supply chain factor (including the deterministic supply chain), four levels of the processing configuration factor, three levels of the ratio of setup cost to inventory charges factor, two levels of the unit requirements factor and ten levels of the batch procedure factor. The length of each simulation run was 800 periods. However, in order to ensure steady state conditions, the results presented below are based on the last 500 periods' simulation output. The output generated from the first 300 periods' simulation was discarded.

ANALYSIS OF RESULTS

This analysis focuses on the cost output produced from the simulation experiments. While a variety of factor interactions were studied, this section highlights only some of the results obtained.

When the effects of customer behavior and supply chain uncertainty were analyzed, the following observations were made:

- It was observed that the more uncertainty inherent in the customer behavior, the more costly it was to operate the production system. Thus, accommodating type C customers was more costly than accommodating type B customers. Similarly, it was more costly to accommodate type B customers than type A customers.
- As the level of uncertainty in the supply chain increased, the cost of the system tended to increase. This increase was notably steeper than that

observed for changes in the customer behavior pattern. However, in the absence of supply chain uncertainty, customer behavior has a much more significant impact on the cost performance of the production system.

- It appears that the effective management of the supply chain uncertainty is more crucial than the uncertainty introduced by the customer behavior.
- When the effects of customer behavior and supply chain uncertainty were evaluated for each individual processing configuration, it was found that the results were largely invariant. This surprising result could be attributed to the fact (as noted earlier) that all four configurations have the same number of manufacturing operations.
- The effects of customer behavior and supply chain uncertainty were further evaluated for each individual processing configuration and setup cost to inventory charges ratio. Even though the magnitude of the cost performance varies significantly from one ratio to the other, the trend, nevertheless, remains largely intact.
- The effects of the choice of batch procedure on cost performance across various customer behavior patterns and supply chain uncertainties were also analyzed. While the overall trend across batch procedures were somewhat similar, this was more pronounced at higher levels of supply chain uncertainties. Of course, the magnitude of the cost performance varied significantly from one batch procedure to another. Given this variation, it is concluded that the choice of batch procedure can play a significant role in containing costs.

CONCLUSIONS

This paper presented an analysis of a customer integrated production system. This is the first attempt at modeling and analyzing customer integrated production systems with uncertainties in the supply chain. Nonetheless it was possible to gain some valuable insight into such production systems. The most important insight gained from this study was the dominant influence of supply chain uncertainties on the performance of the system when compared to uncertainties arising from customer behavior patterns.

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