# REAL-TIME SALES & OPERATIONS PLANNING WITH CORBA

## *Linking Demand Management with Production Planning*

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Keywords: Real-time planning, CORBA in manufacturing, Demand management.

Abstract: Several existing mechanisms for order processing, such as Available-to-Promise (ATP), Materials Requirements Planning (MRP), or Capable-to-Promise (CTP), do not really include simultaneous capacity and profitability considerations. One of the major issues in the incorporation of profitability analysis into the order management system is the determination of relevant costs in the order cycle, and the real-time access to production parameters (i.e., target quantities based on current cycle time) to be included in the computation of planning and profitability. Our study attempts to provide insights into this novel area by developing a Decision Support System (DSS) for demand management that integrates real-time information generated by process control and monitoring systems into an optimization system for profitability analysis in a distributed environment via CORBA (Common Object Request Broker Architecture). The model can be incorporated into current enterprise resource planning (ERP) systems and dynamic use of real-time data from various functional support technologies.

## 1 INTRODUCTION

The well-known Available-to-Promise (ATP) mechanism is a powerful tool for order promising and order date negotiation for many firms (Vollman, Berry and Whybark 1997). ATP links manufacturing and order management, thus synchronizing production and sales/marketing activities. Depending on the information technology used, ATP implementation can simply use inventory position in a single location or multiple locations. If the product ordered is not currently available in any location, customers may be promised delivery dates based on when the product can be produced. In the typical case, an additional materials requirements planning (MRP) run with the added product demand can determine a future availability date which then can be used for order promising. However, as is well known, MRP uses fixed lead times and does not consider the current load at the shop level, and therefore, does not necessarily provide accurate promise dates.

A more contemporary approach to order promising is to actually schedule the production in the current manufacturing system in real-time scheduling, through an Advanced Planning and Scheduling (APS) software. This would result in a more accurate, deliverable order promise date. Real-time scheduling systems can manage instant priority shifts when customer requirements or management objectives change with resulting benefits of reduced costs, reduced manufacturing cycle time, increased throughput and better customer responsiveness (Layden 1994). This concept is currently known as Capable-to-Promise (CTP).

As far as CTP implementations exist in varying degrees in practice, real-time CTP is yet to become an integral part of supply chain management and optimization. This is mainly due to the complexity of exchanging information, in real time, between the order management system, typically used by customer service representatives, and the production scheduling system, typically used by schedulers/MRP controllers.



Kirche E., Zalewski J. and Tharp T. (2005).
REAL-TIME SALES & OPERATIONS PLANNING WITH CORBA - Linking Demand Management with Production Planning.
In *Proceedings of the Seventh International Conference on Enterprise Information Systems*, pages 122-129
DOI: 10.5220/0002528301220129

While all of the above mentioned approaches are primarily concerned with the understanding of existing process constraints and the balancing of the flow of materials through the production process in order to meet customer requirements, they do not consistently utilize profitability analysis as an input into order promising decisions. Clearly, a truly effective order management approach should include both capacity and profitability considerations. This approach, in practice, is referred to as Profitable-to-Promise (PTP). PTP is the ability to respond to a customer order by determining how profitable it is to accept this order. Successful PTP applications are the 'holy grail' of electronic commerce for manufacturers and the next avenue for many of the supply chain management/optimization software developers.

One of the major issues in the incorporation of profitability analysis into the order management system is to determine which costs are relevant, and to have real-time access of production parameter (i.e., current cycle time) to be included in the calculation of planning and profitability. Our study attempts to provide insights into this novel area by developing a Decision Support System (DSS) for demand management that integrates real-time information generated by process control and monitoring systems into an optimization system for profitability analysis in a distributed environment via CORBA, Common Object Request Broker Architecture (Bolton 2002). The model can be incorporated into current enterprise resource planning (ERP) systems and dynamically use-real time data from various functional support technologies as indicated in Figure 1.

## 2 THE DECISION SUPPORT SYSTEM FOR DEMAND MANAGEMENT

Many manufacturing environments use MRP, material resource planning (MRPII) or ERP systems for medium term planning. Such systems divide the planning horizon into discrete time buckets and require a medium term production plan for several future time buckets, which is used to provide due dates and release dates for detailed production scheduling. Previous attempt to address an effective sales and operations planning (S&OP) strategy to react to changes in the demand has been difficult, since there has been a lack of real-time information concerning system status (Ovacsik and Uzsoy 1994).

However, the advent of computerized information systems capable of tracking job and machine status in real time has changed this situation, and real-time performance measurement is the next frontier of operational excellence. In many of the process industries, information is generated in real time by process control computers. In discrete parts manufacture, computer systems for the entry and distribution of data, such as video display units and bar code scanners, are placed at various locations on the shop floor, to record information concerning the location and status of jobs and resources, and to display this information for control purposes. Feedback can be generated from several or all work centers to track jobs and update their progress. This technology is comparatively cheap and very effective in many businesses and manufacturing applications (Castillo 2001; Singh 2002).

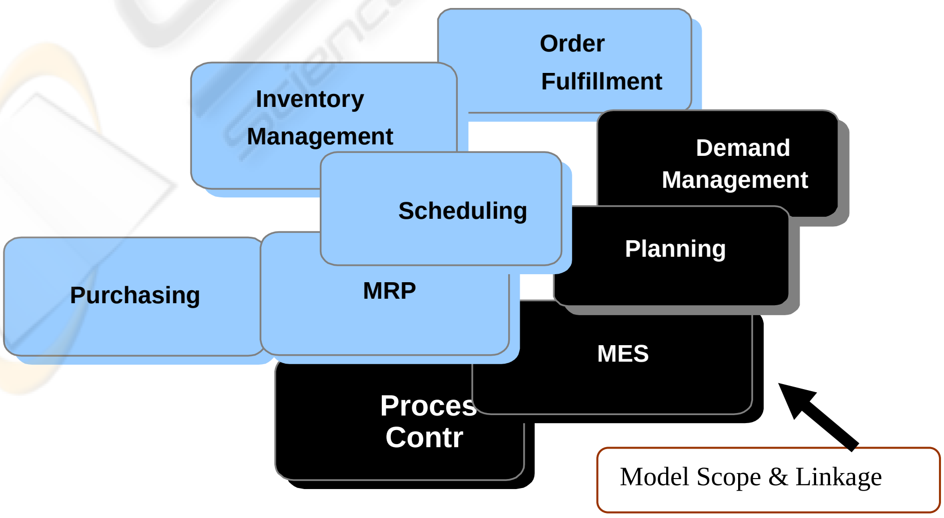


Figure 1: Model Interface with Enterprise Resource Systems (ERP)

Real-time data are commonly used to improve estimated values of processing parameters, such as processing time or worker performance (Steele et al. 2001), but rarely used for demand management and profitability analysis. In this study, we apply a DSS for distributed environment utilizing CORBA to interface with production, sales and financial application technologies as shown in Figure 2.

The operational system continuously tracks processing time at work centers and uploads information to an operational data server, performing immediate computations and display of the production target based on current cycle time. With instantaneous network access for monitoring and reporting, it broadcasts production information in real time to the entire factory floor. Concurrently, the financial server maintains current cost and price information on raw material, work center costs, inventory, and other pertinent accounting data. An advanced planning system (MIMI®, from Aspen Technology Inc.) containing an optimizer module (CPLEX) downloads on demand up-to-date information from both operational and financial servers via CORBA for evaluation and allocation of resources to meet customer order request in the most efficient manner.

The request can be made from various levels at the organization but the primary use is in the support sales for demand management to increase profitability. The goal of the real-time system is to dynamically integrate end-to-end processes across the organization (key partners, suppliers and customers) to respond with speed to customer changes and market requirements. The real-time CORBA framework enables employees to view current process capability and load on the system and provide immediate information to customers.

The decision to employ CORBA is based on its importance in complex control systems (Sanz and Alonso 2001) and the integration capabilities it offers for real-time and embedded systems (Sanz 2003). The CORBA open system has vast resource scalability and potentially can serve an unlimited number of players and virtually any number of manufacturing processes and partners in the production environment. It provides an integrated view of the production process for an efficient demand management. Other benefits include continuous availability, business integration, resources availability on demand, and worldwide accessibility.

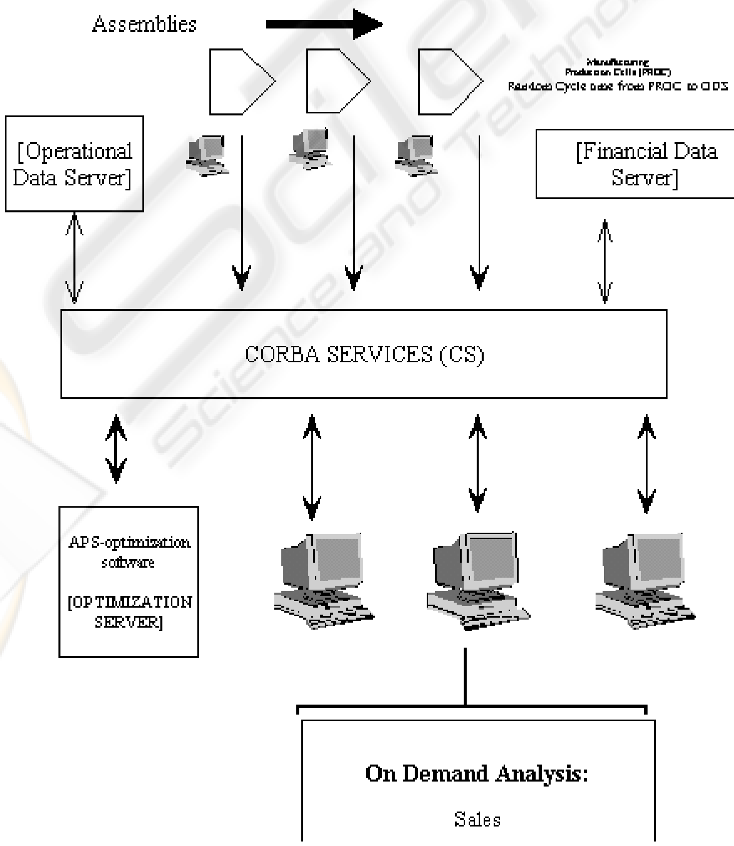


Figure 2: Process Description – Distributed Service

The optimizing server uses a mixed integer program (MIP) to plan order and optimize resource allocation to maximize profits as orders arrive in each period. Orders are for different products, quantities and for a specific due date. If the order is unfeasible for the current production period (that is, cannot be produced without delaying a previously accepted order) it will have to be renegotiated with the customer (in real time) for a later due date or a reduced order that can fit in current production.

The optimizer accesses current production parameters from the operational server to plan and schedule accepted orders for the next production horizon. Typically in productions systems, unforeseen events such as unscheduled down times, production losses, change orders, bottleneck constraints, and other issues make difficult the synchronization of planning and scheduling of work centers. However, the integration and enterprise visibility created by the real-time demand management system will tune resourses and balance workloads to maximize production efficiency and adapt to dynamically changing environment.

## 3 CASE STUDY

The manufacturing environment consists of a firm that has limited production capacity geared to produce multiple product lines. Products within each line are processed in batches of varying sizes according to the demand load. Production comprises of a sequence of activities with processing times that may change with load and manufacturing conditions such as unscheduled downtime. The production activities are of two types:

1) a sequence of activities common to all product lines, and

2) a sequence of activities specific to each product line. Each product line includes several variations (of finished goods).

The common activities precede the product line-specific activities and take place in the Common Part Cell (CPC). The final assembly cells ($P_iC$), where *i* sub-index denotes the product line, are specific to product line and product lines assume different identities only after product line-specific activities are performed in their respective final assembly cells. Any accumulation of inventory (WIP) between the common and product line-specific activities comprise of a homogeneous intermediate product (Common Part – CP). This production environment is depicted in Figure 3 and is similar to those used in other studies (O'Brien 1996; Umble et al. 2001).

Production takes place under a demand-pull system, i.e., a customer order initiates production activity - the processing of raw material (RM) and subsequent processing at the common and product line-specific cells. If there is excess work in process (WIP) inventory (of the CP), no production activity is initiated in the CPC; the required CP quantity is transferred to the specific product line-cell. We assume that there were no delays for moving parts and/or raw materials among cells. If there is sufficient finished goods inventory to cover an order request, production is not initiated. Inventory exists because one batch (or multiple batches) may be greater than the order quantity, and the units produced in excess of order quantity are placed in stock. The capacity utilization level for each cell is set as suggested in (Yang and Jacobs 1999).

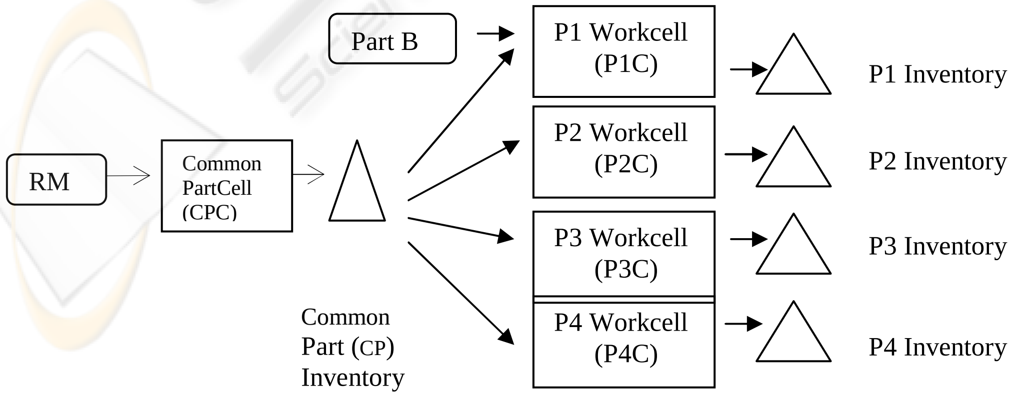


Figure 3: Manufacturing Process Flow

The manufacturing time and cost parameters are downloaded on demand in an advanced planning system, MIMI®, Manager for Interactive Modular Interface, Version 5.0 (from Aspen Technology, Inc), which is utilized to optimize the production scheduling. Reports can be generated for current demand load, production sequence and profits.

# 4 PRODUCTION PARAMETERS

The production environment is for a supply chain composed of several suppliers of raw material serving a single plant and materials are delivered assuming instantaneous lead-time. Within the plant, there are several overhead activities to support production, engineering, purchasing and marketing operations. Order arrival rates ($\lambda$) and order size (q) are set relative to an average capacity of the Common Part Cell (CPC) to produce the common part (CP), making the CPC cell the production bottleneck by design. Yang and Jacobs (1999) suggested a capacity utilization rate of 72% per period without set time. In this research, we designed the run time capacity (practical capacity) for all work cells at 6 hours per period.

Table 1 indicates the parameters associated with each cell and product type. Product P1 is made up of two components - raw material A which is first semi processed in CPC work center, and purchased component B. Other products are made of only raw material A, also processed in work center CPC. Raw material A and purchased component B are available from two suppliers, although the model in the study allows for a flexible number of suppliers, parts and components, and finished goods. These parameters are stored in the operational server which interfaces directly with plant floor machinery to facilitate accurate, real-time data collection for better business planning.

The system updates and stores all production part numbers and desired quantities scheduled for each period, so there is minimum operator involvement. In addition to acquiring production counts directly from production equipment, the system updates current cycle time, inventory counts, productivity and other production parameters. This information, in addition to financial data stored in the financial server, is uploaded to an APS via CORBA for production optimization and profit analysis on demand (as shown in Figure 2). The financial data are displayed in Table 2.

Table 1: Production Parameters

| | Products | | | | |
|---|---|---|---|---|---|
| | CP | P1 | P2 | P3 | P4 |
| Manufacturing cell for specific products | CPC | P1C | P2C | P3C | P4C |
| Mean run time per unit (hours) | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Batch size (units) | 4 | 4 | 4 | 4 | 4 |
| Setup time (hours) | 0.5 | 0.333 | 0.333 | 0.25 | 0.25 |
| Number of procurement transactions per order | 0 | 3 | 2 | 1 | 1 |
| Max run time in each cell (hours) | 6 | 6 | 6 | 6 | 6 |
| Max time for setups in each cell (hours) | 3 | 2 | 2 | 1.5 | 1.5 |
| Total capacity in each cell per period (hours) | 9 | 8 | 8 | 7.5 | 7.5 |

Table 2: Product Cost and Pricing

| Product | | CP | P1 | P2 | P3 | P4 |
|---|---|---|---|---|---|---|
| Order cost per unit (average order size = 6) | | - | 14.29 | 9.52 | 4.76 | 4.76 |
| Batch cost per unit | | 6.25 | 4.17 | 4.17 | 3.13 | 3.13 |
| Unit cost | | 2.92 | 2.08 | 1.67 | 0.83 | 0.83 |
| | sub-total 1 | 9.17 | 20.54 | 15.36 | 8.72 | 8.72 |
| | | | | | | |
| CP cost | | | 9.17 | 9.17 | 9.17 | 9.17 |
| | sub-total 2 | 9.17 | 29.70 | 24.52 | 17.89 | 17.89 |
| | | | | | | |
| Cost of purchased material | Raw material A | 30.00 | 30.00 | 30.00 | 30.00 | 30.00 |
| | Component B | - | 10.00 | - | - | - |
| | | | | | | |
| Total Manufacturing Costs (TMC) | | 39.17 | 69.70 | 54.52 | 47.89 | 47.89 |
| | | | | | | |
| Price ~(200 % over TMC) | | - | 130.00 | 110.00 | 95.00 | 90.00 |
| Inventory costs | | 0.01 | 0.05 | 0.05 | 0.05 | 0.05 |

## 5 SIMULATION ANALYSIS

According to Pritsker (1986), simulation models must be verified and validated before relying on their results. He states that verification is the process of establishing that the computer program executes as intended, whereas validation is the process of establishing that a desired accuracy or correspondence exists between the simulation model and the real system. A pilot study is simulated to provide parameter boundaries for a more comprehensive experiment, evaluate the proposed model formulations, and provide understanding of how the model behaves in a real application.

We first validate and verify results of the simulation through an illustrative example. The models used in this experiment were verified by testing them as a whole and in subsections. For example, each manufacturing cells were completely evaluated individually to match orders and cost considerations.

The orders were traced from suppliers to production timing, bottleneck influence of other activities, inventory quantities generated by the order and conformance to due date restrictions. All costs incurred during the production cycle were also verified to correspond to each specific activity. Through debugging, refining, and redesigning, all models were completely verified. As a result, it has been concluded with confidence that all models are performing as intended.

Validation is the process of establishing that the desired accuracy or correspondence exists between the simulation model and the real system being simulated. The performance criterion in this validation process is the general knowledge and logical intuition of how the system should behave. For example, in the stage of randomly generated product orders, a specific number and type of orders was generated for specific due dates and quantities. This ensures that these products are the only inputs and expected outputs of the system. Table 3 indicates a typical order set to be operationalized by the model.

Table 3: Demand Information

| Part # | PO # | Delivery date | Order quantity | Order date |
|---|---|---|---|---|
| P1 | 10 | 1/15/04 | 14 | 1/13/04 |
| P1 | 11 | 1/24/04 | 11 | 1/13/04 |
| P2 | 12 | 1/26/04 | 15 | 1/13/04 |
| P3 | 12 | 1/17/04 | 17 | 1/14/04 |
| P2 | 14 | 1/29/04 | 5 | 1/14/04 |
| P1 | 15 | 1/20/04 | 6 | 1/15/04 |
| P3 | 16 | 1/29/04 | 5 | 1/15/04 |
| P4 | 17 | 1/30/04 | 9 | 1/16/04 |
| P4 | 18 | 1/29/04 | 19 | 1/16/04 |
| P3 | 19 | 1/27/04 | 3 | 1/16/04 |
| P4 | 21 | 1/22/04 | 9 | 1/16/04 |

Order management applications interface with the user in sales through the demand information (Table 3), which is stored in the financial server. It can be accessed via CORBA by the salesperson for order confirmation and input of the new orders. After a new order is entered into the table, the user can run the optimizer (APS) to update and confirm the feasibility of the order. If the order can produce a capacity feasible schedule, the information is stored in the financial server and the profitability of the order can by be generated as indicated in data presented in Table 4.

Table 4: Profit Analysis

| PO # | Order quantity | Order date | Profit |
|---|---|---|---|
| 10 | 14 | 1/13/2004 | |
| 11 | 11 | 1/13/2004 | |
| 12 | 15 | 1/13/2004 | 2401.60 |
| 13 | 17 | 1/14/2004 | |
| 14 | 5 | 1/14/2004 | 3434.00 |
| 15 | 6 | 1/15/2004 | |
| 16 | 5 | 1/15/2004 | 4184.98 |
| 17 | 9 | 1/16/2004 | |
| 18 | 19 | 1/16/2004 | |
| 19 | 3 | 1/16/2004 | |
| 20 | 9 | 1/16/2004 | 5778.32 |

The production schedule and profitability analysis is possible because the APS accesses real-time data from the financial and the operational servers via CORBA to generate reports. The APS, when producing the updated schedule, will also generate several reports to support production in the shop-floor (Table 5), and other required accounting transactions to meet the new customer order. Table 6 indicates the required purchasing order to be placed with vendors to maintain a feasible schedule and guarantee the contractual delivery date with the customer. The purchasing requirements can be electronically sent to vendor via CORBA and stored in the financial server for later retrieval.

Table 5: Production Scheduling.

| Production period | Part # P1 | Part # P2 | Part # P3 | Part #P4 | Part # CP |
|---|---|---|---|---|---|
| 1/15/2004 | 16 | 0 | 4 | 0 | 20 |
| 1/24/2004 | 0 | 0 | 4 | 0 | 4 |
| 1/26/2004 | 0 | 0 | 12 | 0 | 12 |
| 1/17/2004 | 0 | 0 | 0 | 4 | 4 |
| 1/29/2004 | 0 | 0 | 0 | 0 | 0 |
| 1/20/2004 | 4 | 0 | 0 | 0 | 4 |
| 1/29/2004 | 0 | 0 | 0 | 0 | 0 |
| 1/30/2004 | 12 | 0 | 0 | 8 | 20 |
| 1/29/2004 | 0 | 0 | 0 | 0 | 0 |
| 1/27/2004 | 0 | 0 | 0 | 0 | 0 |
| 1/22/2004 | 0 | 0 | 0 | 0 | 0 |
| 1/29/2004 | 0 | 16 | 0 | 0 | 16 |
| 1/26/2004 | 0 | 0 | 0 | 0 | 0 |
| 1/27/2004 | 0 | 4 | 8 | 0 | 12 |
| 2/04/2004 | 0 | 0 | 0 | 16 | 16 |
| 2/01/2004 | 0 | 0 | 0 | 12 | 12 |

Table 6: Purchasing Orders.

| Part# | Vendor | Delivery date | Order quantity |
|---|---|---|---|
| A | SUP1 | 1 | 20 |
| A | SUP1 | 2 | 4 |
| A | SUP1 | 3 | 12 |
| A | SUP1 | 4 | 4 |
| A | SUP1 | 6 | 4 |
| A | SUP1 | 8 | 20 |
| A | SUP1 | 12 | 16 |
| A | SUP1 | 14 | 12 |
| A | SUP1 | 15 | 16 |
| A | SUP1 | 16 | 12 |
| B | SUP2 | 1 | 16 |
| B | SUP2 | 6 | 4 |
| B | SUP2 | 8 | 12 |

## 6 CONCLUSION

In order to remain competitive in the global market, companies need to establish a well connected supply chain to synchronize production and order decisions in through information technology.

This study introduced an application of a decision support model with CORBA for synchronized sales and operations planning in a multi-stage manufacturing environment. Our objective was to gain insights into how real-time order management decisions could be used to maximize profitability while ensuring that the firm has adequate resources to satisfy the demand. The model interfaces in real time with enterprise-wide planning systems to directly access financial and plant floor machinery data for better business planning.

The model presented considers availability and cost of supply chain resources (including raw material, work-in-process, finished goods inventory and production and distribution capabilities) and allocates these scarce resources to incoming orders to maximize profitability. It suggests that the synchronization of resource utilization across the supply chain and the real-time cost of resource information provided by the CORBA environment can lead to more reliable order commitment and increased profitability. By synchronizing the organization's cycle times with those of key suppliers and customers, the company can order and produce the exact quantity at the right time. The heightened visibility and accuracy bring about more streamlined process and greater adaptability to changing customer requirements.

The added benefits of the real-time model includes increased customer relationships through fast and reliable deliveries, lower operation costs (buying and producing only what is needed at the right time), and increased flexibility in order management.

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