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Modeling Accuracy of Promised Ship Date and IT Costs in a Supply Chain

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ABSTRACT

In the current dynamic, competitive business environment, customers expect to see products they purchase to be shipped on the date it is promised. However, accurate calculation of promised ship date by suppliers can only be obtained at expense of corporate IT systems that provide accurate availability data. Our study indicates that refresh frequency of availability data in IT system substantially impacts accuracy of the ship date that is promised to customer. The value of customer service level corresponding to accuracy of promised ship date needs to be estimated against the costs

of having necessary IT system. The estimation requires a simulation model of availability management process. In this paper, we describe how to model and simulate the availability management process, and quantify the customer service level resulting from various availability refresh rate.

INTRODUCTION

Being able to promise customers the desirable shipment (or delivery) date and fulfilling the orders as promised are important aspects of customer service in a supply chain. With the recent surge and wide-spread use of e-Commerce, shoppers can now easily assess and compare customer service quality in addition to quality of goods and price among different vendors. This creates a very competitive business environment, thus making customer service a critical factor for success and survival of many companies. Competitive pressures are forcing companies to constantly look for ways to improve customer services by evaluating and redesigning supply chain processes. The Availability Management Process (AMP), also called Available-to-Promise (ATP) process, is a key supply chain process that impacts customer service since it determines customer promised ship (or delivery) dates, the accuracy of the promised ship date, order scheduling delay and order fulfillment rate as well as inventory level.

It is possible for suppliers to have accurate promised ship date; however, it may require a high IT expense. In an ideal e-business environment, when a customer order is scheduled and a ship date is computed and promised to the customer, the availability of the product should exist when it is time to fulfill the order. However, in reality the availability data that are used for the scheduling the orders are not real time availability (physical availability), but they are availability information stored in an IT system (system availability). The availability data in the IT system (static view of availability) are typically refreshed (synchronized with real time availability) only periodically since it is very expensive to update the database in real time. Due to this potentially inaccurate view of the availability, some orders can't be shipped on the promised ship date. Therefore, for certain customer orders, products are shipped later than the promised ship date resulting in customer dissatisfaction. The accuracy of promised ship date can improve with high capacity computer hardware and software and improve the customer service; however, it would also cost substantially high IT expense. Therefore, one of key decisions in order fulfillment process is to properly balance IT system (e.g., IT expense) and accuracy of promised ship date. In this work, we study how availability fresh rate (IT system) impacts customer service level. The simulation model we develop helps making critical business decision on refresh rate of availability, and adequate investment in IT system.

Availability management involves generating an availability outlook, scheduling customer orders against the availability outlook, and fulfilling the orders. The generation of *availability outlook* is the push-side of the availability management process, and it allocates availability into ATP (Available-to-Promise) quantities based on various product and demand characteristics and planning time periods. *Order Scheduling* is the pull-side of the availability management process, and it matches the customer orders against the availability outlook, determines when customer orders can be shipped, and communicates the promised ship date to customers. *Order fulfillment* is executing the shipment of the order at the time of promised ship date. Even if an order is scheduled for shipment for a certain date based on the outlook of availability, the resources that are required to ship the product on the promised ship date may not be actually available when the ship date comes. A key role for effective availability management process is to coordinate and balance the push-side and pull-side of ATP, and to have adequate Information System (IS) capabilities so that a desirable and accurate ship date is promised to customers, and products are actually shipped on the promised date.

AMP or ATP process has been described in several research papers. Ball et al. (2004) gave an overview of the push-side (Availability Planning) and pull-side (Availability Promising) of ATP with examples from Toshiba, Dell and Maxtor Corporation. They stressed the importance of coordinating the push and pull-side of availability management for supply chain performance by making good use of available resources. Although ATP functions have been available in several commercial ERP and Supply Chain software solutions such as SAP's APO, i2's Rhythm, Oracle's ATP Server and Manugistics' SCPO modules etc. for several years (see Ball et al. 2004 for details), those ATP tools are mostly fast database search engines that schedule customer orders without any sophisticated quantitative methods. Research on the quantitative side of ATP is still at an early stage, and there are only a limited number of analytic models developed in supporting ATP.

For the push-side of ATP, Ervolina and Dietrich (2000) developed an optimization model as the resource allocation tool, and described how the model is used for a complex Configured-to-Order (CTO) environment of the IBM Server business. They also stress how the push-side (Availability Promising) and pull-side (Availability Planning) have to work together for the overall availability management performance.

For the pull-side of ATP, Chen et al. (2002) developed a Mixed-Integer Programming (MIP) optimization model for a process where order promising and fulfillment are handled in a predefined batching interval. Their model determines the committed order quantity for customer orders that arrive with requested delivery dates by simultaneously considering material availability, production capacity as well as material compatibility constraints. They also studied how the batching interval affects supply chain performance under different degrees of resource availability. Moses et al. (2004) also developed a model that computes optimal promised ship date considering not only availability but also other order-specific characteristics and existing commitments to the previous scheduled orders. Pan et al. (2004) developed a heuristics-based order promising model but with an E-commerce environment in mind. They modeled a process where customer orders arrive via Internet and earliest possible shipment dates are computed in real-time that are promised to customers.

All the previous work described above deal with either push-side of ATP or pull-side of ATP with an assumption that accurate inventory data are available in real time. However, in reality the inventory data not always accurate, and even if the optimal ATP tools are in place, order fulfillment performance would be less than perfect. The perfect fulfilment performance can be approached only if there exists Information Technology (IT) in the availability management process making available accurate inventory data in real time. In this paper, we describe an availability management simulation tool that estimates the accuracy of ship date commitment at the presence of imperfect, but realistic, IT environment, which results in inaccurate view of available inventory.

Determination of promised ship date is based on availability (inventory) information kept in a computer system (system inventory), which is assumed to be accurate. In actuality, the system inventory and the actual inventory (physical inventory) are synchronized only occasionally due to various reasons such as IT costs for the data refresh, inventory shrinkage, transactional errors and incorrect product identification. The error between the system inventory and the physical inventory could accumulate over time and is not corrected until the refresh of availability (synchronization of inventory), which takes place only periodically (for example, once a day, or a few times a day) since it is expensive to generate a new snapshot of availability that is consistent throughout various corporate business systems including ERP (Enterprise Resource Planning) system. In fact, inventory inaccuracy has been identified as a leading cause for operational inefficiency in supply chain management. A recent study (DeHoratius and Raman, 2008) shows that the value of the inventory reflected by these inaccurate records amounts for 28% of the total value of the on-hand inventory of a leading retailer in the U.S.

There have been studies on impact of inventory inaccuracy on supply chain performance, including Iglehard and Morley (1972), Wayman (1995), Krajewski et al. (1987) and Brown et al. (2001). More recently, Kang and Koh (2002) simulated the effect of inventory shrinkage (thus inaccuracy) in an inventory replenishment system with an (s, S) policy. Kang and Gershwin (2004) and Kök and Shang (2004) developed methods to compensate for the inventory inaccuracy in replenishment. Fleisch and

Tellkamp (2005) analyzed the impact of various causes of inventory discrepancy between the physical and the information system inventory on the performance of a retail supply chain based on a simulation model. Lee at al. (2009) discussed one way to improve the inventory accuracy through RFID in supply chain, and quantified the improvement using a simulation model. This work also studies the impact of inventory inaccuracy, but focuses on the impact of inventory accuracy resulting from inventory database refresh on the accuracy on ship date commitment through a discrete-event simulation modeling approach.

Discrete-event simulation has been around for many years in simulating Supply Chain Management (SCM) processes to evaluate its effectiveness. McClellan (1992) used simulation to study the effect of Master Production Scheduling (MPS) method, variability of demand/supplier response on customer services, order cycle and inventory. Hieta (1998) analyzed the effect of alternative product structures, alternative inventory and production control methods on inventory and customer service performance. Bagchi et al. (1998) evaluated the design and operation of SCM using simulation and optimization, analyzed SCM issues such as site location, replenishment policies, manufacturing policies, transportation policies, stocking levels, lead time and customer services. Yee (2002) analyzed the impact of automobile model variety and option mix on primary supply chain performance metrics such as customer wait time, condition mismatch and part usage. Lee et al. (2004, 2008) simulated the impact of RFID on supply chain performance through improvement of inventory accuracy. However, there hasn't been any simulation modeling work that analyzes the impact of IT system on the supply chain performance. The development of simulation model for supply chain such as availability management process can be time-consuming. We hope that the simulation modeling framework we describe in this paper can be easily adapted to simulate various availability management situations in many business environments. The simulation framework has been used at IBM for several years, and has played a critical role in making strategic business decisions that impacted customer services and profitability in IBM.

The rest of chapter is organized as follows. In the next section, we describe the availability management process. In the following section, we describe how ship date promising is modeled simulated in various availability refresh frequency. Then, we describe simulation experiments done for IBM's server business, its impacts and results. Finally, we provide concluding remarks.

AVAILABILITY MANAGEMENT PROCESS

The availability management typically consists of three main tasks: (1) generating availability outlook, (2) scheduling customer orders against the availability outlook, and (3) fulfilling the orders. The process described here is based on IBM's hardware businesses, but general characteristics would be common for many other businesses. For certain business, customer orders arrive without any advance notice, requesting earliest possible fulfillment of the orders, usually in a few days. For some other businesses, on the other hand, customers place orders in advance of their actual needs, often a few months in advance. Typically, this kind of customers place the orders as early as 3 months before the requested delivery (due) dates, and early delivery and payment are not expected. Many buyers in this environment purchase products based on careful financial planning, and they typically know when they want to receive the products and make payment.

The generation of *availability outlook*, is the push-side of the availability management process, and it pre-allocates ATP quantities, and prepares searchable availability database that are used in promising shipment of future customer orders. For certain business, an availability outlook is generated by daily buckets, and the availability planning horizon goes out to a few weeks into the future. For some other businesses, an availability outlook is allocated by weekly buckets, and the availability is planned in much longer horizon, often a quarter (3 months) into the future. The ATP quantity is called *availability outlook* for this reason. The availability outlook is typically generated based on product type, demand classes, supply classes, and outlook time buckets. The product type can be finished goods (FG) level for Make-to-Stock (MTS) business or components level for Make-to-Order (MTO) or Configured-to-Order (CTO) business. Demand classes can be geographic sales locations, sales channels, customer priority, sensitivity to delivery dates, profitability and demand quantity. Supply classes can be degree of constraints and value of products. Availability is pre-allocated into *availability outlook* bucket based on the dimension described above, and is rolled-forward daily or weekly. The availability outlook is determined based on availability of components, finished goods, WIP (Work-In-Process), MPS (master production schedule), supplier commitment, and production capacity/flexibility. When customer orders arrive, the availability outlook is searched in various ways according to scheduling polices to determine the shipment (delivery) date, which is then promised to customers.

Customer *order scheduling* is the pull-side of availability management, and it reacts to customer orders and determines shipment dates for the orders. Customer orders arrive with various specifications such as product types, the demand classes, customer classes and due dates. The order scheduler then searches through the availability outlook database, and identifies the availability that meets the specifications. The scheduling can also be done by an ATP engine that uses certain algorithm to optimize the schedules considering various resources, policies and constraints. The scheduler then reserves specific availability against each order, and decrements the availability according to the purchase quantity of the order. The ship dates of orders are determined from the time buckets where the availability reserved, and they is promised to customers. However, if the availability data are not accurate, incorrect ship dates might be determined and promised to customers. Depending on the business environment, various rules and policies are applied in this order scheduling process. Examples include first-come-first-served policy, customer priority-based scheduling, and revenue (or profit)-based scheduling etc. In a constrained environment, certain ceiling can also be imposed to make sure the products are strategically allocated to various demand classes.

Order fulfillment is executing the shipment of the product at the time of promised ship date. Even if an order is scheduled with a specific promised ship date based on the availability outlook, the availability (ATP quantity) may not actually exist when the ship date comes. One reason for the inaccurate ship date is due to the capability of IT system that supports the availability management process. The order scheduling is done based on the availability outlook data in an IT system, which is typically refreshed periodically since it can be very expensive to update the database in real time and it can take substantial amount of time. The availability information kept in the IT system (system availability) is not always synchronized with the actual availability (physical availability). As the synchronization (refresh) frequency increases, the accuracy of promised ship date also increases; however, the resulting IT cost would also go up because high capacity of computer hardware and software may be required to be able to refresh the availability data in certain frequency. Due to the potentially inaccurate view of availability, unrealistic ship dates can be promised to customers. Therefore, for certain customer orders the necessary ATP quantities may not be available when the promised ship dates arrive, thus creating dissatisfied customers. The impact of IT on the fulfillment is discussed in detail in the later section. A key role for effective availability management process is to coordinate and balance the push-side and pull-side of ATP as well as IT resources so that customer service target is met while corresponding IT cost stays within budget.

SIMULATION OF SHIP DATE PROMISING

In this section, we describe the availability management simulation model that we develop to analyze the relationship between accuracy of promised ship date and IT costs. The model simultaneously simulates the three components of availability management process; generating availability outlook, scheduling customer orders and fulfilling the orders, as well as the effect of other dynamics such as customer shopping traffic, uncertainty of order size, customer preferences of product features, demand forecast, inventory policies, sourcing policies, supply planning policies, manufacturing lead time etc. The simulation model provides important statistical information on promised ship date, accuracy of the ship dates determination, scheduling delay, fulfillment rate as well as inventory level.

<u>Modeling of Availability Outlook</u>

Availability outlook (also called availability quantity) is modeled by multi-dimensional data array which represents various attributes of availability such as product type, demand class, supply class and planning period. The product type can be either finished goods or components depending on whether the business is MTO or CTO. As a simple example, for a process where there are two attributes of availability (product type and time period), the availability outlook is represented by 2-dimensional data array shown as cylinders in the Figure 1. The availability outlook is time-dependent; e.g., there is availability quantity for the current period (t=1), and there is availability quantity for future periods (t=2, 3, …) as more availability quantity is expected to be available through production or procurement in future dates. The availability time periods can be daily buckets or weekly buckets depending on business environment. For example, in the Figure 1, quantity 3 of component 1 is available in the current day, and 5 more are expected to be available a day after, and 10 more are expected be available for day 3 and so on. The availability outlook can be determined from demand forecast and supply contracts etc., but it can also be computed by push-side ATP optimization tool. The availability outlook is used in computing the ship date of customer requests and orders. The availability quantity changes as a result of many events in the business.

Simulation of Ship Date Promising

The Figure 1 shows an example of how the ship date calculation is simulated in this work. Customer orders or ATP requests arrive in certain stochastic interval, usually modeled as a Poisson process. Each order has one or more line items, and each line item has one or more quantities. The order quantities can be modeled with probability distribution functions, which can be derived based on historic data. The line items and quantities are determined as the order is generated in the order generation event (details described in the next section). For each line item, certain components are selected as the building blocks of the product using a distribution function representing customer preference of component features. For example, in the Figure 1, the line item #3 of the order # 231, requires components 1, 3 and 4, one unit each.

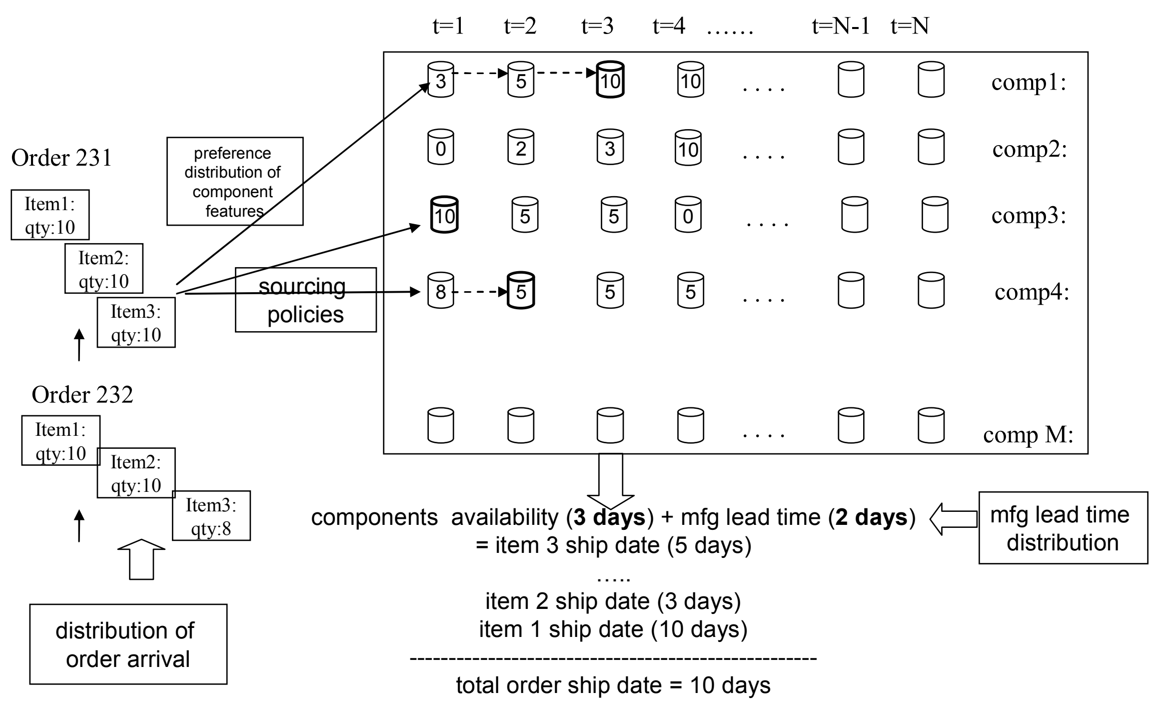

Figure 1. Simulation of Order Scheduling and Ship Date Calculation for As Early As Possible Orders

For the orders that are requested to be fulfilled as early as possible, the simulation model looks for specified quantity of a chosen component starting from the first time period to the latter time periods until the availability of all the quantity is identified. In this example, the time periods (buckets) are in days. For the component #1, the requested quantity of 10 is identified in the first 3 days; 3 in day 1 (t=1), 5 in day 2 (t=2), and 2 in day 3 (t=3). Therefore, for the line item#3, the required quantity of component 1 is available by the third day. A similar search is carried out for component #3, which is available on the first day, and for component #4, which is available by the second day. Therefore, the component availability of line item#3 of the order#231 is the 3rd day. In this example, let's assume that the availability calculated for the line item#1 is 8th day, and that of the line item#2 is 1st day. When all the components are available, the product is assembled or manufactured, which takes a certain amount of time. The manufacturing lead time can be a fixed number of days or it can be described with a distribution function. The lead time to ship date is then calculated by adding the manufacturing (assembly) lead time to the availability lead time. Assuming that the manufacturing lead time for this example is 2 days, the partial ship date for item#1 is 10th day, for item#2 is 3rd day, and for the item#3 is 5th day, if the customer is willing to receive partial shipments. And the total order ship date is 10th day from the date of order or request. Therefore, the promised ship date for the order #231 is simulated to be 10 days from the order date for this example. When this order is scheduled, availability quantities are reserved (e.g, the availability is decremented) for the order. Typically, for each order, availability is reserved from the latest possible availability bucket so that the availability in earlier time bucket can be used for generating favorable ship date for future orders. In this example as shown in the Figure 1, quantity of 10 for component 1 is reserved in t=3, and quantity of 10 for component 3 is reserved in t=3. However, for component 4, quantity of 5 is reserved for t=1, and another 5 is reserved t=2 instead of quantity 8 being reserved of for t=1 and 2 for t=2 because having availability of 3 at t=1 is more valuable than the availability of 3 at t=2 for scheduling and fulfilling future orders. Scheduling logic can vary based on the business rules and policies. Scheduling can also be carried out by a pull-side ATP optimization engine that optimizes order scheduling simultaneously considering inventory costs, backlog cost and customer service impact etc.

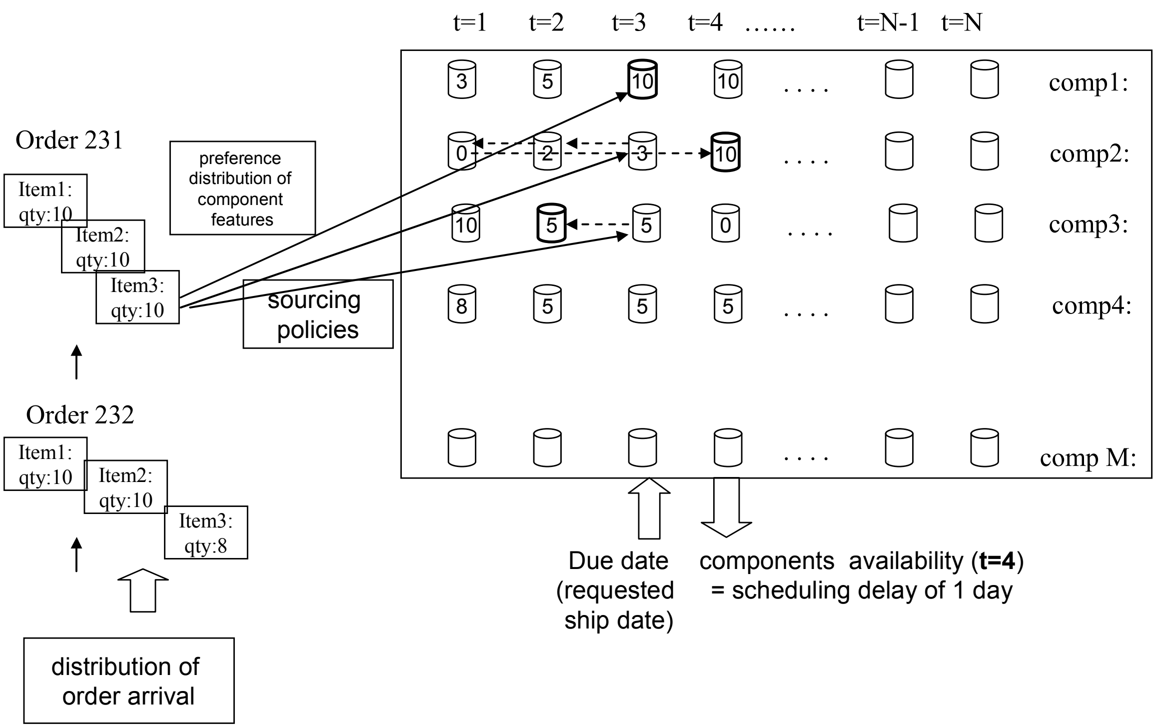

Figure 2. Simulation of Order Promising and Ship Date Calculation for Advance Orders

For the orders with advance due dates, the simulation model looks for specified quantity of a chosen component starting from the time period of due date (requested ship date), searches backward into the earlier time periods, and then forward to later time periods until the availability of all quantity is identified as shown in the Figure 2. For this example, the item 3 of the order #231 requires for the quantity of 10 of component #1, #2 and #3. However, in this case the order comes with requested ship date of t=3, say 3 days from the time of order. For component #1, the simulation model finds the availability of 10 on t=3, and reserves the availability. For component 2, it finds quantity of 3 on t=3, then it searches backward to find 2 more quantity on t=2 and then moves forward to find 5 more on t=4. But, in this case the simulation reserves availability quantity of 10 all on t=4 making availability quantity intact for t=2 and t=3 for future orders. For component 3, the simulation model finds availability of 5 on t=2 and t=3 each, and reserves them. In this case the overall availability date is t=4, a day after the due date. Therefore, the promised ship date for the order is simulated to be t=4, a day past the requested ship date.

Simulation of Event Generation

In this work, *availability outlook* changes as a result of four events; (1) demand event, (2) supply event (3) roll-forward event, and (4) data refresh event as shown in Figure 3. Each event changes the *availability outlook*; the demand event decrements the availability, the supply event increments the availability, the data refresh event refreshes the availability and the roll-forward event shifts the availability as explained in the next section. The data refresh event is the one that refreshes (synchronizes) system availability data. The events can be generated independently using probability distribution functions or fixed intervals. The model can be easily extended to include more events depending on the supply chain environment being modeled.

The demand event is the pull-side of availability management, and it includes order scheduling and fulfillment. The demand event is triggered when customer orders are generated, and it decrements the availability outlook (quantity) when it schedules customer orders. Customer orders are generated in certain stochastic interval, usually as a Poisson process. At the time of the order generation, each order is assigned with one or more attributes such as quantity, product type, demand class, supply class and due dates.

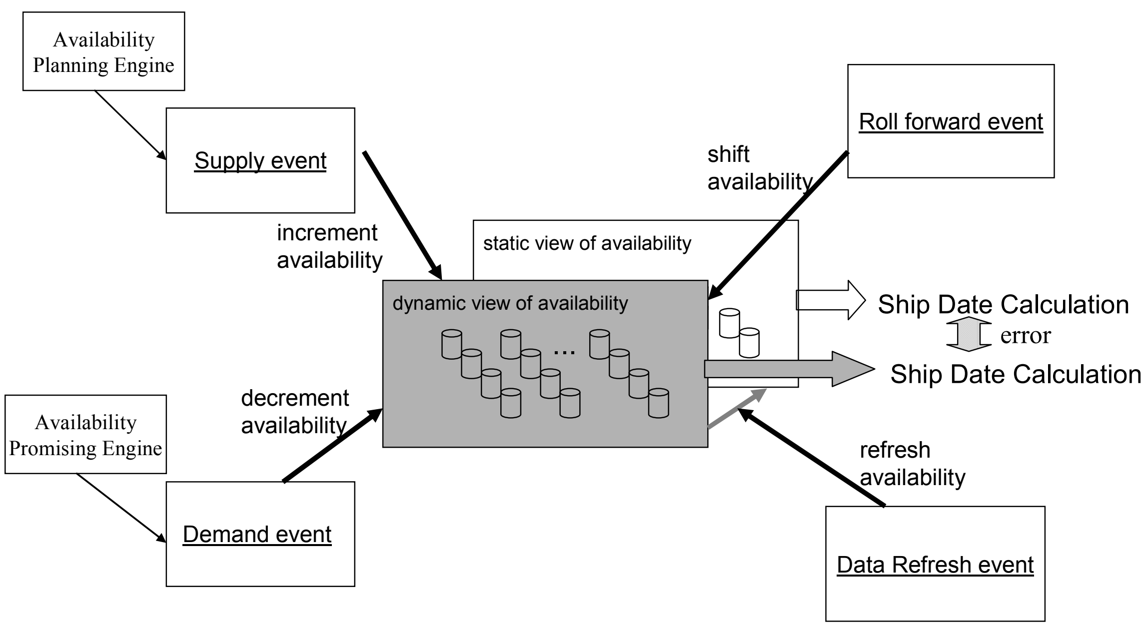

Figure 3. Multiple Events that Affect Availability

This assignment of attributes can be modeled with probability distribution functions based on historic sales data or expected business in the future. When an order is scheduled, specific availability quantities are searched in the availability outlook, which are then reserved for the order and are decremented from the availability outlook. The reservation (consumption) of specific availability can be decided by the various policies and rules, such the sourcing policy, scheduling polices and fulfillment policies. The reservation of availability outlook can also be determined by *availability promising engines* that were described earlier. An ATP engine can be connected to the simulation model and communicates the optimal ATP reservation quantities it computes to the simulation model.

The supply event is the push-side of availability management, and it generates availability through schedules of production and procurement of components. The supply event is triggered in certain interval, e.g., weekly or monthly, and it increments the *availability outlook*. As finished products or building block components are reserved when customer orders are scheduled and fulfilled, additional availability is added to the availability outlook through production or procurement. This activity, supply event, is planned in advance of expected demand, e.g., months, weeks or days before the availability are actually needed in order to accommodate lead time for production and procurement. As a result of the supply planning, the availability outlook is updated and replenished. The replenishment quantity is typically determined based on the forecast of customer demand. The frequency and size of the replenishment are also decided by various replenishment policies. The allocation of availability outlook can also be determined by availability planning engines, some of which have been described previously. These ATP engines can be connected to the simulation model and communicate the optimal ATP allocation to the simulation model.

As simulation clock moves from a time bucket to another, the availability of products or components that have not been consumed are carried forward to an earlier time bucket. For example, at the end of the first day, the availability quantity of 2nd day moves to the availability quantity of 1st day, and that of 3rd day becomes that of 2nd day etc. Also, the availability quantity that is not consumed on the 1st day stays on the same day, assuming it is non-perishable. The roll-forward event can be triggered in a fixed interval, e.g., daily or weekly, depending on the business environment.

There are two instances of availability outlook; one representing the availability quantity at real time (dynamic view of availability, or physical availability), and another representing availability recorded in the availability database (static view of availability, or system availability). The system availability is the one that is used for scheduling of customer orders, and it not always accurate. The system availability is synchronized with physical availability only periodically because it is expensive to have IT architecture and capacities that allow real time synchronization. This synchronization between physical availability and system availability is modeled in the data refresh event. For example, the static view of availability is refreshed in every few minutes, every hour, or even every few days.

The discrepancy between the physical availability (dynamic view of availability) and the system availability (static view of availability) causes inaccurate ship date calculation. In our simulation model, ship dates are computed using both dynamic and static view of the availability, as shown in the Figure 3, and the magnitude and frequencies of ship date inaccuracy are estimated. The accuracy of promised ship date is an important indication of customer service level. The data refresh event can be modeled as fixed interval event or randomly generated event described by a distribution function. The analysis on how the refresh rate impacts the ship date accuracy is described in the following section.

Figure 4 shows a simplified overview of availability simulation model we developed. Here, the rectangles represent various tasks (and events), circles represent availability outlook, and the arrows represent the movement of process artifact (customer orders in this case). Generation of orders (or on-line shopping) is modeled in the first rectangle on the left side of the Figure 4, and general availability of products, features and prices are also available for customers here. An order then proceeds to the next task where a specific product is configured from the availability of components. A ship date is also determined here in the availability check (shop) task, which accesses the IT system that contains availability outlook data. If the customer is satisfied with a ship date, an order moves to next step, the availability check (buy) task, and is submitted. A promised ship date is calculated again here using the availability outlook data and order scheduling policies. A submitted order goes through the order processing task in the back office and order fulfillment process, where the model simulates the availability being consumed. The tasks specified as rectangles in Figure 4 can have certain processing time. They can also require certain resources such as an IT server, a part of whose resource is tied up in processing orders.

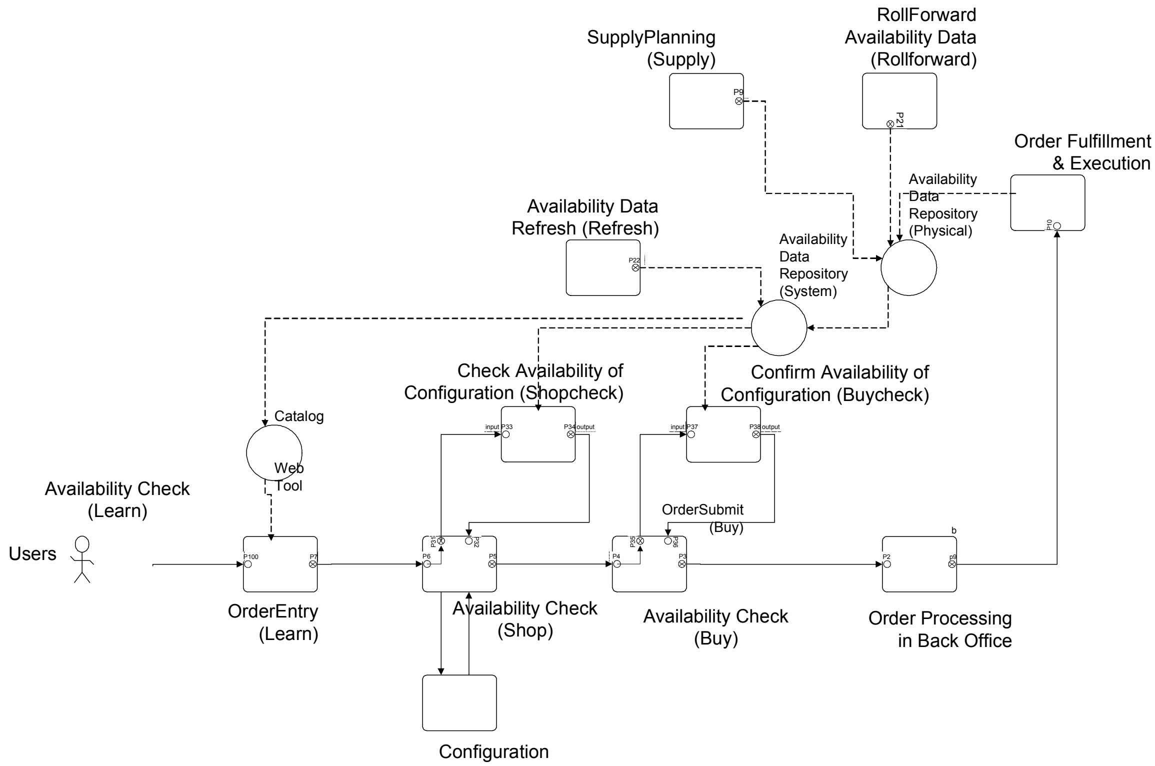

Figure 4. A Sample Availability Management Simulation Model

SIMULATION EXPERIMENTS AND RESULT

The analysis for the accuracy of promised ship date and availability refresh rate described here is based on an actual business case for an IBM's computer hardware business. For the business, ship dates are determined and promised to customers during the customers' shopping process at "web-speed". Customers make decisions on purchase based on the promised ship dates in addition to other criteria such as price and quality of goods. Once orders are placed, customers expect the products to be delivered on the promised dates. Often, keeping the promised ship date is more important than the promised ship date itself. Therefore, accuracy of promised ship date is very closely related to customer service.

In this business case, we used the availability simulation model to evaluate how the frequency of availability data refresh affects the accuracy of ship date information given to customers. The time bucket for availability outlook for this example is weekly; e.g, ship date is promised in weekly unit. Figure 5 shows a simulated ship date error profile for 3 months period for a product and for a demand class when the frequency of availability data refresh is once a day. The figure shows that there are quite a few occurrences of the ship date errors, whose magnitude are mostly 1 week. The simulation result shows that the magnitude of the ship date error increases to 2 weeks toward the end of the quarter.

Figure 6 compares ship date errors for four refresh frequencies, for customer orders arriving with three different demand classes for a specific business setting of the IBM hardware business. Table 1 also summarizes the simulation results. In average, the ship date error went down to 1.4% from 3.2% as the refresh frequency increases from once a day to four times a day. However, the ship date error does not decrease substantially as the refresh rate increases beyond 3 times a day. This indicates that it is not worthwhile to improve IT system to refresh the availability more than 3 times a day for this particular business setting.

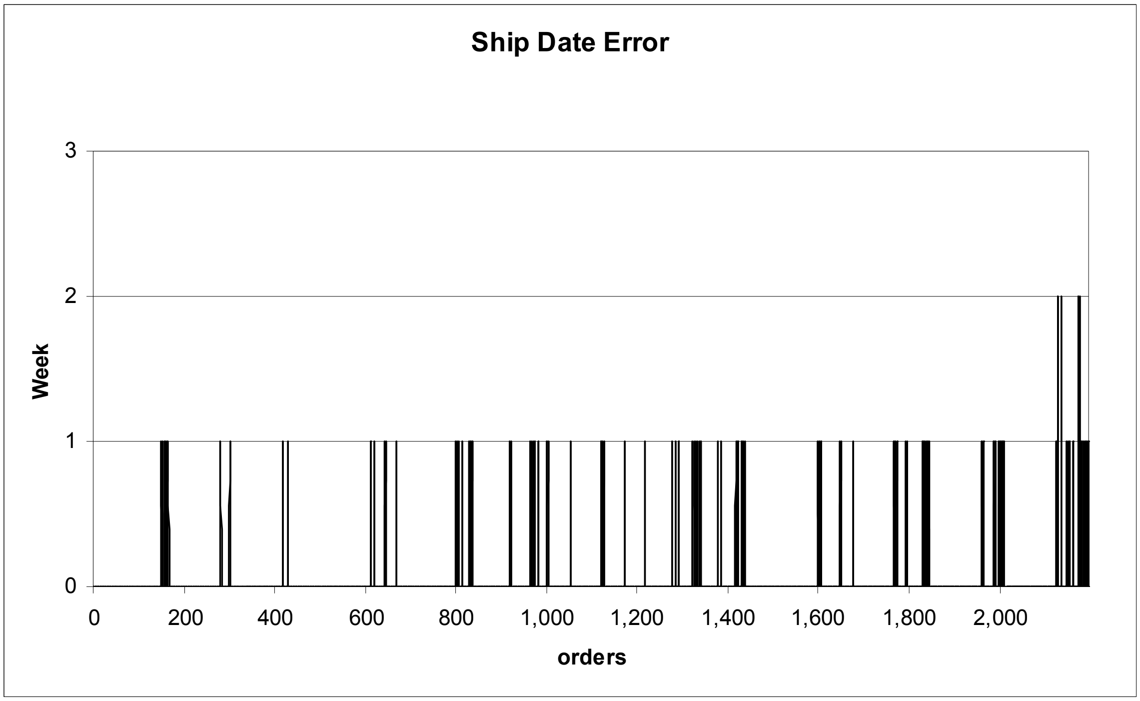

Figure 5. Ship Date Error for DM class 1 with Once a Day Refresh

Figure 7 shows a trade-off between ship date error and IT Costs for refreshing the availability outlook in an IT system. As it is shown, as the refresh rate increases from once a day to four times a day, the IT costs increase substantially from $1.2 million to $2.3 million due to required computer hardware and software capacities. Although the general relationship between ship date error and IT Costs are not a surprise, the quantification of the trade-off is the key information that business leaders need to have to make sound business decision on the availability management process. The right decision is the balancing the ship date error (customer service) and IT costs that are reasonable for a business at the time of analysis. The simulation results from this case study clearly show that IT system that refreshes the availability influences the accuracy of ship date calculation when customer orders are processed. Simulation is a useful tool for determining the trade-off between IT costs and supply chain performance. For this particular business environment, once a day refresh was decided as a reasonable frequency.

The simulation models described above for the cases studies were all validated by examining the simulation outputs of the AS-IS cases with actual data from the business. After the validation of the AS-IS cases, simulation models of TO-BE cases were used for analysis.

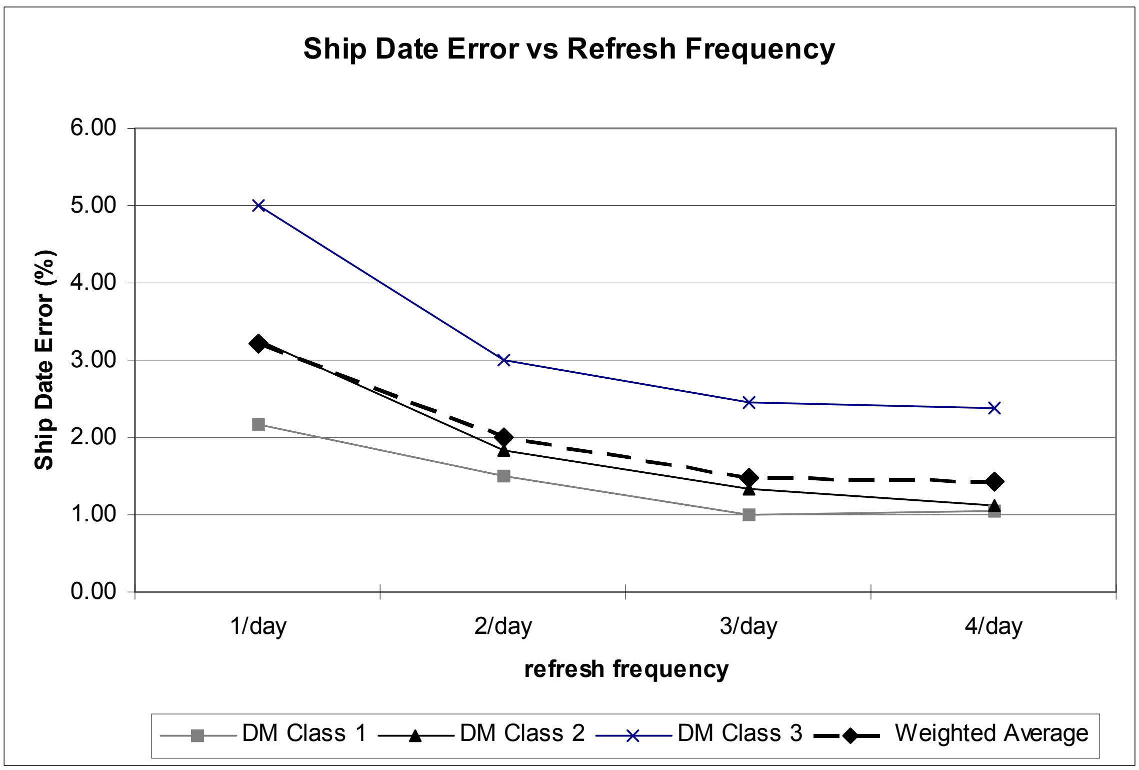

Figure 6. Ship Date Error for 3 Various Refresh Frequencies

Table 1. Ship Date Error Summary for Various Refresh Frequencies

	Ship Date Error			
Refresh Frequency	**Once a day**	**Twice a day**	**3 Times a day**	**4 Times a day**
DM Class 1	2.16%	1.51%	1.01%	1.04%
DM Class 2	3.25%	1.84%	1.33%	1.13%
DM Class 3	5.00%	3.00%	2.46%	2.39%
Weighted Average	**3.22%**	**2.00%**	**1.49%**	**1.42%**

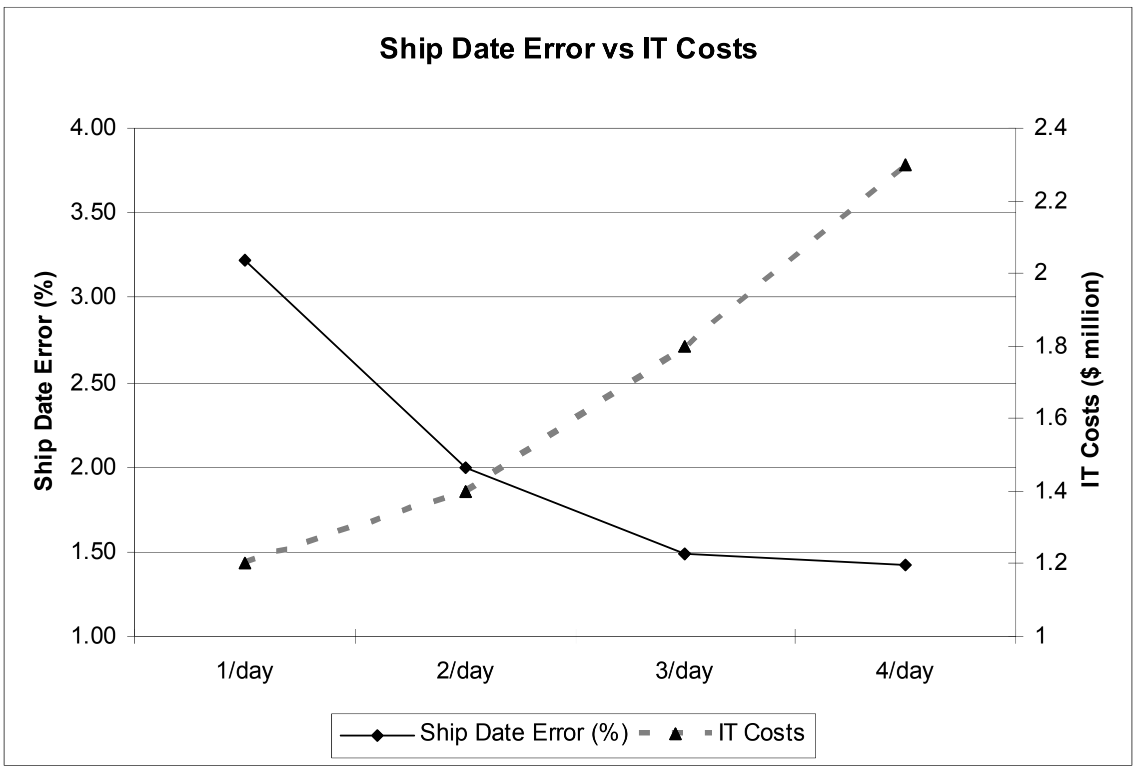

Figure 7. Trade-off between Ship Date Error and IT Costs

CONCLUSION

We develop a simulation model to study how refresh frequency of availability data in corporate IT system impacts accuracy of the ship date that is promised to customer. Our study quantifies accuracy of promised ship date for various refresh frequencies of availability data in a supply chain setting. As the refresh frequency of availability data increases, the accuracy of promised ship date improves too; however, a high refresh rate of the data can require expensive IT system and is not practical for suppliers. Therefore, it is important to appropriately balance customer services resulting from the accuracy of promised ship date and IT costs resulting from IT system of computer hardware and software so that corporate goal for a customer service level within reasonable IT expenditure is met. Simulation has been proven to be a useful tool for the analysis. This work has helped business leaders in making informed decisions of balancing customer services and costs.

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