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SUPPLY CHAIN MANAGEMENT TRADEOFFS ANALYSIS

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ABSTRACT

Supply chain management involves understanding complex interactions between many factors and using the understanding to achieve balance between conflicting objectives. Simulation is a very useful technique to evaluate the impact of changes in factors such as inventory control and business process parameters. This paper describes a simulation based study for analyzing the tradeoffs among service level, inventory and lead times for a large logistics supply chain. The study highlights the use of simulation in understanding seemingly non-intuitive results and guiding the effort for performance improvement.

1 INTRODUCTION

Supply chain management involves dealing with a whole range of control parameters and a multitude of key performance indicators. SCOR model (Supply Chain Council 2003) lists a number of performance indicators to track the performance of a supply chain. These include measures such as: delivery performance, order-fulfillment lead time, and supply chain management costs. Effective management of supply chain requires understanding how high level business objectives translate to selected performance metrics. The supply chain manager then has to focus on improving the performance of these selected metrics.

Typically, management of supply chain requires improving performance of conflicting objectives. The push is to reduce inventory while at the same time improving the service levels. Generally speaking, high service levels can be achieved using high inventories. The manager has to find a balance between these two conflicting objectives. The cost of potential lost sales has to be balanced with cost of carrying large amounts of inventory. Similarly, there are other conflicting objectives that need to be balanced such as maintaining high service levels while keeping the transportation costs low.

Ideally, an optimum operating point should be determined that balances multiple conflicting objectives. A supply chain can be visualized as a large network. Network optimization problems have been found to be NP-optimal, that is, they cannot be solved optimally within a reasonable amount of time. This is the case for supply chains providing a large variety of parts which move across multiple suppliers and distribution points.

Discrete event simulation provides a viable alternative to determine operating points that achieve the desired balance between conflicting objectives. It can be iteratively used to understand the impact of varying multiple control parameters and to identify the desired operating points.

This paper reports on a study for understanding the impact of control parameters for a large logistics supply chain. The understanding is used to identify the potential operating ranges that balance the desired performance objectives. Section 2 briefly describes the supply chain that was the subject of this study and the key performance measures of interest. The parameters that were selected for sensitivity analyses are discussed in section 3. Section 4 presents the discrete event simulation based methodology used. The experiments and results for developing insights into the interrelationship among major factors is provided in section 5. Section 6 describes the experiments for understanding the trade-offs and identifying the operating region that balances the objectives. Section 7 concludes the paper with potential future steps.

2 BACKGROUND

The subject of this study is a large logistics supply chain with customers located in all 50 states of USA and 27 countries around the world. The distribution operations involve over 500 sites located close to, and partnered with, customers and suppliers. It maintains two main channels for meeting customer demand. A majority of parts are maintained in inventory at its own distribution centers and supplied to customers from these centers on demand. The second channel is based on vendor-managed inventories with the vendor shipping the products directly to customers based on the orders communicated to them through the organization. Figure 1 shows a conceptual representation of the supply chain.

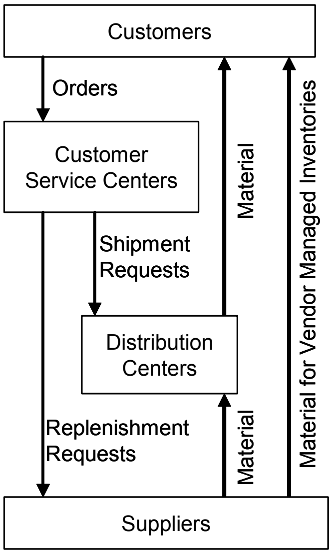

Figure 1. Conceptual Representation of the Logistics Supply Chain

The organization is focused on following key performance indicators (KPIs):

1. Service levels
2. Inventory investment
3. Order to delivery lead time

More details on the organization and scope of the effort are available in Jain et al. (2001a) and (2001 b).

The original simulation model of this supply chain was built a few years ago to estimate the potential benefits of a large project involving business process improvements and implementation of ERP, Supply Chain Planning and procurement software. The simulation model has been continually updated to reflect the improved understanding and estimates of process parameters as the project has progressed through its implementation.

3 CONTROL PARAMETERS

The overall study included sensitivity analysis on a number of potential control parameters. This paper reports on the experiments carried out to understand the impact of the administrative business process time for processing of customer orders and using the understanding to identify the operating range in conjunction with results from earlier similar studies.

The administrative business process time (ABPT) is a component of the customer order to delivery process. It starts from the time a customer order arrives at the customer service center and ends when a shipment order is received at a distribution center. It is followed by the execution process time (EPT) that starts from the time the shipment order is received at a distribution center to the time the shipment is delivered to the customer. Thus,

Total customer order to delivery time = ABPT +EPT.

The ABPT is comprised of the following components: order processing time, time for waiting for arrival of inventory if enough inventory is not available, and the time for transmission of shipment order from customer service center to the assigned distribution center. The order processing time is the activity of ensuring the order is valid and checking the availability of inventory to meet the order. Orders and requests are managed several different ways:

- If enough inventory is available the order is transmitted to the distribution center that is nearest to the customer and has enough inventory.
- If enough inventory is not available, the order is placed on the backorder list and a request for replenishment is sent to the planning department.
- If the part is under a standing supplier contract, the planning department generates a purchase order and sends it to the supplier.
- If no standing contract is available, a request is sent to the procurement department to establish a new contract.

A purchase order is generated once the contract is established. Once the material is received from the supplier at the distribution center, a material receipt notification is sent and, in turn, a shipment order is transmitted to the distribution center for sending the ordered quantity to the customer. The ABPT time thus can range from under a day in case sufficient inventory is available to months at the other extreme when a new contract has to be established for acquiring the material. Most of the parts that receive regular demands are on standing long term contracts. Only rarely requested parts may require establishment of new contracts.

It should be clear from the above discussion that ABPT is really a result of several decisions that impact the components comprising the measured time as shown in Figure 2. Two of the components, the order processing time and shipment order transmission time, were already in the range of few hours and did not have much variation. The following parameters from the planning and procurement activities were identified as those that would potentially impact the ABPT:

1. Manual processing time for purchase orders: Some of the purchase orders required manual modification and approvals that added to lead time.
2. Cancellation rate of purchase orders: Some of the purchase orders had to be cancelled due to several factors including, cancellation of customer order,

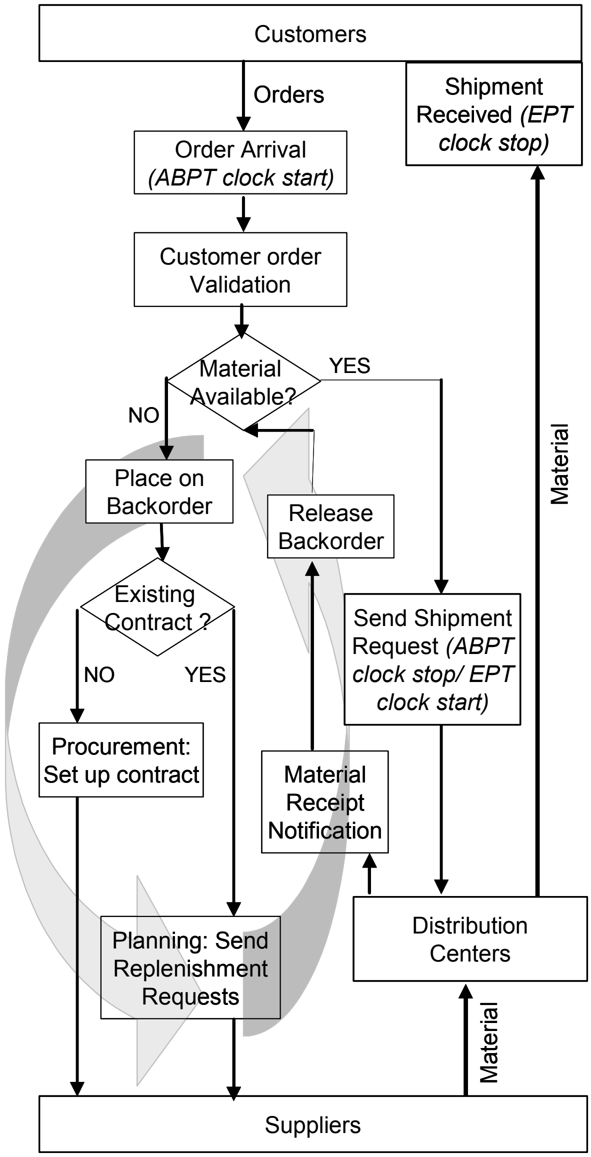

Figure 2. Customer Order to Delivery Process Flow with Definition of ABPT

combining multiple purchase orders into one order, and errors. Such orders took up valuable process time thus delaying other orders and further time from personnel for tracking and cancellation.

3. Percentage of purchase orders processed through automation: Higher the percentage of orders that can processed automatically, lower the lead time.
4. Time for corrections of technical specifications: Some of the parts that had not been ordered for a long time would have outdated technical specifications and drawings. These were sent to engineering department for corrections.
5. Procurement time for large purchases: Large purchases required lot of personnel time and thus added to the lead time.
6. Maximum procurement time for medium purchases: Medium size purchases comprised a large percentage of procurements and thus influenced the lead time.

The study had to first identify the parameters from the above list that had a large influence on the ABPT and can provide an easy way to control the ABPT values. The study hence was executed in two stages:

1. The first stage experiments focused on developing insights into relationships. First, control parameters were identified for the administrative business process time (ABPT) for order processing. Then, the control parameters were used to vary the ABPT over desired range and understand its impact on key performance indicators.
2. The second stage identified the operating range based on the desired balance between conflicting objectives.

4 METHODOLOGY

The study used a methodology based on discrete event simulation. A model of the customer order to delivery process and the supporting activities in the supply chain was developed using the software ARENA (Bapat and Sturrock 2003). The business processes included in the model were selected based on their relevance to the customer order to delivery process and included:

1. Order Fulfillment
2. Procurement
3. Demand and Supply Planning

The organization supplies millions of part numbers to its customers. A representative set of products from the wide population was selected for use in the model. The products were selected to provide a representation of the cross-section of the product population across all major business units. Please see Jain et al. (2001a) for more details on the development of the simulation model.

The study used experimentation with the developed simulation model for both the stages. The model was used in first stage to develop insights into the relationships among major factors. It was used to determine the control parameters that have the most impact on the measured business process time. Then the model was used to vary the values of the identified control parameters to generate a range of values of the measured business process time and associated performance. In stage II, further experiments were carried out to vary other related control parameters to map out the performance space and to identify the desired operating region.

A designed experiment with multiple factors at multiple levels was not used as the interest was to understand the mechanics of how change in value of identified parameters propagates to change in KPIs. The purpose of the study was primarily developing insights into the mechanics and relationships and using the insights for tradeoffs. In future, a designed experiment may be considered for setting multiple control parameter values.

The supply chain decision makers from the organization focused on in this study had specific questions regarding supply chain performance, and hence specific scenarios of input variable combinations were evaluated. Project timelines, as well as, constraints associated with the lengthy run time of this enterprise supply chain model prevented a more rigorous design of experiments approach or a more isolated analysis of specific factors of interest.

5 USING SIMULATION TO DEVELOP INSIGHTS

The results of the experiments in the first stage are discussed in this section.

5.1 Determining Control Lever for ABPT

This step involved varying the values of the six factors, listed in section 3, one at a time to determine their influence on the ABPT. The objective was to identify a control lever for ABPT that can be use in turn to vary the values of ABPT and understand the impact on the key performance indicators. The experiments identified that factor six, maximum procurement time for medium size purchases, had a large influence on the ABPT. The relationship is almost linear and is show in Figure 3. Please note that the base case refers to a designated To-Be performance level that was used at the early stages of the project to establish the business case for the project.

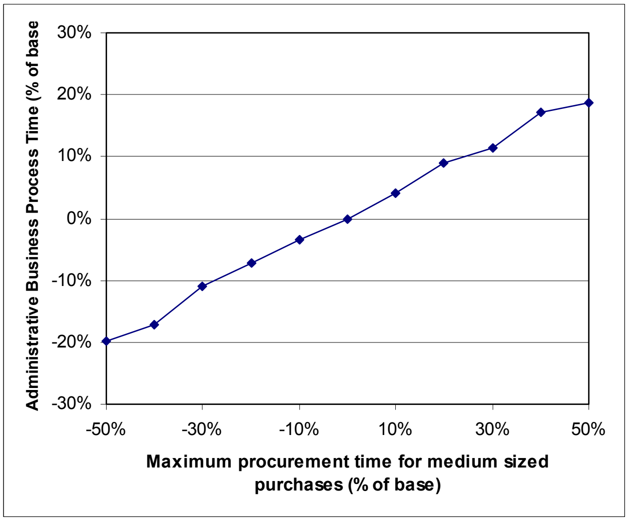

Figure 3: Relationship between Maximum Procurement Time for Medium Sized Purchases and ABPT

The large influence of the single factor on ABPT was understandable since this factor affected the a large percentage of orders that had to go through procurement. Other factors in the list affected smaller fractions of the purchase order. The single factor was selected as the control lever to realize the variation in administrative business process time for experiments in the next step discussed below.

5.2 Impact of ABPT Changes

In this step, the experiments results were analyzed to understand the relationship between the administrative business process time (ABPT) and the key performance indicators (KPI) of interest. While the service level KPI showed an intuitive trend of decreasing with the increase in ABPT as shown in Figure 4, the inventory KPI showed a *non-intuitive* trend of decreasing with the same change as shown in Figure 5.

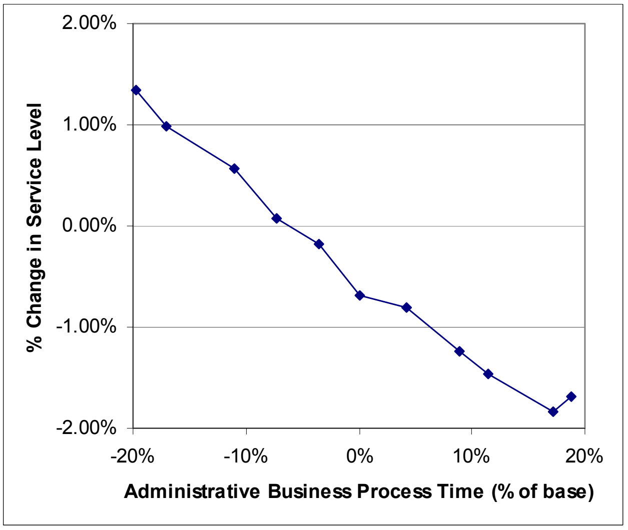

Figure 4: Relationship between ABPT and Service Level meeting Intuitive Expectations

The service level deteriorates as the ABPT increases. This is expected since as the ABPT increases, the delivery to customers are delayed. More importantly, delayed deliveries to customers results in delayed placement of replenishment orders in turn resulting in delayed arrival of inventories. This leads to deterioration in service level.

The relationship between ABPT and inventory level appears to be *non-intuitive* at first glance. A poorer performance on one aspect, that is, longer ABPT, is leading to a better performance on the inventory KPI! However, on further analyzing in the relationships the result is quite understandable, a hint of which is provided in the explanation of the intuitive results presented in Figure 4. Essentially, longer ABPT leads to delayed deliveries and hence delayed replenishment orders. This leads to inventories arriving later than in the base case while the order are arriving at the same time.

As a result, material is staying in inventory for shorter time and hence the lower inventory levels. Please note that the percentage change in inventory levels on the Y-axis in Figure 5 is defined with respect to As-Is model.

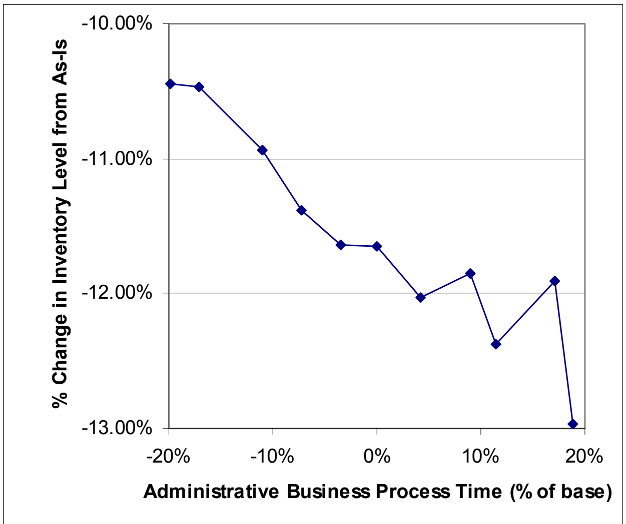

Figure 5: Non-Intuitive Relationship between ABPT and Inventory Level

As pointed out earlier, the supply chain management involves dealing with conflicting objectives. The reduction in inventory level is coming at the cost of reduction in service level. The decision of whether such a tradeoff is acceptable depends on the cost of the inventory, cost of lost sales and on their perceived value by the supply chain managers. It should also be noted that there are several other aspects that need to be considered before making a decision. For example, a reduction in ABPT may lead to reduced personnel requirements and free up manpower for use elsewhere in the organization. Also, the above results are based on changes in one parameter only. If the base service level is in acceptable range, the benefit of reduced ABPT can be translated into reduced inventories by adjusting the inventory control parameters. Such balancing of objectives is the subject of the next sub-section.

6 ACHIEVING BALANCE

This stage focused on balancing KPIs of interest within the desired operating range. The decision makers for the subject organization had indicated the desire to maintain the service levels in the same range as in the As-Is model while reducing the costs of operation through business process improvements and implementation of advanced software solutions.

The identified business process improvements were anticipated to decrease the ABPT. As presented in preceding sub-section, this would result in increased service levels but at the cost of increased inventories. To achieve the goal of reduced cost with the same service levels, the next step was to translate the benefits of reduced ABPT into reduced inventory levels. The basic idea is from the classical inventory theory – a shorter replenishment lead time should lead to lower inventory requirement for covering the lead time demand. This can be achieved by reducing the reorder points (ROP) for the inventories maintained in the distribution centers.

A reduction in reorder points was implemented by using a reorder reduction factor across all the part inventory parameters. The subject organization supplies millions of part numbers, and as a first step an across the board reduction in reorder points was evaluated. This was done with the motivation of ease of implementation of the reduction. The reorder reduction factor is a simple fractional multiplier used with each of the defined reorder points, a smaller value of reduction factor indicates a lower reorder point, i.e., a larger reduction in inventories.

The balancing of service level was done by changing the reorder reduction factor corresponding to range of ABPT identified in stage I experiments. The change in reorder points not only changes the inventory but also the ABPT since one of its constituent is based on the availability of inventory to meet incoming demand. The result is effectively a reduction in the range of ABPT variation and maintenance of service level within the desired range as shown in Figure 6.

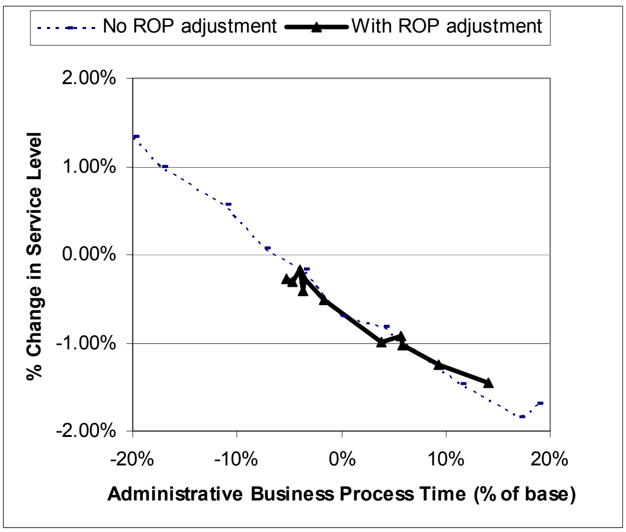

Figure 6: Holding the Service Level at Acceptable Value with Reorder Point Adjustments

Figure 6 shows that with ROP adjustments the service levels are held close to the specified value. The earlier change in service level with ABPT from stage I experiments is shown for reference and is identified as “No ROP adjustment”. The control parameter for ABPT is still varied through the same range as for stage I experiments. However, ROP reductions are used to avoid the inventory build up caused by the previous ABPT reductions in -10% to -20% range. A reduction in ROP results in replenishment orders to be placed later than earlier case and thus inventory arrivals are delayed resulting in lower service levels and holding the ABPT closer to the base value.

The use of ROP adjustments allows trading off the gains in service levels and ABPT reductions against inventory gains as shown in Figure 7. The lower ROP values lead to lower inventory levels and thus reduce the cost of operations. The experiments thus helped identify the mechanism for translating the ABPT reductions through process improvement and software implementations to inventory reductions.

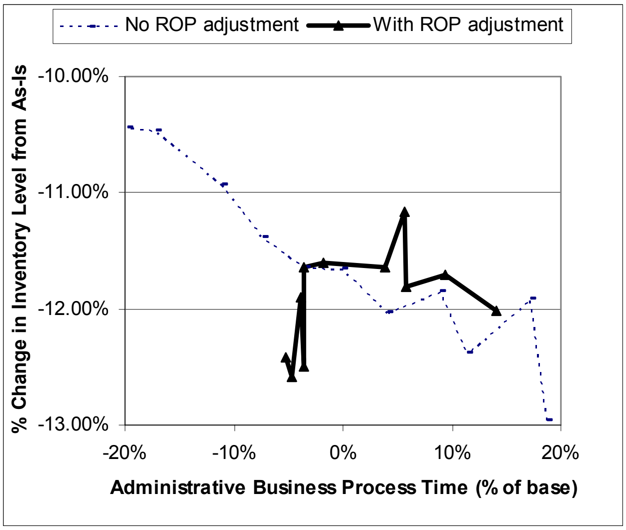

Figure 7: Reduction in Inventory Level Achieved by Trading Off Service Level and ABPT Gains

The results also point to the desired operating region for this supply chain as shown in Figures 6 and 7. The desired operating region allows maintaining the service level close to its existing value (change near 0%) while bringing the inventory down (between 12% to 13%). A higher value of service level (up to +1%) could have been achieved but at a cost of higher inventory (reduction between 10-11% instead of 12-13%). A lower value of inventory could have been achieved (reduction of up to 13%) but at the cost of lower service level (up to -2%). The identified region not only provides a balance between the two extremes, it improves on it through judicious use of other control parameters.

7 CONCLUSION

This paper presented a discrete event simulation based study for tradeoffs analysis of a logistics supply chain operation. Simulation modeling was used to identify control parameters that affected the administrative business process time (ABPT) in customer order processing. The control parameters were used to understand the impact of ABPT on key performance indicators. This understanding of the behavior was instrumental in identifying that reorder points (ROP) can be used to trade-off the gains in service level and ABPT against inventory levels. Targeted experiments helped identify an operating region that balanced the service level goals with desired inventory reductions.

The mechanism used for ROP reduction was the use of a fractional multiplier across all parts. This method offers ease of implementation for the large number of parts handled by the subject organization. Recommendations for future work suggest identifying customized ROP adjustments based on part classifications for targeted increase in service levels for important customers and targeted reduction in inventories of expensive parts. A designed experiment to determine the settings across multiple control parameters should also be carried out.

The case study described in this paper demonstrates the applicability of simulation to improving the supply chain performance. The effort used simulation to gain insights into the interrelationship among major factors and used these insights to identify the operating region that aligns the supply chain performance with the strategic objectives of the organization.

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