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ANALYZING THE SUPPLY CHAIN FOR A LARGE LOGISTICS OPERATION USING SIMULATION

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ABSTRACT

This paper presents a case study of using simulation for analyzing the impact of proposed changes in the supply chain processes for a large logistics operation. The major changes explored include business process changes, and use of new supply chain software. The results of the analysis indicate that the changes in forecast accuracy provide much larger savings compared to process automation changes. A number of insights are drawn from the results of the analyses.

1 INTRODUCTION

The implementation of new processes and supply chain software can help tremendously improve the performance of a supply chain. However, it is a large undertaking for an organization requiring large budget expenditures and large commitment of time and resources. The decision to implement new processes and software needs to be carefully evaluated to ensure the return on investments of time and money.

The implementation of new processes and software impacts every aspect of an organization. The organization fundamentally changes through such implementations. The changes, hence, have to be evaluated with methodologies that provide a high degree of confidence in the results. At the same time the methodology should allow high degree of flexibility in terms of level of detail included. Simulation is a methodology that meets these requirements. The issue of evaluating benefits of Enterprise Resource Planning (ERP) systems implementation has received some attention. Richie-Dunham et al. (2000) describe the development of a systems dynamics based educational tool for evaluating the benefits of ERP implementation and use of Balanced Scorecard Framework. A discrete event simulation based approach for evaluating supply chain software allows more flexibility than the systems dynamics based approach. It allows modeling critical processes in detail together with the option of adding more detail as the project moves from high level business case analysis to design phase.

Evaluation of impact of new processes and supply chain software requires modeling of all major aspects of a supply chain. A virtual supply chain needs to be developed in the computer similar to the virtual factory proposed by Jain et al. (1998) that includes integrated modeling of material, business and communication flows. The performance of the supply chain is the result of interactions of material, business and communication flows in the organizations comprising the supply chain. For example, the customer order to delivery lead time is impacted by the communication processes involved in transmission of order from the customer to the logistics organization, the business processes in the logistics organization for order processing, and the material flow comprising of pick and ship activity at the warehouse and the transportation to the customer.

This paper describes the use of discrete event simulation for evaluating the impact of new business processes and supply chain software. The approach uses integrated modeling of material, business processes, and communication flows to capture all aspects of the proposed changes. Section 2 provides a brief background of the case and section 3 defines the objective of the study. The approach is described in section 4 with emphasis on the major features and aspects of the To-Be processes and new supply chain software included in the simulation model. Section 5 presents the results of the basic As-Is and To-Be model comparison and additional relevant experiments. The last section draws insights from the results and concludes the paper.

2 BACKGROUND

The subject of this study is a large logistics operation that supplies a range of products to a customer base in all 50 states and 27 countries around the world. It has 500 sites, some located close to or partnered with its customers and suppliers. The range of products include machinery, equipment, electronics, clothing, medical and food items, and include service parts for machinery and equipment that have been in operation for a number of years. The organization uses two major channels, supplying the products to customers either through its own distribution centers or through partner vendors.

The organization's supply chain systems and processes were established a few decades ago. Most of the legacy software applications are in-house developments. The organization has embarked on an effort to install processes and systems that will bring its systems in the same class as best industry practices.

3 OBJECTIVE

The objective of the study was to support the business case for the implementation of new processes and supply chain software. The new processes included those that execute or support the operation of the supply chain. The new supply chain software included:

1. an enterprise resource planning (ERP) package
2. an advanced planning and scheduling (APS) package
3. a specialized procurement package

The results of the study were required to determine the impact of the new processes and software on the performance of the supply chain. The impact was to be quantified using selected key performance indicators including, order to delivery lead times, service levels and inventory.

4 APPROACH

The overall approach was to quantify the impact of new processes and systems using a comparison of As-Is and To-Be simulation models. Commensurate with the objective of a high level business case analysis, the models were developed with a high level of abstraction. The following major business processes are included in the simulation models:

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

For each process, major activities in the process flow have been included. Jain et al. (2001) discuss the design and the abstraction level of the model used in this study.

To capture the impact of the To-Be process and the new supply chain software, major features and aspects with an impact on the key performance indicators are included in the To-Be model. These features are described below.

4.1 Order Fulfillment

4.1.1 Near Real Time Processing for Customer Orders

The infusion of new information technology capabilities on the timing of order processing in the Order Fulfillment Processes will produce a relevant impact on the cycle time of these transactions. In the existing system, orders are not acted upon immediately when entering the system. Rather, these orders wait in a queue until the queue is emptied with one large "batch run." This batch run currently occurs only a few times per day, meaning that orders can wait for up to half a day before processing. Additionally, because of the large volume of orders that has accumulated in the queue, the time needed to electronically process these orders can be several additional hours. It is estimated that the technology and processes of the To-Be Process will decrease the time each order must wait, and that the orders will be processed in near real time.

4.1.2 Near Real Time Transmission of Orders from Customer Interaction Centers to Distribution Center

The current process requires several hours for transmission of shipment requests to Distribution Centers based on timing of the batch cycles of relevant systems. It is estimated that with the new systems in place this transmission will take place in near real time eliminating any delays due to non-synchronization of batch cycles.

4.2 Planning

4.2.1 Forecast Accuracy for Replenishment Part Numbers

Several key aspects of the To-Be design are expected to have a positive effect on forecast error. These enhancements include increased collaboration with customers, SKU-based and hierarchical forecasting, the implementation of a formal process to measure and improve accuracy, and developing a "one number" forecast that enjoys organizational buy-in. It is estimated that a minimum forecast accuracy of 75% will be achieved with the major changes in forecasting process in the To-Be scenario.

4.2.2 Inventory Management for Slow Moving Service Parts

The slow moving service parts make up almost half the current inventory owned by the organization. With infrequent small demands these part numbers are hard to forecast and are administered on a separate inventory control policy. Input from key subject matter experts was used to group these part numbers in sub-categories with targeted process and policy changes. These included:

- Identifying the more active service parts and using a forecast to drive their inventory management.
- Use of customer collaboration to improve the quality of forecast.
- Modification of parameters of inventory control policy for the service parts.

4.2.3 Timeliness of Information Processing for Recommended Buys

The implementation of closer to real time information processing by the systems of the To-Be Design will change the timeliness of replenishing the stock of organization-managed inventory parts. In the current system, if a product's reorder point has been reached, a replenishment request is automatically generated. However, the IT systems that process these replenishment requests actually process orders only a few times per week. Thus, a lag can exist between when the reorder point is reached, and when an order to obtain more product is actually processed.

With the To-Be process it is estimated that these replenishment requests will be processed by the new systems at least daily.

4.2.4 Reduced Incidences of Replenishment Request Cancellation

Better asset visibility and more accurate inventory accounting with the To-Be system implementation will lead to reduction in replenishment request cancellations and their regenerations.

4.2.5 Faster Time for Processing of Replenishment Requests

The To-Be processes and systems will incorporate features such as better filtering of replenishment requests before the manual review by managers. Such changes will reduce the workload on managers and allow faster processing.

4.3 Procurement

4.3.1 Reduced Lead Times

The more efficient To-Be process, automated solutions and the partnerships with suppliers will all contribute to reductions in lead times.

4.3.2 Reduced Technical Rework Loops with Data Currency and Accuracy

The integrated database of new supply chain software will improve data currency and accuracy, and thus reduce the occurrence and lead time for technical rework loops.

The changes in all core processes above lead to reductions in business process lead times. The impact of these reductions translates into reduced re-order points since inventory is required to cover the demand for a shorter time frame until the replenishment arrives. Combined with improved forecast accuracy, the reduction in re-order points aim for substantial reductions in inventories.

4.4 Simulation Run Parameters

The following specifics were used for simulation run parameters and control:

- Major inputs – demand volume and profiles, business process times at the customer interaction centers, supplier lead times, distribution center lead times, etc.
- Multiple random number streams for statistical distributions for modeling variabilities in all of the major inputs
- As a variance reduction technique, unique common random number streams are used for major factors with variation
- Key experimental parameters – business process times, process flow branching percentages, and forecast accuracy.
- Simulation horizon – 3 years
- The simulation is initialized with the net inventory position for each item at the beginning
- A warm-up period of one year is used to allow accurate capture of slow moving service parts and to fill the replenishment pipeline before statistics are captured.
- Run times – 70-90 minutes per run on a 1GHz workstation

5 RESULTS AND DISCUSSION

5.1 As-Is and To-Be Comparison

Table 1 presents the change in the value of key performance indicators (KPIs) captured from As-Is and To-Be simulation models. These percentages quantify the impact of the proposed To-Be process and the new supply chain software.

Table 1: %Change in Key Performance Indicators from the As-Is to To-Be Simulation Models

Key Performance Indicator	% Change
Service Level	-0.3%
Inventory Turns	18.7%
Inventory Level (in Units)	-13.1%
Order to delivery lead time	-10.9%
Distribution Center Operation Costs	-4.37%

The results show substantial improvements in KPIs for inventory and order to delivery lead times while keeping the service level about the same. The 0.3% difference in the service level is considered insignificant given the randomness in the simulation model. The service level is considered as holding steady between the As-Is and To-Be models. The inventories go down in quantity due to better forecasting and due to reduced replenishments as a result of reduction in lead times. The order to delivery lead time reductions are achieved due to reductions in various activity times estimated along the customer order to delivery process. The reduction in inventory results in a reduction in storage costs. This in turn reduces the distribution center operation costs.

A substantial reduction in inventory costs has been estimated above with the implementation of To-Be processes and systems. The study suggested that the direction for further reduction in inventories is through reduced lead times. While the To-Be processes lead to reductions in organization's own business process times, there are large vendor delivery lead times that contribute to the requirement of keeping large inventories. The vendor delivery lead times can be targeted for further reductions in DLA inventories. Another major target area is reduction in variabilities in lead times that contribute to requirements for high safety level quantities. More predictable lead times for replenishments and order deliveries will allow better synchronization of demands and replenishment and thus further reductions in inventories.

5.2 Forecast Quality

The forecast quality is defined as the minimum agreement between the forecast and demand. A 75% forecast accuracy means that the forecast value is within +/-25% of the demand for the period.

5.2.1 Scenario Description

The forecast accuracy is expected to improve in the To-Be solution for a variety of reasons, including increased collaboration with customers, the implementation of improved forecasting algorithms and statistical process controls, more accurate and timely data, and improved asset visibility across the network. This experiment tests the sensitivity of the KPIs to changes in forecast accuracy of fast moving parts. The forecast accuracy of small fraction of slow moving service parts that are "forecastable" in the To-Be model is maintained at a lower value.

The baseline To-Be model discussed in previous section is based on the most likely value of forecast accuracy of 75%. The other values tested in this scenario are 30%, 60% and 80% to show the range of possible outcomes.

5.2.2 Results and Analysis

The results of the runs with the two alternate scenarios for forecast accuracy together with that of the baseline To-Be scenario are presented in Table 2 in terms of percentage improvement in KPIs as compared to the As-Is model.

Table 2: Summary of Results for Forecast Accuracy Experiments

Key Performance Indicator	% Difference from As-Is Model for To-Be Model with Fast moving item forecast accuracy of:			
	30%	60%	75% (To-Be)	80%
Service Level	-0.4%	-0.3%	-0.3%	-0.5%
Inventory Turns	7.9%	13.2%	18.7%	20.0%
Inventory Level (in Units)	-3.9%	-8.4%	-13.1%	-13.3%
Order to delivery lead time	-9.7%	-11.1%	-10.9%	-10.8%

The primary impact of forecast accuracy is on inventory that gets significantly reduced with increase in accuracy. The existing inventory management practices indicated that while the proportion of under-forecasted and over-forecasted part numbers is about the same, on average the amount of over-forecasting is larger as compared to the amount of under-forecasting as a percentage of demand. The difference in extent of over and under forecasting leads to the above results of large reductions in inventory with increasing forecast accuracy. If the under and over-forecasting were by roughly the same amount, the increase in forecast accuracy will have reduced the inventory of over-forecasted part numbers while increasing the inven-

Table 3: Example for Explanation of Reduction in Inventory while Maintaining Availability

	Over-forecasted part numbers			Under-forecasted part numbers		
Part number	1	2	3	4	5	6
Demand	100	100	100	100	100	100
Original Forecast	200	135	250	65	70	50
Original Availability	100%	100%	100%	<100%	<100%	<100%
Forecast with Accuracy of 60% (or +/-40% error)	140	135	140	65	70	60
Availability with improved forecast	100%	100%	100%	<100%	<100%	<100%

tory of under-forecasted part numbers, and the net impact would not have been significant.

Consider the example of forecast and demand numbers in Table 3, with an even split of over and under-forecasted part numbers. The over-forecasted part numbers have an error of more than 100% while the under-forecasted part numbers have an error of maximum 50%. When the forecast accuracy is improved to 60%, it results in large reduction in over-forecasted part numbers and only small, if any, increase in under-forecasted part numbers. This, in turn, leads to lower replenishments for over-forecasted part numbers and lower inventories with no appreciable change for under-forecasted part numbers. The service level of over-forecasted part numbers stays at 100% while the availability of under-forecasted part numbers stays at their original values. The end result is that there is reduction in total inventory with no impact on availabilities. The service levels do not see much impact with a change in forecast accuracy as explained in the above example. The part numbers that are over-forecasted continue to have high service levels even with reductions in inventory since it is still generally higher than demand. The part numbers that are under-forecasted continue to have lower service levels since the inventory generally stays below the demand. Where there are changes, since the proportion of over and under forecasted parts is about the same the gains at one side are neutralized by losses in the other. In addition, data analysis has indicated that the average order size of under-forecasted part numbers is greater than over-forecasted ones. That is, the impact of forecast accuracy improvements on the availability of under-forecasted part numbers will only show with large increases in inventory.

Changes in forecast accuracy do not impact the lead times, though timing of replenishments will be affected. Hence no significant changes are seen in the order to delivery lead time results with the change in forecast accuracy.

5.3 Procurement Time

5.3.1 Scenario Description

The current procurement practices and procedures involve long procurement times for establishing new contracts. For existing contracts, the procurements are processed in few days. The To-Be processes discussed earlier target a maximum procurement time of 50 days for purchases under a certain threshold dollar amount. This scenario evaluates a more aggressive target of limiting the procurement time for purchases under the threshold amount to a maximum of 15 days.

5.3.2 Results and Analysis

The results for this scenario are summarized in Table 4. The results indicate that achieving the target of 15 day maximum procurement time for establishing new contracts under the threshold amount will provide significant advantages in reducing the order to delivery lead time with a corresponding increase in service level. The gain in service level occurs due to faster arrivals of procurements resulting in inventory being available earlier for servicing the orders.

Table 4: %Change with To-Be Model with 15 day Maximum Procurement Time for Purchases under Threshold Dollar Amount

Key Performance Indicator	*% Difference from As-Is Model*
Service Level	+2.7%
Inventory Turns	+12.5%
Order to delivery lead time	-22.5%
Distribution Center Costs	-3.45%

6 CONCLUSIONS

This paper described the use of simulation models of the As-Is and the proposed To-Be processes for the comparison of their performance. The study has provided quantified estimates of the performance improvements based on the detailed descriptions of and assumptions about the To-Be processes. The simulation study provided following key insights:

- The supply availability can be maintained while achieving major reductions in inventory through improvements in forecast accuracy. Usually, a reduction in inventory leads to reductions in supply availability. However, due to half the items carrying inventories much higher than demand, major reductions can be achieved in inventory without impacting the availability.

- The reductions in business process lead times in different process areas – order fulfillment, planning and procurement, together provide a significant impact on inventory reduction. This occurs through re-order point adjustments corresponding to the lead time reductions.

A large reduction in inventory is estimated based on the use of more accurate forecasts coupled with reductions in customer order to delivery lead times. The conclusion regarding the large impact of the forecast accuracy is in agreement with the observation made by Ingalls (1999) who noted – "the most critical factor in supply chain performance is demand variance or forecast error". Beyond the improvement of forecast accuracy, further improvements may be realized through reduction in supplier lead times and reduction in variabilities of the lead times.

The case study described in this paper demonstrates the usefulness of simulation to evaluate the performance of supply chains. The use of an integrated model of material, business process and communication flow allows capturing of the major aspects of supply chain operation. This integrated approach provides a systems view of organizational and technological changes that affect the performance of a supply chain, and helped gain a high level of confidence in the results among the customers of the study.

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