EVALUATING FORECASTING ALGORITHMS AND STOCKING LEVEL STRATEGIES USING DISCRETE-EVENT SIMULATION

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ABSTRACT

The part division of a major automobile manufacturer is analyzing methods of managing the supply chain of automotive service parts. That analysis includes parts flowing from its warehouses to its dealers, and from dealer to dealer. This paper describes the use of simulation to evaluate various part forecasting and level setting strategies for automobile dealer part inventories, and the impact that implementing a common strategy across a set of dealers could have on overall inventory levels.

1   BACKGROUND

Through its parts division, a major automobile manufacturer sells and distributes parts to over 5000 North American dealerships. At any time, the total variety encompasses about 250,000 different parts, but on a monthly basis specific part numbers may be introduced or retired due to new model introductions, engineering changes, or obsolescence. Distribution thus embraces both sales and material returns (excess stocks, obsolete parts) through the supply chain.

The manufacturer recognizes that improving the parts service level (percent of time an ordered part is in-stock at a dealer; often called "fill rate") has significant benefits to customer satisfaction with all dealer products and services. Clearly, dealers cannot afford the investment, staffing, or space to stock any but a small subset (typically a few thousand) of the total parts lines. While efficient dealer part stocking will certainly yield high inventory turns and increase dealer profitability, efficient dealer inventory decisions will also help manufacturer and parts division profitability by avoiding signaling parts demands that trigger over- or under-stocking parts at the warehouses. Thus, the manufacturer views improving dealer parts inventory decisions as a "win-win" for the company and for the dealers.

Dealers operate businesses independent from the manufacturer, and from the manufacturer's service parts division. From over 50 different third-party vendors, dealers purchase in-house business systems (IHBS) that perform accounting, sales support, vehicle service support, and parts inventory support functions. The IHBS embeds various common algorithms for parts sales forecasting options (e.g., exponential smoothing vs. moving average forecast) and inventory decisions; the dealer parts manager can manipulate parameters of those algorithms (e.g., safety stock levels). These same systems often exchange data with manufacturer-supplied information systems that enable electronic document interchange (EDI).

At this time, no coordinated inventory stocking strategy exists between the parts division and the dealers. While warehouses base stocking decisions on dealer part purchases, every dealer independently decides what parts will be stocked and the levels at which those parts will be stocked. The manufacturer commissioned this study to determine potential benefits of promoting a new, common inventory stocking strategy among the set of independent dealers.

2   APPROACH

For the project, the simulation team created an "as-is" parts department model. The team then modified the "as-is" model to evaluate the effect of implementing concepts such as automated dealer-to-dealer order referrals (sales of parts between dealers), new forecasting formulas, and policy changes.

To create the "as-is" model, simulation team members relied on experience in manufacturer and dealer operations, and on visits to dealers and manufacturer part warehouses. These visits served to verify assumptions, to confirm or uncover misconceptions about current processes, and to record the times and sequences of the events when ordering parts.

2.1 Dealer Model

A common view of the dealer parts ordering process emerged from the dealer visits. Each visit lasted approximately two hours, during which time the team interviewed the parts manager (and in one case the dealer principal) to gain a better understanding of how dealers run their businesses. Common questions the simulation team posed included:

- What IHBS was used? What forecasting and stocking algorithms and parameters were used?
- How does the dealer measure the performance of his parts operation?
- For parts obtained from each different source (e.g., dealer referrals, primary warehouse, secondary warehouse(s), backorder), what is the range of lead time?
- What parts locator services does the dealer use? (Third-party vendors offer parts locator databases to assist long-distance dealer referrals.)

To facilitate discussion and assure topic coverage, the simulation team used a flowchart of dealer parts ordering procedures (see Figure 1). Results of the dealer interviews formed the basis of the "as-is" dealer simulation model. Dealership processes modeled included daily orders, weekly stock orders, monthly material returns of excess stock, selling and picking parts, stock putaway, locating parts at other dealers by phone, and locating parts at other dealers using the current EDI system.

3 MODEL CONSTRUCTION

The simulation team created the model using the Arena simulation tool (Systems Modeling Corporation, Sewickley, PA). Arena is a general purpose modeling tool that allows modeling a process using predefined constructs and data analysis tools. A graphical user interface supports model development, and model animation is available, allowing users to "view" the process performance.

3.1 Input Data

Automotive dealer parts sales include the dealer's own service operation, wholesale (e.g., a dealer selling to a Firestone service store), retail (e.g., a "shade-tree mechanic"), and dealer referrals. Arguably these different sales types should exhibit different demand patterns, and the dealer is more concerned about filling certain parts orders (e.g., his own service bays).

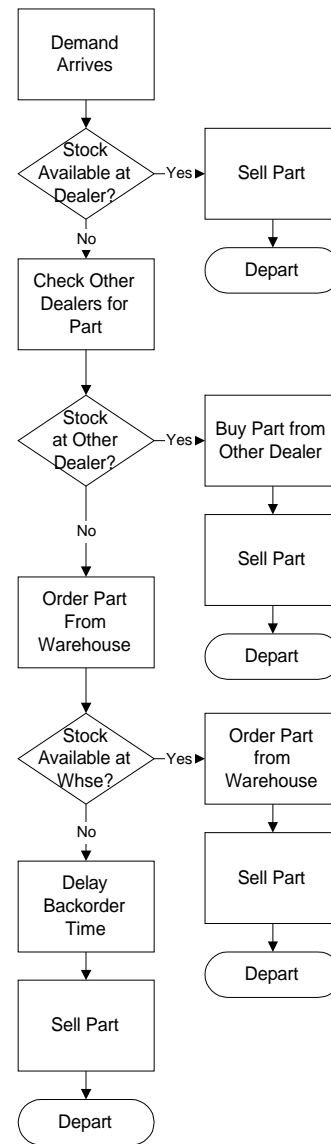Unfortunately, readily available dealer records give an incomplete categorization of dealer part demands.

Figure 1: Dealer Counter Processes

The team used sales history data from a dealer to create a set of input data for the simulations. From this dealer's 18,486 part records, many of which were memos or pointers to newer parts, the team selected a set of 123 representative parts. The parts selected matched the dealership's overall inventory in terms of percentage of active parts with 0-3 sales in the last 12 months (70%). The team selected the remainder of parts in the inventory using the same ratio of number of sales to total sales. Also, the top 20% of volume parts accounted for approximately 75% of the dollar value of the inventory.

3.2 Demand Arrival

The simulation team based an average order interarrival time on the weighted interarrival times of each part. Order size was a function of the hourly part mean sales.

The team determined hourly part mean by dividing the past year's sales by the number of working hours in a year. Interarrival time was the reciprocal of the part hourly mean.

3.3 Counter Processes

Parts counter processes include the tasks a dealer parts specialist performs in filling an order for a part. The counter order may be a "walk-up" (e.g., a mechanic), a phone order (e.g., from another automotive service business), or an EDI message (e.g., a dealer referral). As demands arrive, a counter person checks the on-hand stock count in the IHBS. If that count is greater than or equal to the demand quantity, then the counter person picks stock from the shelf. If the quantity is less than that requested, the counter person checks alternative sources to fill the entire ordered quantity. These tasks comprise the "locate section" of the simulation model.

In locating an out-of-stock part, the counter person first attempts a referral by phoning one or more local dealers to determine if stock is available and whether a stocking dealer will sell the needed quantity. In a large metropolitan area many nearby dealers may carry the required parts, but each phone call engages the counter person for many minutes. From experience with other dealers' practices, the scarcity of the part in question, and the time to locate a referring dealer, the counter person will usually contact only a small number of dealers (at most three). If parts are available, and the dealer holding them agrees to sell them, then a delay occurs while the stock travels between dealerships. When the parts arrive, the counter person invoices the parts and the filled demand leaves the modeled system. (Note that, because the dealers are independent businesses, the manufacturer is unaware of part orders filled by dealer referrals.)

If a dealer referral is not possible, the counter person must order the part through a manufacturer warehouse. Dealers may order parts from their primary warehouse on a daily order or a weekly stock order. For non-expedited orders, the manufacturer delivers the ordered parts to dealers by a "circuit-rider" delivery service. To encourage dealers to stock reasonable varieties and quantities of parts, the manufacturer offers more generous discount and return allowance terms on stock orders than on daily orders. Dealers must pay a surcharge to receive parts guaranteed-overnight on an "emergency" (expedited) order.

Failing a local dealer referral, the counter person uses the EDI system to determine if the parts are available at the dealer's primary warehouse. If the parts are available, the parts manager places the ordered quantity as an order line on a daily order and transmits it to the warehouse that evening. In the event that the daily order is placed within two days of a stock order arriving with the needed part, the demand will wait and be satisfied when the part arrives. Deferring the order line to the stock order helps maximize discount or return allowance percentage gains for the dealer. After a daily order arrives, the counter person unpacks the stock, posts the quantity to inventory in the IHBS, and then invoices them. The model simulates the counter person's tasks in adding the order line, submitting the daily order, and receiving the daily order. The model also simulates the delay associated with distributing the parts from the warehouse through a daily or stock order.

If the part is not available at the dealer's primary warehouse, the counter person waits while the EDI system searches through a referral pattern of all part warehouses to determine part availability. When parts ship from a non-primary warehouse, the delivery time of the part will be longer than when the part ships from the primary warehouse. Otherwise, the modeled tasks and delays for receiving and invoicing the parts are the same.

When parts do not exist in the warehouse chain, the part goes on backorder (e.g., it must be manufactured) and arrives between one and 90 days thereafter, with a most likely lead time of 30 days. The simulation model represents all of these delays and tasks.

3.4 Lost Sales

At each stage of the effort to locate the part, a lost sale may occur. For example, if the part is not immediately available on the dealer shelf, the customer may cancel the order rather than wait for the dealer to locate and deliver the part from another dealer or a manufacturer warehouse. The simulation models this lost sales behavior with a different probability at each stage (fill from off-the-shelf, local dealer locate, warehouse locate, backorder) that the customer will cancel his order. The dealer visit data provided the probabilities used in the model.

The simulation model also represents probabilistically whether the lost sale is recorded by the dealer counter staff, for while the IHBS provides a lost sale recording facility, busy counter staff do not reliably use it. (However, at least one dealer claimed to record over 99% of lost sales.) Occurrence of lost sales and dealer failure to record them creates errors in parts sales forecasts, and the simulation model provides a facility to model the lost sales creation, unreliable recording, and resulting forecast errors.

3.5   Daily Orders

At the start of each morning, counter personnel unpack and stock the daily order on the shelves in the parts department. Seven and one half hours into each day, the daily order preparation begins. The parts manager gathers and submits the daily orders through EDI to the manufacturer. The parts ship from the dealer's primary warehouse if they are available. The model checks a warehouse referral pattern to satisfy other orders. If the parts are not available in the pattern, they go on backorder with most parts shipping in under 30 days.

3.6   Stock Orders

The stock order process runs on a weekly basis. During this routine, the simulation models the IHBS's forecasting and stock guide ("order-up-to") quantity decision processes for each part in the dealer's inventory. To determine order quantity, the model calculates the difference between the on-hand quantity of the part and the guide. If the guide is higher than the on-hand quantity, the model places a stock order for the part. If the guide is less than the on-hand quantity, no order arises.

After calculating the stock order quantities, the parts manager transmits the stock order to the warehouse using the EDI device. From this point, a cycle begins which first checks the primary warehouse for available stock. If all or some of the ordered quantity is available, it arrives from the primary warehouse to the dealer, with times ranging from 24 to 72 hours. If some or all of the parts ship from another warehouse, the model checks a number of warehouses for available quantities. If found, the parts will ship to the dealer with a longer lead time than if shipped from the primary warehouse. In some cases, the part goes on backorder, with backorder lead times ranging from one day to three months with an average of one month.

After the stock order arrives, a counter person puts away the stock order. At this time, the stock order process signals that the parts are available to fill any customer demand waiting for the part.

The simulation model embodies all the decision logic, lead times, and tasks of the dealer stock order process.

3.7   Material Returns

The material return process runs monthly to return excess stock to the primary warehouse. On this cycle, the parts manager and counter personnel accumulate, pack, and ship the excess stock for each part (IHBS on-hand minus best stocking level) to the warehouse. Dealers periodically review inactive parts, such as those with no sales in 12 months, to purge the inventory of non-performing stock. While the simulation model includes decision logic and tasks for material return of excess stock, the material return of inactive parts is not part of the dealer model.

3.8   Other Periodic Processes

For accounting purposes, a weekly process runs to calculate average values of total inventory, excess inventory, and inventory turns.

3.9   Animation

Animation provides a means of visually communicating the processes mathematically captured in the model. For the dealer model, a dealership parts department has the following static entities: bins, counter, shipping/receiving area, and parts manager desk. The following dynamic entities are present: counter staff, customers, IHBS system screens, EDI screen, telephones, the parts manager, and trucks.

Demands arriving into the system first appear as a person entering the parts department. The counter person checks the IHBS system for the part. While this check occurs, the IHBS system screen is green, indicating that it is in use. When parts are available, a counter person walks to and from the bins to pick the parts. Similarly, counter staff move throughout the bins to gather parts for material returns. The parts manager moves between the desk and the EDI station to transmit orders and material returns.

4   RESULTS

4.1   Forecasting Methods

Including the base forecasting method, the team modeled, simulated and evaluated four different forecasting algorithms. While dealer systems do create forecasts, they only address the demand that is expected in the next ordering cycle. The IHBS immediately converts the forecast number into best stocking levels and reorder points for each part. Based on these figures, the system creates the suggested weekly stock order. In the dealer model, the forecast values created by these methods are immediately converted into best stocking levels and reorder points.

The four forecasting methods evaluated included single exponential smoothing, double exponential smoothing, Bayesian, and simple moving average. In practice, several factors are important in selecting and implementing a forecasting method:

- Accuracy with actual part sales data (e.g., erratic demands, slow vs. fast moving, new model parts)
- User understanding and control (e.g., selecting appropriate exponential smoothing factors)
- Inherent adaptability of the forecasting method to changes in the data
- Computer data storage and processing, which directly affect the time to prepare the stock order

Best known among short-term forecasting methods, the **exponential smoothing** and **moving average** methods appear in all current dealer business systems. Double exponential smoothing additionally provides some estimation and accounting for an upward or downward trend in sales to adjust the next-period sales forecast. All three methods effectively average previous sales data to forecast next-period sales. The formulae for exponential smoothing and moving average methods are thus closely related, though the data and computer processing requirements for moving average are considerably greater. The best choice of parameters to maximize forecasting accuracy with these methods is not obvious to the user, and dealer visits indicated that most parts managers used the default parameter values supplied by their IHBS vendor. Research (Croston) suggests that exponential smoothing overestimates sales of the erratically demanded parts that dominate dealer inventories.

Double exponential smoothing is the default forecasting method in the "as-is" dealer simulation. By definition, double exponential smoothing offers two user-selectable parameters: a base smoothing constant and a trend smoothing constant. In dealer business system practice, the same constant value applies to both the base and trend values.

In practice, the **Bayesian forecasting method** is relatively new, and research (Sherbrooke; Bradford and Sugrue) suggests that it may be effective in forecasting the erratic demand for the slow moving parts comprising the majority of Mopar dealer inventories. In contrast to the purely empirical exponential smoothing or moving average methods, the Bayesian method assumes that past parts sales follow a particular probability distribution. Knowing this prior distribution, the probability distribution of next-period sales is immediately available, and the method can forecast next-period sales of a part by a simple formula. Some forecasting vendors (e.g., American Software) have incorporated a Bayesian forecast based on the Poisson distribution, which intrinsically assumes that part sales mean and variance are equal. Published research (Sherbrooke) on a large set of part demand data suggests that the Poisson is an inappropriate probability distribution. From analysis of part sales history and other published work (e.g., Sherbrooke), it is assumed that part demand follows the negative binomial probability distribution, for which variance is strictly greater than the mean. This discussion highlights the principal weakness of the Bayesian forecasting method: proper implementation requires thorough historical sales data analysis and careful selection of an appropriate probability distribution of sales. However, once selected, the sales probability distribution is implemented in software and the dealer user need not adjust any parameters (e.g., an exponential smoothing constant).

4.2   Modeling of Forecasting Method Performance

Most IHBSs use a simple moving average based forecasting methodology. The average daily sales for a part is calculated, giving a daily forecast figure. The systems then calculate reorder point and guide quantity, called Best Stocking Level, from this figure. The dealer may control the high and low days supply parameters used in calculating the Best Stocking Level.

The existing In-House Business System method (moving average) will be referred to as the "IHBS method." The IHBS method creates the Best Stocking Level using the following calculations:

$$SW = 12$$
$$ADS = \Sigma_{I=1}^{I=SW} (A_{SW}) / (SW*7)$$
$$ROP = ADS * LD$$
$$BSL = ADS * HD$$

Where:

SW	= Weeks history to search
ADS	= Average daily demand
ROP	= Reorder Point
BSL	= Best Stocking Level
LD	= Low Days
HD	= High Days

The key for using the IHBS method is calculating the average daily sales for each part. Reorder point is Average daily sales multiplied by the Low Days setup parameter. Once the on-hand quantity of the part has fallen to the reorder point, the system orders enough stock to bring the system back up to the best stocking level, which is average daily sales times high days.

Each of the forecasting methods was used in conjunction with this level setting routine in order to determine reorder points and best stocking levels during the simulations. The team performed simulations for each forecasting method across a set of days supply figures. This tested the ability of each of the algorithms to meet customer demands at increasingly lower levels of inventory.
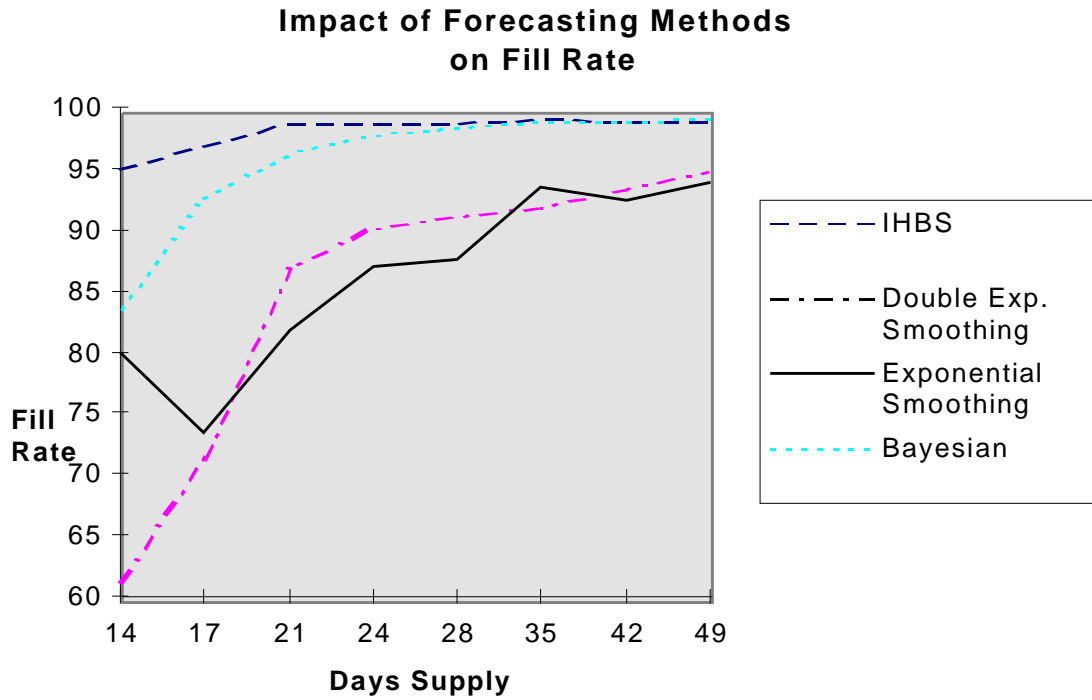
Impact of Forecasting Methods on Fill Rate

Figure 2: Graphical representation of tested forecasting method impact on fill rate using varying days supply

All methods show similar performance in that as days supply was reduced from 45 days to 27 days. As the days supply was lowered below 21 days, the fill rate dropped quickly. Figure 2, above, graphically displays a comparison of the four methods with respect to the impact on fill rate of lowering the days supply.

As is shown, the IHBS and Bayesian forecasting methods perform at very high fill rate levels when days

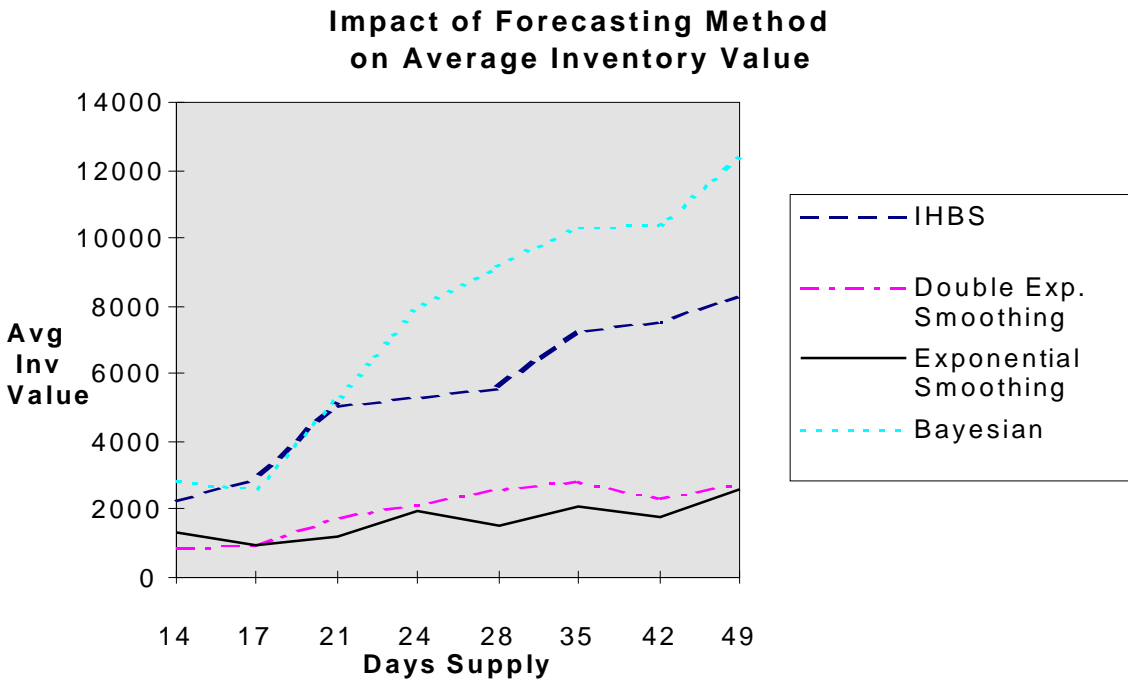## Impact of Forecasting Method on Average Inventory Value

Figure 3: Impact of forecasting method on average inventory value

supply is above 27. The exponential smoothing and double exponential smoothing algorithms lag 5-7 points behind. Once the days supply falls below 27, however, the IHBS method provides higher fill rates than all other methods. This performance comes with a high price. Both the IHBS and Bayesian forecasting methods require a substantially larger inventory investment than do the two exponential smoothing methods.

A measure defined as the percentage of fill rate provided each dollar spent on inventory shows the cost effectiveness of each forecasting method. As shown in Figure 3, above, the exponential smoothing and double exponential smoothing methods are far more cost effective than either the Bayesian or IHBS methods. Generally, a dollar invested with exponential smoothing or double exponential smoothing provides a 2:1 payback over either of the other forecasting methods. For example, at 24 days supply, the IHBS and Bayesian methods create approximately 0.018% of fill for each dollar invested. The exponential smoothing and double exponential methods create 0.040% of fill per dollar.

Utilizing exponential smoothing or double exponential smoothing appears to provide a balance between maintaining a high fill rate while reducing inventory investment. While no improvement in fill rate

inventory investment. This model also cannot predict what the parts manager will do with the savings generated. Increasing inventory breadth, as mentioned above, is one option. He may also choose to deepen inventory levels on some parts to improve overall fill rate. Investment of inventory saving in other areas of the dealership is also an option.

4.3 Reduce Safety Stock

Many dealers regularly maintain a 60-day supply of parts, including fast moving parts and those on which fill rates from the primary warehouse are near 100%. These parts managers believe that they need to stock at this level to avoid any chance of a stockout. Dealers believe that they must also stock at higher levels to avoid periodic, but regular, failures by the primary warehouse to fill part orders. Evaluation of safety stock values varying from 6 weeks to 1 week shows the impact of this reducing stocking levels on the measures of fill rate and inventory turns. This test is performed assuming a constant warehouse fill rate of 85% on all parts.

As shown in Figure 4, as inventory high days supply falls, inventory turns increase before the fill rate starts to fall. Dealers generally maintain high days supply at a value over 45. As shown above, dealers could lower the
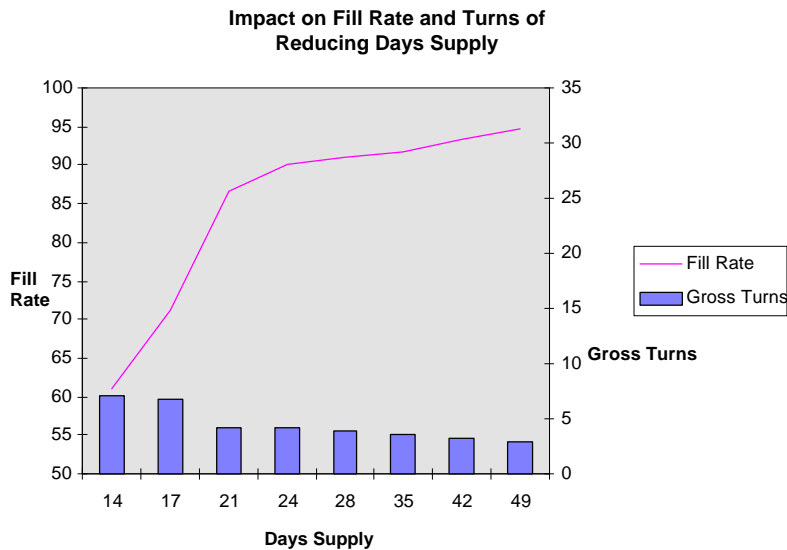

Figure 4: Impact on fill rate and inventory turns of reducing days supply of parts

results directly from this change, a dealer may choose to broaden the inventory to help increase fill on slow moving parts.

Use of exponential smoothing or double exponential smoothing represents acceptance of a trade-off between a small measure of fill percentage for a large reduction in

high days supply figure and continue to maintain a high fill rate. The fill rate begins to fall off rapidly when high days supply declines to between 21 and 27 days. Inventory turns increase gradually as days supply decreases. The data represented by the above chart reflect use of the double exponential smoothing

forecasting method. Data from the other three methods show the same effect.

These results present an opportunity area for dealers to continue to provide existing service levels using a lower inventory investment. With additional freed capital, parts managers may increase the breadth of their inventory, helping to satisfy demands on less frequently requested parts.

5   CONCLUSIONS

The simulation model of dealer parts operations and decision making provided significant benefits. The process of constructing the model raised the awareness of both the manufacturer and its dealers of the tasks involved in ordering parts and of the decisions involved in stocking parts. The most significant finding was that overall dealer part stocking levels can be reduced by one third with minimal impact on fill rates. For the dealer, this frees up capital to bring more variety into the inventory, and reducing the need to acquire parts from local dealers and the need to place parts on more costly daily orders from the manufacturer. Carrying a broader part inventory brings the possibility of increasing the dealer's customer satisfaction ratings. Across a number of dealers in a geographical region, broader part inventories allow all dealers to more quickly satisfy customer part demands. Experiments with the simulation model showed how control of key decision parameters (e.g., safety stock) could yield fill rate improvement through better distribution of inventory investment.

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