Inventory Control Methods in a Long-Term Care Pharmacy: Comparisons and Time-Series Analyses

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Abstract

Background: Current inventory theory is based on simulated data and unrealistic formulae. Inventory replenishment processes are therefore commonly disrupted, and out-of-stock (OOS) events are unnecessarily frequent. **Objective:** OOS events at a large-volume, long-term care pharmacy in North Carolina were compared among 4 sequentially applied methods of inventory control: (a) a manual system without Six Sigma protocol, (b) a manual system with Six Sigma protocol, (c) a computer-assisted system with Six Sigma protocol, and (d) an automated system with Six Sigma protocol. **Methods:** Daily OOS rates were recorded for 11 weeks during the implementation of each method. Between-group comparisons were performed, and time-series analyses were conducted during each implementation to determine the significance of the change in OOS rates over the evaluation period. **Results:** In terms of the 2 manual systems, OOS rates were lower for the system to which a Six Sigma protocol was applied. In terms of the 3 Six Sigma systems, ranked differences were significant. The computer-assisted system had a lower OOS rate than did the automated system, and the automated system had a lower OOS rate than did the manual Six Sigma system. OOS rates were significantly reduced over an 11-week period for the computer-assisted and the automated systems. **Conclusions:** Six Sigma was found to be an effective process improvement strategy in the selected pharmacy setting. The study was the first inventory analysis performed with OOS events used as an empirical measure, in contrast to the simulated data used in prior studies.

Keywords

pharmacy inventory control, Six Sigma, inventory theory, total quality management

The basic goals of inventory management are to minimize inventory investment while maintaining a balance in supply and demand that meets customer expectations.¹ Exploring and understanding the optimal utilization of inventory is critical to pharmacy operations. Health care service organizations, such as pharmacies, have lagged behind industrial and retail sectors in developing and implementing effective process improvement strategies and techniques.²

Although representatives of pharmacies and other health care service organizations have made significant efforts implementing strategies to improve the delivery and quality of health care products and services, less effort has been spent on actual process improvement. The improvement focus of these organizations has been the end products or services rather than the actual processes that yield the end products or services.¹ Out-of-stock (OOS) events are indicators of inventory process failures in need of improvement.³

An OOS event refers to an event that occurs when an item is unintentionally not available for sale for a certain contiguous time period. OOS events represent both a failure to meet customer expectations and an inventory control

process failure. We defined inventory control for this study as the process of minimizing the investment in inventory while balancing supply and demand such that OOS events are reduced to customer specifications.

One protocol designed to improve operational performance and eliminate process defects is Six Sigma. Six Sigma is a rigorous and focused implementation of data and statistical analysis. Six Sigma involves a simple model known as Define-Measure-Analyze-Improve-Control, or DMAIC.⁴

Background

Orthodox inventory theory is founded on classical economic order quantity (EOQ) methodology, developed in 1915 by a Westinghouse employee.⁵ According to orthodox

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theory, when a specific inventory level is reached, an inventory reorder point is established. Subsequently, if inventory is ordered, inventory costs are assumed to be minimized.

According to the orthodox model, efficiency can be measured by the availability of inventory for consumer purchase, or inversely by the OOS rate. Assumptions of the traditional EOQ model are that (a) demand is certain and constant over time, (b) no shortages are allowed, (c) lead time for order receipt is constant, and (d) the order quantity is received all at once.⁶ However, these assumptions rarely hold true in real-world business environments, including pharmacies.⁵ Since the development of the EOQ model, many mathematical formulae have been developed to determine optimal inventory levels for businesses in all sectors. Nevertheless, even these numerous formulae cannot predict the innumerable possible situations that can occur in the field.

Computer-driven inventory control systems, such as automated and computer-assisted systems, appear to offer a better solution to managing complex mathematical formulae than do manual systems.¹ The reason is that computer-driven systems enable perpetual inventory-level calculations.⁵ However, the OOS rate across all industries remains at 8.3%, even among firms where computer-driven systems are used. Thus, factors other than the variables within the EOQ model may be affecting the OOS rate. An example of such factors may be internal process failures related to user activities.³

We based the current study on a different theoretical perspective for examining inventory control. Rather than providing a new formula to simulate a single real-world market condition, we based the study on an examination of inventory control efficiency in an environment of internal process improvement. The foundation of this approach was the work of Deming.⁷ Deming theorized that systems could be made more efficient by improving the internal process design, or quality, rather than by relying on unrealistic models. Deming argued that quality was adversely affected by systems not in control. According to Deming, all processes exhibit inherent variation, known as common-cause variation. However, systems and processes not in control are affected by special-cause variation, which results from factors that are not part of the process. Deming proposed that the causes of special-cause variation could be identified and removed, thereby improving efficiency and process quality. According to Deming, when quality is built into a process, variations (ie, errors) are reduced along with associated costs. Deming further argued that quality could be achieved using statistical methods that identified, reduced, and controlled process variation.

Six Sigma was designed as a process improvement strategy based on Deming's work on process improvement.⁸ The DMAIC approach was designed to target the root

causes of process variation.⁹ The process variations under consideration in this study were the components and user activities associated with each inventory system investigated. In this study, Six Sigma protocols were introduced to measure changes in process variation within the inventory control systems under consideration.

The Six Sigma 5-step DMAIC method, based on the work of Deming, was developed on the basis that reducing process variation would result in process improvement.¹⁰ According to Deming, when process variation is reduced, defective process outputs are decreased. For the current study, we tested the effect of Six Sigma process improvement techniques in a long-term care pharmacy setting using OOS events as the critical-to-quality variable, or the process output being measured for defect reduction.

Six Sigma is represented as a process improvement method. On the basis of Deming's theory, the application of Six Sigma was predicted to lead to a decrease in OOS rates. Additionally, although orthodox inventory control theory involves an implicit assumption that automated systems are the most efficient inventory control system,¹ this assumption has never been tested. The findings from this study enabled a determination of which inventory control systems were the most efficient with regard to reducing OOS rates.

Current inventory theory is based on formulae and simulations. This study contributes to inventory theory through a comparison of realistic OOS rates across the most common inventory control systems currently being used in retail organizations. The study fills a knowledge gap in inventory theory with a determination of changes in efficiency levels when internal processes are changed.¹¹ Unlike findings in classical or current inventory studies, the findings in this study were not based on demand forecasting or simulation modeling as contributing factors for determining inventory efficiency. Instead, the study provided measurements to compare the effects of different inventory control and process methods using empirical data collected in real-world settings. The findings have the potential to change existing inventory control models used throughout the retail sector.

Purpose of the Study

The purpose of this quasi-experimental study was to compare the most commonly used inventory control methods (manual, computer-assisted, and automated) in terms of the number of daily OOS events generated. We investigated a large-volume, long-term care pharmacy in North Carolina. The 4 inventory control methods, introduced sequentially, were (a) the historical manual inventory system without Six Sigma (Stage 1), (b) a manual inventory system using Six Sigma (Stage 2), (c) a computer-assisted system using Six Sigma (Stage 3), and (d) an automated system using Six Sigma (Stage 4).

Table 1. Six Sigma Tools Introduced During Stages 2, 3, and 4^a.

Name	Description	Function
Project charter	A definition of customer needs, project scope, project goals, team members, and project deadlines	Establishes an agreement between management and the pharmacy about what will be accomplished
Brainstorming	A method used to creatively and efficiently generate ideas without criticism or judgment	Keeps the project focused on the established goals and objectives
Cause and effect diagram	A method used to identify, explore, and graphically display, with increasing detail, possible causes related to a problem or condition	Uses collective knowledge to identify the root causes of the problem under consideration
Process map	A visual display of a process that details the inputs and outputs	Illustrates the process complexity and identifies non-value-added activities such as rework loops and redundancy
Failure mode effects and analysis	An assessment of customer risks resulting from process failure	Determines actions that minimize risks from process failure
Suppliers-inputs-process-outputs-Customers	A schematic that illustrates high-level process understanding, including upstream and downstream links	Identifies customers, defines project boundaries, indicates data collection points, and supports process thinking

^aAdapted from Grue G. *Six Sigma for Managers*. New York, NY: McGraw-Hill; 2005:47-48, 117, 125-126. Copyright 2002 by McGraw-Hill. Reprinted with permission.

Method

Study Design

Daily OOS events, along with the total number of prescription requests, were recorded on a tally sheet for approximately 11 weeks, 6 days per week, or until 64 data points for each of the 4 methods ($N = 256$). First, we conducted a sequential comparison, comparing OOS rates for the manual method based on whether Six Sigma had been introduced. We then compared OOS rates for the 3 methods involving Six Sigma. The inventory control methods, which functioned as the independent variables for the comparisons, were applied sequentially during the normal business course of the selected pharmacy. OOS rates were collected as a real output of actual operations. The OOS rates thereby represented empirical data rather than simulated data. Finally, we examined the relationships between the elapsed time and the change in OOS rates over the 11-week application of each inventory control system tested. The purpose of these time-series analyses was to determine whether OOS rates decreased linearly over the course of each intervention. We assumed that the sample of daily dispensing records used for this study was typical of the entire population of current and future daily dispensing records for the selected pharmacy.

The Implementation of Six Sigma

As part of the normal business operations of the pharmacy, Six Sigma tools were applied to the inventory control systems for each application of the independent variable as part of the DMAIC protocol. Table 1 shows the Six Sigma tools

applied during each stage of the study. Permission was granted to reproduce the table.

Group members exchanged tacit knowledge of the inventory process during group meetings. A suppliers-inputs-process-outputs-customers (SIPOC) chart was developed to illustrate the process components and establish a baseline understanding of their relationship and function. The target areas identified in the SIPOC chart as potential areas for improvement were then used to develop a cause-and-effect diagram, as suggested by Arendt.¹² High-level process maps were developed for each inventory process to provide visual aids for identifying the process differences in detail.

A failure mode and effects analysis (FMEA) was conducted for each inventory system, with the high-level process maps used as a template. A FMEA is a team-based, systematic, prospective technique of risk assessment commonly used as a Six Sigma tool during the improve stage.¹³ The FMEA method is used to identify potential vulnerabilities in complex high-risk processes.¹⁴

The FMEA technique involved mapping out a high-risk process, identifying the failures that can occur, and then scoring each of these potential failure modes in terms of probability of occurrence, severity of effects, and detectability. Team members developed a separate score sheet with a list of criteria and a 10-point scale for each FMEA probability factor. The product of these 3 scores yielded a risk priority number (RPN). The process step with the highest RPN was the step most in need of attention.¹⁵

Using the FMEA formula, team members identified process areas of each inventory control system and their corresponding potential failure modes. The severity effect of

each failure mode was scored. Causes for the failure were identified and scored for an estimated rate of occurrence. Controls, if any, were also listed for each failure mode of each inventory system under examination. The controls were then evaluated on how well they led to detecting the failure. If a control was not in place for a specific failure mode identified, the detection score was still given based on the observed rate of detection.

An RPN was then calculated as the product of the 3 scores (severity, occurrence, and detection). The RPN was an assessment of the risk to the total process when component steps of the process failed. The completion of the FMEAs for each inventory control system helped prioritize the actions taken to minimize the risks and improve each system.¹⁶ The FMEA allowed prioritization of improvement efforts as a way of providing the maximum system benefit in terms of decreasing the OOS rate.

The manual system with Six Sigma. For the manual system with Six Sigma, the FMEA indicated that improvement priority should be given to reducing the number of users involved in the ordering process and to establishing minimum and maximum inventory levels for each stock unit. The RPN was 336, the highest score of all RPNs generated during this stage. The corresponding improvement effort resulted in limiting the number of individuals ordering inventory from 6 to 2. Team members also recognized that when a manual system was in place, users often ordered replacement inventory based on "judgment calls." These judgment calls introduced variation into the process, which could lead to process failure.

As a result, team members developed an algorithm designed to make the ordering process more uniform when multiple operators were involved. Establishing minimum and maximum inventory levels for more than 6000 line items of inventory in the pharmacy was not feasible. Therefore, team members decided that minima and maxima should be calculated for the top 200 moving line items based on the average daily quantity dispensed for the preceding 6 months of dispensing activity.

The computer-assisted system with Six Sigma. For the computer-assisted system, the FMEA indicated that the inaccuracy of minimum and maximum inventory levels as generated by the software was the area most in need of improvement. The RPN score was 448, the highest score of all RPN scores generated during this stage. As a result, team members decided that establishing a system of cycle counting, both scheduled and random, would ensure that the level of actual inventory on hand was consistent with the level indicated by the software. Inventory staff members used a daily recommended list of inventory line items generated by the software. This list was to be physically counted and entered into the software as an inventory-level update. The

software generated this list from an algorithm that emphasized the level of movement and the occurrence of transaction activity. Higher levels indicate a greater discrepancy between the amount of inventory physically present and the amount of inventory on record in the software. Scheduled cycle counting, using the computer-generated recommended list, was strongly reducing OOS events. Therefore, a random cycle-counting procedure was introduced to validate the on-hand quantity of each 10th inventory item used against the level logged into the inventory software, thereby improving the accuracy of minimum and maximum levels.

The automated system with Six Sigma. For the automated system, inventory record inaccuracy was the area most in need of improvement. The RPN was 448, the highest of all RPNs generated during this stage. However, given the constraints of the current study, the team members were not permitted to use the inventory software as a tool to improve the system itself. Instead, staff members used supportive methods to improve the system. Staff members were trained to receive and place inventory in the correct location, with wholesaler-provided shelf tags installed for all inventory line items. This process was implemented to prevent the occurrence of phantom inventory.

Data Collection and Analysis

All prescription orders in the study environment originated from an electronic request received from a nursing facility and were entered onto the Out-of-Stock (OOS) Tally Sheet. Historical (pre-Six Sigma) data were collected for 64 business days, representing records from January 1 to April 5, 2011. We selected this time interval to align the start month with the January 2012 start date for the Six Sigma data collection. Each inventory control system under analysis was assigned a number. We drew numbers from a hat to determine the order in which the 3 Six Sigma systems were introduced. Data for the manual system with Six Sigma (Stage 2) were collected from January 23 to April 5, 2012. Data for the computer-assisted system (Stage 3) were collected from May 1 to July 16, 2012. Data for the automated system (Stage 4) were collected from July 17 to October 1, 2012. The time gap between Stage 2 and Stage 3 was due to the need to validate the on-hand quantities of inventory items prior to proceeding to the next stage.

We downloaded historical data to MS Excel, where daily OOS rates were computed. With each stage of the study, OOS events were recorded on the OOS Tally Sheet. An inventory item was considered OOS when it was physically unavailable for fulfillment of a prescription order.

OOS events were totaled daily and recorded as part of the data observation. As the study pharmacy was a closed-door pharmacy, all OOS situations were observed and recorded. The daily data collected included (a) the data

Table 2. Median Scores, Minima, and Maxima for Each System^a.

System	Mean (SD)	Median	Minimum	Maximum
Manual, pre-Six Sigma	4.95 (2.20)	4.63	1.74	14.65
Manual, with Six Sigma	4.01 (1.63)	3.70	1.58	11.94
Computer assisted	1.87 (0.56)	1.88	0.89	3.90
Automated	2.51 (0.66)	2.42	0.82	5.22
Total	3.34 (1.88)	2.84	0.82	14.65

Abbreviation: SD, standard deviation.

^an = 64 for each system; total N = 256.

observation number, (b) the date of observation, (c) the total prescription requests for the date of observation, and (d) the total OOS events observed on the observation date. These data were entered into an MS Excel spreadsheet. The daily OOS rate was calculated as the total OOS events divided by total number of prescription requests.

We downloaded data from Excel spreadsheets to SPSS (version 21) statistical software for analysis. Outliers, defined as OOS rates more than 3 standard deviations from the mean, were present in the data for all 4 systems. Therefore, we used nonparametric statistics for analysis. We used a Mann-Whitney *U* test to compare the OOS rates for the 2 manual systems (Stages 1 and 2) and a Kruskal-Wallis test to compare OOS rates for the 3 Six Sigma systems (Stages 2, 3, and 4). To correlate the day of entry with the OOS rate, we used Spearman's rank correlation coefficients. We used an α significance level of .05 for all analyses.

Results

Table 2 shows the distribution of OOS scores for all systems (manual without Six Sigma, manual with Six Sigma, computer-assisted, and automated). The computer-assisted system had the lowest mean OOS rate (1.87, standard deviation [SD] = 0.56), and the historical system (manual without Six Sigma) had the highest mean OOS rate (4.95, SD = 2.20, median = 4.63).

The OOS rate for the pre-Six Sigma system (Stage 1) was significantly higher than was the rate for the Six Sigma system (Stage 2), Mann-Whitney *U* = 1437.5, *Z* = -2.91, *P* = .004. The differences between the 3 Six Sigma systems (manual, computer-assisted, and automated) were significant, $\chi^2(2, N = 192) = 108.34$, *P* < .001. We then conducted post hoc pairwise comparisons to evaluate the difference between each pair of Six Sigma systems. The computer-assisted system (Stage 3) had a lower OOS rate than did the automated system (Stage 4), and the automated system had a lower OOS rate than did the manual Six Sigma system (Stage 2). All pairwise differences were significant, *P* < .001.

Finally, we performed time-series analyses by correlating the day of entry (from 1 to 64) with the OOS rate for

each system. For the historical system (Stage 1), the correlation was fractionally above the significance level, Spearman's $\rho(62) = -.24$, *P* = .051. For the manual system with Six Sigma (Stage 2), the correlation was not significant, Spearman's $\rho(62) = .17$, *P* = .18. For the computer-assisted system (Stage 3), the correlation was significant, Spearman's $\rho(62) = -.46$, *P* < .001. For the automated system (Stage 4), the correlation was significant, Spearman's $\rho(62) = -.30$, *P* = .02.

Discussion

The results of this study supported the conclusion that the assumptions of the orthodox EOQ model were insufficient for minimizing the OOS rate in a pharmacy environment. During the application of each value of the independent variable, these assumptions were violated numerous times. For example, demand was shown to be variable rather than constant. Replenishment orders differed daily. There were often shortages in the replenishment order from the wholesaler. The lead time was not constant, because there was not a scheduled delivery from the wholesaler on Saturdays and the pharmacy was not open on Sundays. Thus, Mondays were busier than other days in terms of the daily average number of prescriptions filled. These violations of the EOQ model assumptions represented a more realistic scenario of business operation than did the scenario assumed in the classical model.¹¹

The current study involved an examination of inventory theory based on the use of the OOS rate as the outcome variable. The OOS rate is a critical determinant of customer satisfaction in retail settings.³ At the same time, OOS events are the most difficult element of inventory control to determine because they often are undetectable and are therefore difficult to measure in most retail settings.¹⁷ In this study, the research setting allowed OOS events to be captured, observed, and measured accurately.

Inventory control systems have been shown to be flawed by inefficiency and inaccurate data. Theoretical models currently used in most inventory research studies were developed with the use of mathematical formulae based on unrealistic assumptions. These models are therefore unreliable and

inconclusive.¹⁸ This study was the first to offer a realistic and workable solution to pharmacy inventory control tested against the systems currently being used in the pharmacy industry. The OOS rate was a real-time metric used to analyze and evaluate empirical data. In contrast, in previous inventory studies, findings were evaluated with simulated data based on mathematical models of the EOQ formula and unrealistic assumptions. The findings of this study therefore represent an important contribution to inventory theory and to the knowledge base.

The Use of Six Sigma Methods

The solution to pharmacy inventory control offered in this study has also been examined under Six Sigma, a process improvement protocol, to determine areas of the system processes with potential for improvement. The identification of areas for improvement and the development of strategies to address these areas represent a contrast to the EOQ model, which addresses mathematical limitations by introducing unrealistic assumptions. The average retail industry OOS rate is 8.3%.³ The most likely cause of this high rate has been internal process failures, even among businesses using computer-driven systems. In the current study, the mean OOS rate in the manual system without Six Sigma protocols was 4.95%, whereas the mean OOS rate in the systems with Six Sigma protocols was as low as 1.87%. Thus, we found Six Sigma to be an important process improvement tool in the selected setting.

The findings of the current study suggest that OOS rates could be reduced across all systems of inventory control when Six Sigma process improvement methods are introduced. The study therefore supported Deming's theory that systems can be made more efficient by improving internal process design, or quality, rather than by relying on unrealistic models. The clearest illustration of this principle was in the comparison of the OOS rate for the manual pre-Six Sigma system (mean = 4.95) to the OOS rate for the manual system with Six Sigma (mean = 4.01). The implementation of Six Sigma, with the reduction of internal process variation, led to a 23.4% decrease in the mean OOS rate.

The results also indicated a significant difference in the OOS rate depending on the type of inventory control system used. Desselle and Zgarrick¹ previously argued that better inventory control was achieved using computer-driven systems. However, these arguments failed to include a metric to measure inventory control and failed to detail the level of computer-driven influence. In this study, we addressed both shortcomings in 2 ways. First, we used OOS rates as the metric to measure inventory control. Second, we partitioned the level of computer influence into 2 categories: (a) computer assisted, with user interaction allowed (Stage 3); and (b) automated, or completely computer driven (Stage 4). The results indicated that all inventory controls systems in

which Six Sigma techniques were implemented provided a decreased OOS rate when compared with the manual system with no process improvement implementation.

The analysis further indicated that the computer-assisted inventory system lowered the OOS rate more than did either the manual system or the fully automated system. This finding, although validating the argument of Desselle and Zgarrick that computer-driven systems improve inventory control, makes the argument more functional for real-world pharmacy managers by helping clarify the level of computer influence that should be implemented in the inventory control process to achieve the desired OOS level.

Time-Series Analysis

In addition to an analysis of the effectiveness of Six Sigma for improving pharmacy inventory control by reducing the OOS rate, the study involved an analysis of the relationship between the day of use and the OOS rate over the 11-week application of each value of the independent variable. The purpose of the analysis was to determine the improvement trend, if any, over the span of the application. Both computer-assisted and automated inventory control showed continued improvement over the 11-week implementation. However, the improvement for the manual pre-Six Sigma implementation (Stage 1) was only fractionally above the significance level, $P = .051$, whereas there was no improvement for the manual implementation with Six Sigma (Stage 2).

The reason for this discrepancy can be found in a closer examination of the data outliers, which we defined as data points more than 3 standard deviations above the mean. For Stage 1, the outlier cutoff was 11.55, and for Stage 2, the outlier cutoff was 8.90. When we removed the outliers from both sets, the maximum value for Stage 1 was 11.38, and the maximum value for Stage 2 was 6.84. Clearly, almost all OOS rates were substantially lowered when we introduced a Six Sigma protocol.

For the sake of argument, we removed all values exceeding 6.84 from both data sets and reran the bivariate correlations. We removed 9 items from the Stage 1 data set and 2 items from the Stage 2 data set. For Stage 1, we now found no significant correlation between the day of entry and the OOS rate, Spearman's $\rho(53) = -.10$, $P = .45$. For Stage 2, there was also no significant correlation, Spearman's $\rho(60) = .15$, $P = .24$. Thus, the higher values for the Stage 1 implementation entirely explained the marginally downward trend in OOS rates. The Stage 2 application lacked such high numbers and therefore demonstrated an improvement over the Stage 1 system, even though there was no downward trend in the data over time.

Finally, when we introduced the 2 computer-driven inventory control systems (Stages 3 and 4), a trend line was resumed. Stage 3 had a maximum OOS rate of 3.90, and

Stage 4 had a maximum OOS rate of 5.22. Despite these lowered numbers, the inverse trend continued downward across days of use. This study therefore demonstrated that either computer system compared favorably to either manual system in reducing the OOS rate.

Assumptions and Limitations

The current study included the following assumptions. We assumed that typical-case long-term care pharmacy selected for this study was representative of a broader population of pharmacies. The selection of the typical case was validated through benchmarking with data provided by representatives of the National Community Pharmacists Association.¹⁹

OOS data for a long-term care pharmacy are reliable. In most retail settings, the number of OOS events is difficult to measure because customers can enter the retail setting, encounter an OOS situation, and subsequently leave without making a purchase, all without the knowledge of either the retailer or the upper managers. Although retailers may be aware of OOS items, typically retailers cannot know how many lost sales occur daily as a result of OOS events. An OOS event can result in multiple lost sales if more than one customer intends to purchase the OOS item. In contrast, long-term care pharmacies are closed-door pharmacies, with no walk-in patients, and all requests for purchase are sent electronically. Pharmacy staff members in the study setting were able to match prescription requests with inventory availability accurately to determine the actual daily OOS rate. As a result, pharmacy staff members knew each time an OOS event resulted in a lost or delayed sale. Thus, we assumed the method of determining OOS events to be accurate and reliable. Additionally, we assumed that the sample of daily dispensing records used for this study was typical of the entire population of current and future daily dispensing records for the selected pharmacy.

An assumption of the study was that there was no carry-over effect on the size of total inventory from the end of one stage of implementation to the beginning of the next stage. We made this assumption because the size of the total inventory was calculated at the beginning and end of each stage to determine changes in the inventory level. Such an increase or decrease in inventory could have affected the OOS rate reported for any subsequent stage. Thus, an increase in inventory during one stage could have led to a lowered OOS at the onset of the next stage, with the lowered rate incorrectly assigned to the second stage. To guard against a carryover effect, a physical inventory was taken at the beginning of each stage to establish a baseline inventory level. Subsequent purchase and sales were computed with respect to the baseline level. The change of inventory was less than 1% during the entire study. As a result, we assumed that the carryover effect from any application of the independent variable was negligible.

An important limitation of this study was the quasi-experimental design. Results may have been affected by the order in which the independent variable was applied. The order of introducing the 3 Six Sigma systems was determined with a random drawing. We cannot know whether study results would have been different if the values had been introduced in a different order, or during a different time period or season of the year. In addition, because we examined only a single pharmacy, the results were not generalizable to other pharmacies in the United States.

Of note, changes in supply may have resulted from seasonal changes in demand for certain medications, such as allergy or flu medication. However, the purpose of the Six Sigma process is to optimize the management of OOS situations using internal inventory control improvements, regardless of external changes in demand. Thus, such shifts in demand, if observed, would have been accounted for in the data and addressed in the improvement process.

Conclusion

The EOQ model provides a baseline understanding of the variables related to inventory management. However, the model is not practical for real business scenarios, because assumptions underlying the model are unrealistic. In the current study, we approached the challenge of inventory control as a process decision and a process improvement challenge. Rather than repeating the trend of previous inventory studies, in which recommendations were made to manipulate the EOQ model assumptions, this study offered a solution that can be implemented in actual business environments.

The major practical recommendation arising from this study is that pharmacies use a computer-assisted inventory control system as the best way to minimize the OOS rate and thereby to improve customer service. The EOQ model failed to account for serviceability, a direct component of customer satisfaction. The only way to reduce stock and maintain high levels of customer service is to improve inventory control.²⁰

Wild recommended a priority system using an ABC analysis²¹ to focus inventory control efforts on the most critical inventory items. The ABC classification system is defined as follows: (a) A = 10% of stock, generating 65% of turnover; (b) B = 20% of stock, generating 25% of turnover; and (c) C = 70% of stock, generating 10% of turnover. An ABC analysis must be based on turnover, but adhering to the percentages of categorization is less important. An ABC analysis is designed not to provide differing levels of service but to provide customer service with the most efficiency and the lowest cost.²¹ ABC analysis is designed not to provide differing levels of service but to provide customer service with the most efficiency and the lowest cost.²¹ Wild's recommendation included the use of Pareto systems.

The practical application of the Pareto Principle for inventory managers leads to the classification of inventory items using the ABC method.

Computer-driven systems that allow user intervention enable the subtleties of inventory control.²² These subtleties are identified and triggered by ABC analysis and Pareto systems. This argument was validated in the current study.

The results of this study suggest that a computer-assisted inventory control system may allow the best opportunity for pharmacies to achieve inventory-influenced customer satisfaction by minimizing the OOS rate. Most pharmacy wholesalers can provide pharmacy managers with computer solutions that will allow them to implement a computer-assisted inventory control system at a minimal cost. One such system is Computerized Inventory Management, offered by Cardinal Health.

This study has practical implications for managers in diverse retail settings facing the challenge of successful inventory management. Inefficient inventory control systems lead to inaccurate inventory data, the leading cause of OOS events. By means of direct comparisons of inventory control systems in a retail setting, findings of this study address the gap in knowledge regarding the relative efficiency of these systems. Findings will enable data-driven managerial decision-making, rather than speculation, about inventory control processes. Managers will be more able to select the optimal inventory control system for improved internal efficiency, increased customer satisfaction, and increased profitability.

Declaration of Conflicting Interests

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