Proceedings of the 2007 Industrial Engineering Research Conference
G. Bayraksan, W. Lin, Y. Son, and R. Wysk, eds.

Inventory Accuracy Improvement via Cycle Counting in a Two-Echelon Supply Chain

Manuel D. Rossetti, Ph.D., P.E., Seda Gumrukcu,
Nebil Buyurgan, Ph.D., John English, Ph.D., P.E.
Department of Industrial Engineering
University of Arkansas
4207 Bell Engineering Center
Fayetteville, AR 72701

Abstract

Inventory record inaccuracy occurs when there is a difference between the actual and the recorded inventory. It causes excess inventory to be held in the system and thus adds to total supply chain costs. In this paper, we present a simulation for a two-echelon multiple item-type inventory system consisting of a distribution center and a retailer that both use cycle-counting as the corrective action. The model can be used to examine the costs of various cycle-counting configurations (scheduled cycle-counting, opportunity-counts) based on how often and how much to count. The results indicate that correct application of cycle-counting increases accuracy and provides significant savings for supply chains.

Keywords
Inventory record inaccuracy, cycle counting, supply chain, simulation

1. Introduction
Inventory accuracy is one of the key performance measures for retail stores that monitor inventory transactions on a continuous basis; however, most retail stores have inventory accuracy problems [1]. The errors within the inventory records can lead to problems in supply chain management such as, insufficient organizational planning and replenishment decisions causing low customer satisfaction and high operational costs. Inventory record inaccuracy is caused by the difference between the actual and the recorded inventory. The most systematic method of solving inventory accuracy problems, cycle counting, is a well-known approach used to manage inventory inaccuracy [10]. It is simply the planned continuous counting of a small set of items during a period. The objective of cycle counting is to determine errors in the process, as well as identifying causes for inventory inaccuracy. Most companies utilize it to achieve better inventory control in their business. It has various methodologies, each having advantages and disadvantages. In general there are four basic steps to cycle counting: determining the items to count, preparation for counting, counting the items, recounting variances, determining and documenting causes. Although it is widely used, the success of the method depends on its implementation. For more details on cycle counting, we refer the reader to Rossetti et al. [10], which gives a brief literature review of cycle counting and describes some of the methods and implementation requirements of cycle counting.

Kumar and Arora [6] suggest that inventory miscounts should be minimized to increase customer satisfaction. They investigate internal audit and cycle counting procedures for reducing inventory errors by developing a model that determines the optimal values for cycle counting frequencies. Morey [8] considers the effects of buffer stock, frequency of counts, and asset error rate on customer service level. Kok and Shang [5] discuss inventory record inaccuracy in a single stage inventory system with a single item. The study shows that "inspection adjusted base-stock policy (IABS)" is optimal for single period whereas, another cycle counting heuristic "Cycle Count Policy with State Dependent Base-Stock Levels (CCABS)" is nearly optimal for finite horizon.

Fleisch and Telkamp [3] develop a simulation model of three echelon inventory system with one product to reduce the total supply chain cost and the stock out level. The research concludes that eliminating inventory inaccuracy can decrease the total supply chain cost and the stock-out level. Under the (Q-R) policy, Kang and Gershwin [4] study two specific models of inventory systems as stochastic and deterministic. They revealed that if no correction is done, even a small error can cause big impacts on system performance.

Ordering patterns and replenishment decisions (replenishment quantity, frequency, time to reorder…e.g.) can affect the performance of the supply chain and lead to customer dissatisfaction and additional costs when the system has inventory record errors. If the error causes less actual inventory than recorded and the actual inventory is also less than the unit demanded, then an undesired stock out may occur. The additional costs here are stock out cost, reordering cost (after correction), overestimated holding cost (e.g.: space for non existing items), and possibly transportation cost. On the other hand, although there is less inventory than recorded, if the actual inventory is greater than the unit demanded, there is no stock out. This type of error will not be realized unless the discrepancy is found but there is still the cost of overestimated holding cost. In these conditions if the inventory recorded is checked and somehow found that there is an error and actual inventory after satisfying the demand is less than the reorder point, there exists the possibility of an additional reordering and transportation cost. If the actual inventory is greater than the records, then there exists an overstock cost.

Although applying cycle counting decreases or removes a considerable amount of inaccurate inventory costs, it is also an additional cost. Therefore, it is required to use this tool as effective as possible. It is necessary to decide when to count, how often to count and how much to count each time. Otherwise, the cost of applying cycle counting can be higher than the benefits to be gained. The literature commonly indicates that inventory record inaccuracy should be minimized to improve customer satisfaction and to decrease total supply chain costs. Generally cycle counting is utilized as a corrective action. A common aim is to find the optimum cycle counting frequency that gives the minimum total supply chain cost. One of the goals to be explored in our research is the cost of applying cycle counting. Although Fleisch and Telkamp [3], Kok and Shang [5] and Morey [8] discuss the costs of cycle counting, they utilized only one item in their models, they haven't considered the transportation between IHPs and neither tabulated the accuracy.

Rossetti et al. [9] constructed a simulation model to illustrate the effect of inventory inaccuracy within a single item supply chain consisting of two retailers, a DC and a supplier. Cycle counting was used as the corrective action. Two cases were modeled. In the first case, learning effects are modeled, which takes into account the fact that process improvements from cycle counting will occur over time. This should result in having less inventory record errors as a cycle counting program is operated over time. In the second case, one of the retailers does not cycle count. We call this situation the bad actor case. The results indicate that average system fill rate decreases significantly when error exists. When a learning effect is introduced into the system, fill rate increases in both cases and when a bad actor is introduced into the system, average system fill rate decreases significantly. This research paper extends the model developed in Rossetti et al. [9] in various ways. The most important extension is the examination of multiple item types in the system as well as a more general amount demanded process. In addition, transportation activity between the retailer and the DC is modeled in a detailed way rather than considering transportation just as a deterministic delay. Because, we have multiple item types, the model is able to provide the accuracy and discrepancy measures for the retailers across the item types. No models in the literature allow this calculation. Moreover, the total supply chain costs are included in the model as an addition to supply chain performance (e.g. system fill rates). The model is able to examine different cycle counting configurations while taking into account the trade-off between fill rates and system costs. Thus, the potential exists to use this model to determine the best possible configuration of cycle counting given a set of SKUs to cycle count. With this motivation, this paper illustrates the positive effect of cycle counting in a supply chain by utilizing the system, performance, and cost measures.

In what follows, we first give a basic overview of the system and the modeling issues included in the simulation model. Note that due to space constraints, we have not included detailed information concerning the Arena simulation model. We then illustrate the use of the model using a set of experiments to investigate the effect of cycle counting type and error type on supply chain costs. Finally, we summarize the research and present ideas for further research.

2. Overview of the System and Simulation Modeling Issues

Under an (R, Q) policy the basic model consists of a supplier, a distribution center (DC) and a retailer. Each demand at the retailer consists of a request for a random amount for a given type of item. When a demand occurs at the retailer level, the amount demanded is determined, and then the system checks for the availability of stock. If the stock on-hand is sufficient to satisfy the demand, the demand is filled and the quantity on hand is decreased. Otherwise, if the stock on-hand is not sufficient to fill the demand, the demand is partially fulfilled and the unsatisfied demand is considered as lost at the retailer level. The inventory position is updated each time after a regular customer demand occurs. When the inventory position falls under the reorder point, a replenishment order is placed. The order will be sent directly to the distribution center (DC). When the demand is filled at the DC, the stock will be transported to the retailer. Once the replenishment order arrives at the retailer the on-hand inventory will be increased. If the DC is out of stock, the entire demand will be backordered, and will wait for the replenishment from the supplier. Thus, the retailer will have to wait for extra time to get its replenishment. Trucks perform scheduled deliveries from the retailer to the DC. When a truck arrives to the retailer to satisfy a demand, a series of activities begins at the retailer level. In-store operations briefly include unloading the items, stocking them to the shelves and picking/reverse picking which take a certain amount of time for each item. Item type is important for the duration and the cost of the in-store and audit activities.

Two main types of inventory errors can occur in this system: stock loss error and transaction error. Stock loss error, described as the unrecorded loss of inventory because of shrinkage, destruction, theft, etc tends to occur more often at the retailer level due to theft and other causes [4]. Thus, we assume that stock loss will be negligible at the DC. Transaction errors are the errors that occur when the retailer receives any shipment from the DC or when the DC receives any shipments from the supplier. These types of errors are typical mistakes (typos, misprints, miscounts…etc.) associated with the transactions [4]. Both of these errors will cause various problems in ordering patterns and replenishment decisions (replenishment quantity, frequency, time to reorder, number of trucks, etc.) at all levels of the supply chain. The system under study will correct the inventory record errors with cycle counting. Cycle counting helps retailers to take corrective actions, and reduce the stock loss. As retailers perform cycle counting, the stock loss errors tend to decrease due to the learning of inaccuracy causes in each cycle count.

We consider two types of counting in our system: One is scheduled cycle counting, while the other is "opportunity counts" that occur when there exists an obvious opportunity to correct the records. The operation of the system can lead to two types of opportunity counts. The first case happens when demand occurs while there is actual inventory on the shelf but the recorded inventory is not enough to fulfil the demand. In a physical retail environment, this situation presents an opportunity to correct the record, because the customer can actually see the items on the shelf. The customer demand is satisfied although the record indicates lost sales; this presents an opportunity to correct the record. The second case involves the situation in which a demand arrives and there is not enough actual inventory on the shelf to satisfy the demand but the recorded inventory record is showing a positive balance. In this case, it is impossible to fill the customer demand fully because there is not enough stock available. This situation leads to lost sales although records show the opposite. This also presents an opportunity to correct the record. In addition to these two cases, in our system, we consider another possibility to count that is counting the items when recorded on hand is close to the reorder point. Since this type of counting lead to counting fewer items, we call them opportunity counts as well. For scheduled cycle counting, the correction of inventory records occurs only when a cycle count is performed regardless of opportunity counts. In this case, even though the opportunities mentioned above are missed, the records will be corrected via the next scheduled cycle count. Both counting/correcting options have advantages and disadvantages. The model allows the comparison of the cost/benefits of these cycle counting types as well as a comparison to a system which has no errors.

Once a demand occurs at the retailer, the model first checks the actual-on-hand inventory assuming that the customer can see the shelves in the store. If actual on-hand inventory is enough to satisfy the demand, the customer demand is filled and the recorded on-hand is updated. This occurs when the customer arrives at the counter to checkout. Every time a customer demand occurs, the system updates the inventory position (IP) and when the IP falls under the reorder point a replenishment order is sent to the DC. At that time, two scenarios can occur: In the first one, the recorded on-hand is not enough to satisfy the demand indicating a discrepancy. This indicates to the system that there is an opportunity to correct the records (opportunity count). The system does not wait to complete the opportunity count to send an order since counting is modeled as an activity delay. In the second scenario the recorded inventory is also enough to satisfy the demand, ensuring that there is no discrepancy. This time the system checks the IP directly without an opportunity count. Similarly, a replenishment order is placed if the IP falls under the reorder point but this time an opportunity count is also performed in order to utilize the shorter counting time of fewer items without any knowledge of an actual discrepancy. In addition, if the IP is greater than reorder point, the system makes an order only if the recorded on-hand inventory is close enough to the reorder point. Again an opportunity count will be scheduled. Moreover in the situation of lost sales, where actual on-hand inventory is not enough to satisfy the demand, the amount that is not filled is considered as lost sales at the retailer (partial fulfillment). The system then checks the recorded inventory and the steps mentioned above are followed similarly for both discrepancy scenarios. (Figure 1)

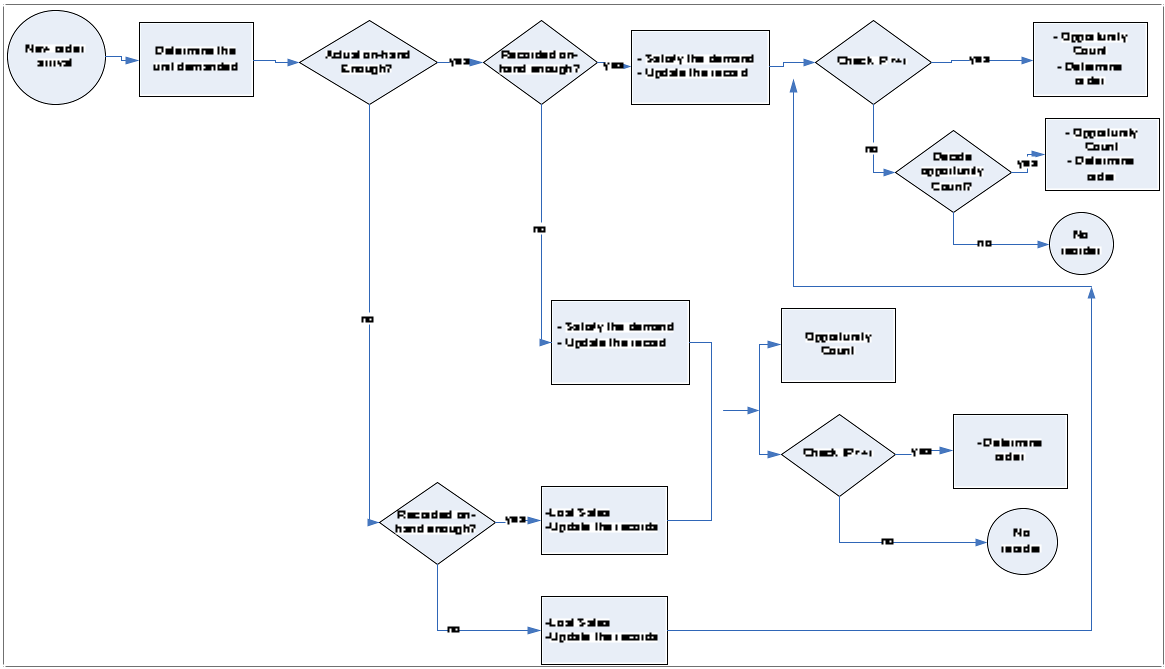

Figure 1: Retailer system

The orders at the retailer will be sent directly to the DC. The DC first checks the recorded inventory. If the recorded inventory is not enough to satisfy the demand, the entire order will be backordered, and will wait for the replenishment from the supplier. The actual on-hand inventory is checked only if recorded inventory is enough to satisfy the demand. If there is a discrepancy and actual on-hand is not enough, then the entire order is backordered. This extra situation occurs because of the errors in the system. In contrast, where there is no discrepancy then the order is filled and the system updates the IP to decide whether to send an order to the supplier or not. DCs perform opportunity counts when recorded inventory is close enough to the reorder point.

The time between arrivals of demand is assumed to follow an exponential distribution; hence the demand process is a Poisson distribution for the retailers. The demand process at the DC depends on the order frequency and order quantity at the retailer. All unsatisfied demands at the DC are backordered, conversely any demand that can not be satisfied is considered as lost sales at the retailer. The backorders are accumulated in a queue and they will be filled on a first-come-first-serve basis after the arrival of replenishment order. While no partial fulfillment of orders are allowed at the DC, the retailer accepts partial fulfillments since the system under study is a physical supply chain environment. Stock loss error is modeled as a compound Poisson process with a mean time between arrivals of stock loss events. Recall that stock loss error is described as the unrecorded loss of inventory because of shrinkage, destruction, theft, etc. All these reasons may depend on item type. Thus, stock loss error should also be related to the item type. For instance, heavy items can have less probability of being stolen. The amount of error is modeled with a Poisson distribution with its mean determined as a percentage of the mean total demand until the stockloss event. Since it is not possible to lose more than on-hand inventory, the amount of stock-loss is set to the current on-hand inventory, when the stock-loss error quantity is greater than the on-hand inventory. Transaction error is modeled as a series of probabilistic processes. Because transaction error is associated with the transactions, it does not depend on the item type. Therefore, we model transaction error independent of item type. But transaction error amount depends on the level; different order quantities in each level will cause different transaction errors. The chance of occurrence of an unintentional gain or loss is chosen as 50% and the amount of error follows a Poisson distribution with mean equal to a certain percentage of the order quantity. A learning curve is utilized to model the reduction in the errors via cycle counting. Mathematical equations with a logarithmic approach are developed to model this learning effect as a reduction in the annual rate of arrival of the stock loss. In other words, this equation explains the increase in the time between arrivals of the stock loss error. An 85% learning rate is used in the simulation. Cycle counting occurs at least once each year in order to cause the inventory control procedure to keep the system stable over time.

3. Results and Conclusions

The model was developed Arena and simulated for 2 years with a warm-up period of 360 days and 5 replications. We have executed the simulation models in 7 cases in order to validate the system structure based on system fill rate and yearly costs. System parameters for the simulation experiments are given in Table 1.

Table 1: System Parameters

System Parameter			
Retailer Reorder Point	12 units	Backorder Charge @ DC	0.2 $/$/year
Retailer Reorder Quantity	20 units	Handling Cost	1.00 $/unit
DC Reorder Point	25 units	Fixed Cost of Transportation	$15.00
DC Reorder Quantity	50 units	Cycle Count Cost	0.10 $/unit
Retailer Time Between Demands	Expo(0.2) days	Retailer Stockloss Error Time Between	Expo(0.35) days
Retailer Replenishment Delay	1 days	Retailer Stockloss Error Percent	20 %
DC Replenishment Delay	2 days	Receipt Transaction Error Prob. @ DC	0.01
Holding Charge @ Retailer	0.35 $/$/year	Receipt Transaction Error Prob. @ Retailer	0.04
Holding Charge @ DC	0.20 $/$/year	Time Between of Scheduled Cycle Counts	2 days
Stockloss Cost @ Retailer	3.00 $/unit		

Using the parameters in Table 1, the following experiments were performed (Table 2). In the first scenario, the system was executed without inventory accuracy errors in order to gather generic information about the system behaviour. Fill rate at the retailer and the DC are found as 86.29% and 98.81% respectively. When the system has stock loss error, which occurs at the retailer level only, the fill rate of retailer decreases significantly, whereas the fill rate of DC stays almost the same. As expected, the retailer's lost sales cost increases in a considerable amount compared to the other cost elements. In the third scenario, the system has only transaction error, which occurs at both the retailer and the DC level. Since having the transaction error is less likely than stockloss error, the transaction error has less impact on the system fill rate and the system cost. The fill rates at both the retailer and the DC decrease, which indicates increased stock outs at the retailer and backlogs at the DC. Thus, retailer lost sales cost and DC back order cost both increase. In the fourth scenario, where the system is under both, stockloss and transaction errors the system displays the worst system fill rates and costs. Notice that, the aim of this study is indicating the significant positive effects of cycle counting within the entire supply chain. As mentioned in the previous parts, two different types of cycle counting investigated in the simulation model. Once the system is introduced with scheduled counting, the fill rates at retailer and DC immediately increase to 82.56% and 98.31% respectively. It is obvious that, cycle counting will decrease lost sales cost at the retailer and backorder cost at the DC. On the other hand, cycle counting is also an additional cost. So in total, a system with scheduled count is more costly than system subject to both stock loss error and receipt transaction error without corrections. The trade-off between fill rate and total cost should be considered in order to decide to implement cycle counting due to the considerable amount of fill-rate increase. In another scenario, the records are only corrected with Opportunity Counts. This time, the fill rates didn't show the same increase as in scheduled count but it provides savings in the total cost. In our last experiment, both counting types are applied together, which gives the highest fill rates. The cost of this scenario is less than the scheduled count case because the total savings from the lost sales and backorder costs is less than the cost of cycle counting. Based on the parameters mentioned in Table 1 applying both counting types together seems as the most desirable option due to the higher file rates and total savings.

Table 2: Results

	System Fill Rate		Cost per year						
	Retailer	DC	Transport	Retailer Lostsales	Retailer Hold	DC Hold	DC Backorder	Cycle Count	Total
No Error	86.29%	98.81%	$11,670	$4,338	$13,882	$6,042	$648		$36,581
Only Stockloss	75.72%	98.27%	$11,895	$6,460	$13,702	$6,062	$652		$38,771
Only Transaction	76.07%	86.58%	$11,267	$5,152	$13,397	$6,026	$1,235		$37,077
Both Error	68.28%	85.43%	$11,415	$6,986	$13,420	$6,162	$1,336		$39,318
Scheduled Count	82.56%	98.31%	$11,792	$6,249	$13,664	$6,085	$687	$1,254	$39,730
Opportunity Count	76.73%	88.01%	$11,410	$5,128	$13,506	$6,085	$1,152	$338	$37,619
Both Counting	85.65%	98.60%	$11,754	$4,466	$13,885	$6,064	$672	$1,633	$38,473

Currently, the simulation model consists of 4 item types with similar characteristics. Future research will cover the effects of 12 types being low or high demanded. These experiments will yield intuition about which items are more worthy for cycle counting or which items should be counted more frequently, or which counting type is more suitable for a specific item type. Another extension will deal with the effort of hiding the effects of errors by adjusting reorder points and reorder quantities which increases the holding costs, thus adds to total supply chain costs. This could be another solution for inventory accuracy errors. Moreover, future work includes the analysis of the optimal timing and sample size for cycle counting programs within a supply chain in order to minimize cycle counting cost and inventory costs while still maintaining overall supply chain inventory record accuracy and customer service objectives.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. 0214478. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Reference:

1. DeHoratius, N., and Raman, A., 2006, “Inventory Record Inaccuracy: An Empirical Analysis,” Working paper, Graduate School of Business, University of Chicago.
2. DeHoratius, N., 2006, “Inventory Record Inaccuracy in Retail Supply Chains,” Working paper, Graduate School of Business, University of Chicago.
3. Fleisch, E., Telkamp, C., 2005, “Inventory Inaccuracy and Supply Chain Performance: A Simulation Study of a Retail Supply Chain,” *International Journal of Production Economics*, 95(3), 373-385.
4. Kang Y., and Gershwin, S. B., 2005, “Information Inaccuracy in Inventory Systems: Stockloss and Stockout,” *IIE Transactions*, 37(9), 843-859.
5. Kok, A. G., and Shang, K. H., 2004, “Inspection and Replenishment Policies for Systems with Inventory Record Inaccuracy,” Working paper, Fuqua School of Business, Duke University.
6. Kumar, S., and Arora, S., 1991, “Development of Internal Audit and Cycle-counting Procedures for Reducing Inventory Miscounts,” *International Journal of Operations & Production Management*, 12(3), 61-70.
7. Kumar, S., and Arora, S., 1992, “Effects of Inventory Miscount and Non-Inclusion of Lead Time Variability on Inventory Performance,” *IIE Transactions*, 24(2), 96-103.
8. Morey, R., 1985, “Estimating Service Level Impacts from Changes in Cycle Count, Buffer Stock, or Corrective Action,” *Journal of Operations Management*, 5(4), 411-418.
9. Rossetti M. D., Buyurgan N., Bhonsle A., Gumrukcu S., and Chittoori K., 2006, “An Analysis of the Effect of Inventory Record Inaccuracy in a Two-Echelon Supply Chain”, submitted to the *International Journal of Inventory Research*.
10. Rossetti M. D., Collins T., and Kurgund R., 2001, “Inventory Cycle Counting – A Review”, The *Proceedings of the 2001 Industrial Engineering Research Conference*, J. Rajgopal, K. Needy, Dallas, Texas.