

Inventory Cycle Counting – A Review

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Abstract

Accurate inventory records are an essential element in the effective use of enterprise resource planning tools and systems. This paper reviews the methods used in cycle counting and examines important issues involved in implementing a successful cycle counting program. In addition, we review the literature to discuss the effects of cycle counting in inventory planning and control as well as indicate potential areas for research.

Keywords

Inventory control, cycle counting, inventory record accuracy

1 Introduction

An inventory record, at a minimum, should consist of the following fields: *Stock number, location, quantity on hand, condition code*. Given the above fields, we can define a record as inaccurate if it has an error in any of the fields. For example, if the quantity on hand does not match the true item count. For the sake of materials requirements planning any discrepancy in quantity, location, and condition should be considered serious. Tersine [31] indicates that the primary goals of cycle counting are: to identify the causes of errors, to correct the conditions causing the errors, to maintain a high level of inventory record accuracy, and to provide a correct statement of assets. Through the proper use of cycle counting, inventory record accuracy above 95% can be consistently maintained. Springsteel [29] reported on a survey of 410 manufacturing companies by The Oliver Wight Companies. The survey performed by Brooks and Wilson, see reference [29] indicated an increasing trend toward the use of cycle counting with “36% of respondents using only cycle counting and 50% of respondents using both wall-to-wall periodic physical counting and cycle counting, with the remaining using only wall-to-wall periodic physical counting”. [29, pg. 18] Springsteel [29, pg. 18] reports that “20% of those firms using cycle counting achieved an (inventory record) accuracy of 98% or higher and more than 60% reached accuracies of 90% to 97%”, where inventory accuracy is defined as the ratio of the total number of accurate records to the total number of records examined. In this paper, we review the types of cycle counting methodologies used in practice. Then, we present a literature review of previous research in cycle counting. Finally, we conclude with areas for future work for this important topic.

2 Types of Cycle Counting

A variety of cycle counting methodologies can be adapted for use within an inventory control process. The primary methodologies include: random sample cycle counting, ABC cycle counting, process control cycle counting, opportunity based cycle counting, transaction based cycle counting, and location based cycle counting. Brooks and Wilson [5] discuss the advantages and disadvantages of cycle counting methodologies. In random sample cycle counting, a random sample from the population of inventory records is generated and the associated items are counted. The sample can be generated using sampling techniques such as constant population, diminishing population, diminishing population with timing so that each SKU has an equal probability of being selected.

ABC cycle counting is a variant of random sample cycle counting in which the population is stratified according to a Pareto analysis into three categories. The categories can be determined based on total annual usage dollars, frequency of issue, length of lead-time, criticality of equipment usage or other specific criteria that are relevant to the organization. The idea is to count more frequently those items that are important given the classification scheme. Class “A” items are counted more frequently than “B” items and class “B” items are counted more frequently than class “C” items. The determination of the frequency of counting within each category is typically

based on the subjective priorities of the organization. Typical count frequencies are 4 times per year for class A, 2 times a year for class B, and once a year for class C items. Given a total number SKU's in each category and the number of SKU's that can be counted per day, the number of cycle counters needed can be established and the counts scheduled over time. Within each of the categories, the items can be sampled using the methods discussed in random sampling, i.e. constant population, diminishing population, diminishing population with timing, until the appropriate number of counts per year is achieved. ABC cycle counting has some disadvantages. First, the counting workload is dependent upon the number of SKUs that are in inventory. In addition, the classification is primarily based on financial considerations. With respect to delaying production or shipments, items in the "C" category can be just as important as class "A" items. Thus, when employing ABC classification it is also useful to consider lead-time, usage, BOM level, and criticality in classifying the SKUs. If SKUs with other important considerations exist then they can be made class "A" items. The classification by total usage dollars can be used as a starting point in analyzing the counting requirements of the SKUs.

Process control cycle counting is discussed in Brooks and Wilson [5]. This method involves counting only items that are easy to count. Brooks and Wilson argue that while the method is "controversial in theory, it is effective in practice." This method depends on inventory records having an item count by multiple location, and that the listing be available to the counter *during* the counting. During the application of this method the cycle counter is free to determine whether or not to count at a location based on whether or not the item at a location is misidentified or miss located, whether or not there is an obvious discrepancy, or whether or not the item is easy to count. The inventory accuracy is then based on those SKUs that were actually counted and included in the sample, i.e. skipped items are not include in the sample. Process control cycle counting is faster and requires significantly less counters since less items may be counted. Sampling by location provides economies in movement during sampling. It has the disadvantage of allowing the counter to decide whether to count by providing the quantity on hand balance. This is not statistically unbiased in two ways. First the counter can decider whether or not to count the item. Second, the counter will not be performing a "blind" count. One may also argue that certain items may never be counted, but this can be alleviated by recording those items that have not been counted (i.e. skipped) and scheduling a count for those items to meet any regulatory requirements. Brooks and Wilson [4] recommend this approach to cycle counting. Their analysis indicates that while the sampling is biased, it is biased towards those items with the greatest probability of containing errors.

In opportunity based cycle counting, counting is performed at particular key events in the process. Counting might be scheduled for: when an item is reordered, when an item is stowed, when the balance drops below a threshold, or when an item is issued. In transaction based cycle counting, counting is scheduled based on the number of transactions experienced by a SKU. For example, we would count a SKU after every 5 transactions. For each of these types of cycle counting methods, the frequency of counting and deciding which items to count are important decision parameters.

Location based cycle counting is very similar to process control cycle counting except that the counter is not given the record count and has no discretion with respect to the ease of counting. A sample area is chosen and every item in that area must be counted. A disadvantage of this method (as well as process cycle counting) is that the characteristics of the items are not used to form the sample. The sample is formed by location. Location may be irrelevant with respect to the needs of production or distribution functions. Large organizations, see Backes [3], often use combinations of the above methods.

3 Previous Research in Cycle Counting

In this section, we review previous literature in the area of cycle counting. The literature can be broadly classified into the following areas: case studies of companies using cycle counting, improvements to cycle counting methods, statistical issues in cycle counting, and cycle counting with respect to inventory policy and control techniques.

3.1 Case Studies

A variety of case studies have discussed the advantages and disadvantages of using cycle counting. These papers primarily appear in trade and professional magazines such as *Distribution*, *IIE Solutions*, *Supply House Times*, *Systems 3X World*, *Automatic I.D. News*, etc. For example, Kulas [14] describes the use of cycle counting techniques at an electronic automotive parts manufacturer. In the case study, cycle counting is discussed within the context of a MRP II and JIT environment. As with many cycle counting case studies, the installation of a cycle

count program is described in order to improve inventory record accuracy. Errors in inventory records can result in part shortages and line shutdowns, the carrying of excess inventory, and unreliable inventory valuations. In a MRP II environment, accurate inventory records (95% accurate and above) are a prerequisite for successful operations because of MRP's reliance on inventory to schedule production. Kulas [14] describes the use of ABC analysis to first classify the inventory. Counting tolerances were then set. Then, count frequencies and performance goals were established. The company started with an ABC cycle counting program because of the simplicity of the method. After initial success, the company moved towards a JIT environment in order to reduce the amount of inventory carried. A side benefit of JIT was also a reduction in the amount of cycle counting. The company implemented a point of use storage system as part of their JIT efforts. Because the parts are now on the shop floor and not within an access controlled environment extra care was taken during cycle counting and cycle counting had to take place during non-production time periods in order to ensure no activity on the part numbers. Finally, the company had to switch from an ABC cycle counting methodology to a location-based cycle counting methodology where the locations were defined by the part storage areas supporting the production lines. The counting frequencies had to be customized based on the inventory accuracies found for each production line and tolerance levels had to be loosened because of the lower levels of inventory and higher number of inventory turns. The company was able to move from dedicated cycle counters to using production personnel for counting because of strict transaction control by warehouse personnel, training, and accountability of the warehouse supervisor to reasonable inventory accuracy metrics. Reference [2] discusses the importance of including inventory accuracy as one of the key performance metrics related to inventory management.

The papers by Meyer [19, 20] present a case study for improving inventory accuracy at a manufacturing company. In particular, inventory accuracy went from 65% to 95%. Through a cost analysis, Meyer [18] concluded that attaining the 95% inventory accuracy level saved the company approximately \$3 million per year and the cycle count program saved \$30,000 per year in counting costs.

3.2 Improving Basic Cycle Counting Methods

Wilson [32], Stahl [28], and Pfaff [25] all discuss the basic procedures involved in implementing cycle counting. Stahl [28] presents cycle counting as a quality assurance process emphasizing the finding and correcting of errors. An important aspect of this process is control group cycle counting. In control group cycle counting, a small representative group of stock keeping units is identified and cycle counted on a regular basis to identify process errors for corrective action. Control group cycle counting is usually used before fully implementing a complete cycle count program. The use and setting of tolerance levels is also discussed in Stahl [28]. Tolerance levels are set to determine whether or not a count on a record is accurate. If the physical count is within the counting tolerance then the record is considered accurate. For example, it is often unnecessary to count a low value easily obtainable item (e.g. bolt) with zero tolerance. Stahl [28, p. 23] recommends the use of the following factors: "value, usage, lead-time, method of counting, critical nature, and BOM level" in determining the tolerance levels. APICS [1] recommends that class A, B, and C items have tolerance of 0.5%, 1%, and 5% respectively.

Other articles propose basic enhancements to cycle counting procedures. Pfaff [25] illustrates the important notion of using multiple criteria to determine the strata for ABC cycle counting. Bergman [4] presents a multiple criteria weighting system by which each SKU is ranked according to common usage across the BOM, lead-time, method of issue, and number of issues. Each of these factors is mapped to a common scale and each part is rated and then classified. Flores and Whybark [9, 10, 11] formally extend the ABC analysis based on usage and dollar value to include non-cost factors such as certainty of supply, impact of a stock out, and rate of obsolescence. Multiple criteria ABC analysis employs a joint criteria matrix to reclassify the categories into AA, BB, and CC by weighing numerical combinations of the criticality and dollar value criteria. Joint criteria examples include the lead-time, dollar usage matrix, the obsolescence, dollar value matrix, and the criticality, dollar value matrix. These factors may outweigh the dollar-usage factor, especially when the potential to halt production is considered.

Other authors, see Lavalley [15] and Orozco [24] argue that ABC cycle counting is inefficient. Lavalley [15] presents an implementation of cycle counting by location that includes the basic forms and procedures to use during the cycle counts. Lavalley [15, p. 82] states that cycle counting by location "results in 10-15 more counts in the same period of time as random sample counting and ABC cycle counting." The efficiency is gained through better planning of cycle counting trips. Orozco [24] makes a strong case against ABC cycle counting based on the argument that inventory record errors can only be introduced when an inventory transaction occurs. He argues that cycle counts should only be performed for those items that had any activity since the last cycle count. Then, items

should be scheduled for a count considering “the most practical moment in time that results in minimum waste and maximum labor productivity.” With appropriate computer support, cycle counts can be interleaved with other trips to allow for optimal trip planning. Because of his activity view, Orozco suggests that dedicated cycle counters can be eliminated and that cycle counting can be handled via warehouse personnel.

3.3 Statistical Issues in Cycle Counting

Statistical sampling forms the basis for many of the cycle counting techniques. Buck and Sadowski [6] illustrate the use of optimal stratified sampling to form strata based primarily on the dollar value of the item. Their emphasis is on finding the minimal sampling plan that guarantees a certain level of statistical confidence in financial reporting. They provide formula for determining the optimum number of strata and the number of observations per strata. They compare their results to ABC cycle counting. Care must be taken in using their method to prevent over sampling (where the theoretical sample size exceeds the actual strata population) within high dollar value strata. Limitations of their work include no guarantee that all inventory item types will be counted during a cycle and an over emphasis on financial control. Tayi [30] developed a similar approach to that given by Buck and Sadowski. Tayi criticizes standard applications of cycle counting (ABC method, etc.) as providing no statistically supported statements concerning inventory record accuracy. Tayi’s approach performs sampling of dollar value items via location. Martin and Goodrich [18] criticize Buck and Sadowski as presenting only a theoretical approach. They develop a “more practical” approach to determining the strata by applying the cumulative square root rule developed in Dalenius and Hodges [7]. The authors caution that their approach does not consider Type II sampling error. A key deficiency of these approaches is that they are based on aggregate dollar value which masks individual errors. Ernst et al. [8] present the tracking of average absolute error of monetary value via control charts.

Sheppard and Brown [26] used discriminant analysis to analyze the key factors that cause errors in inventory records. They conducted a field experiment at an electronics manufacturer to assess the following factors: number of transactions experienced by a SKU, quantity per transaction, total quantity on-hand, weigh-counting, total dollar value of the stock, item value, and part commonality in the BOM. They found evidence “that item value, dollar value of the stock, and quantity on hand do play a role in determining the likelihood of error.”[26, pg. 48] They also found that low value high volume items had a lower accuracy. Surprisingly, they did not find that the number of transactions or the quantity of the transactions caused increases in inaccuracy; however, this may have been due to the transaction control procedures used within the company under study.

3.4 Effects of Cycle Counting on Inventory Policy and Control

As indicated in the literature, many factors can affect the determination of an efficient cycle count program. A set of articles, Iglehart and Morey [13], Morey [21], Young and Nie [33], Neeley [22, 23] examine the tradeoffs between inventory record accuracy, inventory costs/policies, and cycle counting frequencies. In Iglehart and Morey [13], the authors attempt “to select the type and frequency of counts and to modify the predetermined stocking policy so as to minimize the total cost per unit time subject to the probability of a warehouse denial between counts being below a prescribed level.”[p. B-389] Their approach is to formulate a cost function for a periodic review inventory situation and ensure that sufficient buffer stock is available to handle an accumulation of discrepancies over a period of time. In a similar paper, Morey [21] develops a model that can determine “the impact on overall service levels due to changes in buffer stock, cycle count frequency, and asset error rates.” Morey develops an equation for $MAPL(B, n) = P\{D_L + M_n < \mu_{DL} + B\}$ where B is the buffer stock, n is the number of periods between counts, D_L is the random demand during lead-time, M_n is the maximum of the average error, and μ_{DL} is the mean demand during lead time. MAPL represents the minimum actual protection level. Subtracting the MAPL from one yields probability of that an asset error in conjunction with demand during lead-time will exceed the mean demand during lead-time and the available buffer stock. Morey’s final results are based on normal approximations for the demand during lead-time and the asymptotic treatment of the partial sum of accumulated errors. Young and Nie [33] formulate a total cost model that includes stock-out cost, cycle count cost, purchase order cost, inventory holding costs, and annual costs of the items. They studied, through the use of simulation, the affect of changes in cycle counting frequencies on an EOQ based inventory system and an ABC based reordering system.

Neeley [22, 23] takes a different approach by formulating the process by which a record becomes inaccurate as a two-state Markov chain. In his analysis, a record can either be accurate or inaccurate (based on count discrepancies). His analysis allows the selection of the time between cycle counting in order to maintain a certain desired accuracy. In essence, Neeley determined that the cycle length can be computed based on the single step

probability of becoming inaccurate given the record was accurate and the desired steady state probability of accuracy. Neeley [23] also discusses the importance of basing this decision on the number of SKU transactions.

Kumar and Arora [17] examined the effect of inventory record inaccuracy and lead-time variability on a single echelon inventory system utilizing a reorder point, R , and reorder quantity, Q , policy. Their approach was to substitute an inaccurate inventory position into a standard (R, Q) inventory model, see Silver, Pyke & Peterson [27] for determining the optimal reorder point policy for a prescribed service level. They derived the system-wide (across multiple items) net holding cost in terms of the relative error of inventory miscount. Their work showed that service levels were not being met due to inaccurate inventory records in conjunction with stochastic lead-time for the service parts management company that they considered. Kumar and Arora [16] presents a method for determining the optimal cycle count frequencies given the inventory counting costs, penalty for the magnitude of the error, demand rate for the item, economic lot size, and mean error rate of the records. They also suggest control procedures to be used during the inventory process.

4 Conclusions and Future Research

Recent benchmarking research by the authors of over 20 companies indicates that best-in-class performance in inventory record accuracy is achieved by those companies that perform cycle counting. Best-in-class performance of 99% and above inventory record accuracy was achieved by those companies that dedicated appropriate resources to cycle counting, that had advanced computer system support, and that emphasized finding and eliminating common process errors. We found that best-in-class companies did not use or emphasize the use of statistical methods (stratified sampling, control charting, etc.) in order to maintain inventory accuracies above 99%. Their key interests in this field lie in ensuring and enforcing appropriate policies and procedures and in determining the appropriate amount of resources necessary to maintain high inventory accuracy.

After a review of over thirty years of research in the area of cycle counting, we can make the following conclusions. First, cycle counting is clearly the dominant method and best practice for maintaining inventory record accuracy. Second, there are still open issues concerning the relative effectiveness of the basic strategies of cycle counting (e.g. ABC method, process cycle counting, location sampling, transaction sampling, opportunity sampling, etc.) In other words, under what conditions should a company decide to use a particular strategy or a particular set of strategies and how effective are combinations of these strategies under a wide variety of conditions. Third, the effect of inventory record accuracy has been examined within the confines of single echelon inventory systems, but has not been examined within the context of multi-echelon inventory systems or supply chains. A quantification of the importance of cycle counting within the members of a supply chain has not been established in terms of overall total inventory and logistics costs and the effectiveness in maintaining inventory accuracy.

Current research is in progress on each of the above issues. Companies are interested in the cost/benefit trade-off associated with cycle counting. A comprehensive follow-up benchmarking study is underway to detail the activities and costs associated with cycle counting. This will provide the direct and indirect cost elements that are important to cycle counting. Detailed process descriptions of cycle counting techniques are under development. From this study a cost estimation model will be developed so that organizations can understand the cost associated with utilizing one or more of the common cycle counting techniques. Secondly, a multi-echelon inventory simulation is under development. The purpose of this model will be to provide an understanding of the impact of cycle counting in a supply chain. The model will include a mechanism for introducing inventory record errors consistent with the findings in reference [23], [24], and [26]. The model will predict the total logistics cost including (inventory, transportation, and cycle counting) for a supply chain and for the individual components (retailers and warehouses). In addition, the model will examine the effect of different cycle counting policies, e.g. transaction-based, activity-based, etc., and assist in setting cycle count frequencies to maintain appropriate levels of inventory record accuracy.

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