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APPLIED CYCLE COUNTING METHOD FOR GROCERY RETAIL INDUSTRY

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ABSTRACT

Grocery stores play an important role in people's daily lives and they have one of the most complex inventory systems for management. Most grocery stores start using the computer based inventory management system nowadays to manage their inventory replenishment. More importantly, they use floor level cycle counting frameworks in different stores to secure inventory accuracy. However, there always are mismatches between computer counting and physical counting, which causes inventory inaccuracy and out-of-stock problems. This thesis will seek to develop a modified cycle counting method based on analyzing an industry leading company's current cycle counting methods. The revamped cycle counting method should reduce the attempts for physical cycle counting by classifying products into different categories, which will not only decrease the cycle counting cost but also increase the efficiency and accuracy of the overall procedure. This thesis will also conclude by offering recommendations for future research including a more statistically based template to deal with uncertainties occurring in different stores, to achieve an optimal cycle counting standard to use in the grocery industry.

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Chapter 1

Introduction

The grocery industry is one of the most critical and diverse industries in the modern marketplace. Grocery stores are playing an important role in people's daily lives and they require highly-efficient and accurate supply chains to manage their suppliers in order to satisfy all customers. Following the technology boom, the increasing availability and transparency of information systems as well as having consistent enterprise data have become essential for stores to win over the market and customers. An accurate inventory database will help stores save money in inventory holding costs and transportation costs. Most importantly, it will meet customers' demands.

Cycle counting becomes one of the solutions to reinforce effective inventory management. Based on the general definition, cycle counting is the process of continually validating the accuracy of the inventory in a system by regularly counting a portion of inventory in the store on a daily or weekly basis (Hurlbut, 2017). Theoretically, the more frequently cycle counting happens, the better the inventory accuracy rate and the healthier the supply chain. However, in reality, cycle counting has many drawbacks due to unanticipated demand, human errors, and time constraints. Therefore, conducting a more effective cycle count becomes a challenge for the majority of grocery stores.

Currently, there are three popular types of cycle counting: Control Group, Random Sample, and ABC analysis that can be used for different supply chain functions. ABC analysis is the most demanded method by warehouses. Getting correct counting data is only the first step. Matching physical counting data with computer-generated data complicates the problem. Deciding how to eliminate human errors during data entries and data checking processes for cycle counting becomes another big challenge for the grocery industry, especially with such a high inventory volume.

There are many case studies and theories on how cycle counting helps companies to reach their successful operations with lean concepts. This thesis will use an industry-leading company as an example by analyzing their current system data to find special patterns in order to seek a more practical cycle counting procedure to decrease data mismatches and improve their inventory accuracy rate. The thesis will conclude with recommendations and a more effective cycle counting procedure for grocery stores in order to maintain a more cost-efficient supply chain by decreasing inventory holding and transportation costs while increasing shelf fulfillment and customer satisfaction.

Chapter 2

Literature Review

Before discussing methods of the cycle counting process, it is critical to first examine the background and driving forces behind company A's current operational system and the purpose for cycle counting in supply chain management. Getting to know the background will not only help to diagnose current issues but also help to develop a more accurate and efficient cycle counting process.

Company Background

Company A is a privately held regional supermarket chain with more than ninety stores. Most company stores contain large areas with a variety of foods aimed at an upscale clientele and the in-store dining area provides customers an experience to taste their freshest food. There is an advanced computer ordering system applied in every store that company A owns. The computer system will automatically place and track orders in order to maintain a healthy inventory level. However, mistakes happen occasionally and the stores need to employ cycle counting to fix the mismatch. At the store level, they provide two types of cycle counting: zero count and high count. Zero count is the only required count when there are empty spaces for items on the shelf, or when there are only a few items left on the shelf. As for high count, it is an optional count for checking the accuracy of items when the store believes the system is ordering more inventory than it needs.

Computer Assisted Ordering System (CAO System)

As mentioned previously, company A utilizes an industry-leading computer assisted ordering system (CAO system) software to help its store level inventory management by tracking its real-time perpetual inventory, performing advanced consumer demand forecasts and generating sophisticated ordering algorithms. The robust data model integrated all product information (seasonality, promotion, special events, etc.) that relate to the system and adjusts forecasting and order quantities based on internal factors and product needs. In addition, to keep the supply chain effective and efficient for company A, the CAO system also helps to detect inventory flaws during cycle counting. The CAO system will keep tracking the perpetual inventory followed by point of sale (POS) strategy to minimize inventory related costs, as shown in figure 1. Company A performs "high/low" count, which is based on shelf and backroom capacities to quickly and efficiently identify inventory errors by checking items with excessive or insufficient inventory (RIS, 2015). By comparing the real count number with the computer system data, company A can determine the problems that exist in the current inventory management process in order to improve its overall operation system.

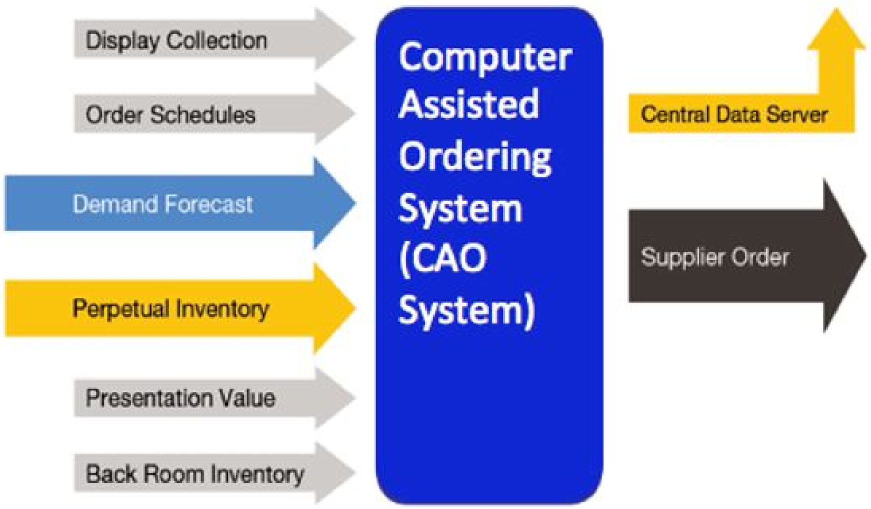

Figure 1 Computer Assisted Ordering System

Cycle Counting

According to the online document "A Statistical Process Control Approach to Cycle Counting for Retail Environment" cycle counting in the industry is a proven methodology used to check and monitor inventory accuracy through continuous verification of inventory (Yu ,2006). Unlike traditional physical inventory counting that requires shutting down the store and counting all items in house at one time, cycle counting happens periodically and is based on the shelf capacities. In other words, cycle counting can happen anytime depending on the store operation condition. Optimized cycle counting can pinpoint mismatches between on-hand units for a given stock keeping unit (SKU) and system-recorded inventories. However, finding the right approach for cycle counting is challenging. Cycle counting is a way to fix the mismatch but it also is a way to cause further inventory inaccuracy if one applies the wrong cycle counting methods. The key to getting the right inventory record is to have a high inventory record accuracy (IRA) rate. There is a question that is generated from the cycle counting methodology: should the entire population be counted or should samples from different categories of products be counted?

According to the book, *Inventory Record Accuracy*, it indicates that sampling has been shown to yield more accurate results than a survey of the entire population – and at much less cost (Brooks & Wilson, 2007). However, this is not always true if the sample itself cannot represent the entire population well. In the book, it provides two characteristics of a good sample: the size of the sample relative to the population and the stability of the sample (Brooks & Wilson, 2007). In other words, selecting a good sample for cycle counting is critical - it cannot be too small, because a small sample will not be able to represent the entire population thoroughly; and it cannot be too large, because a large sample will lose the purpose of sampling. Moreover, the sample has to be reliable and relatively stable, which means it cannot be affected by the fluctuation of overall product populations or market promotions.

No matter how accurate the cycle counting is performed or how perfect the samples are, there are always errors in the cycle counting process. Even though the purpose of cycle counting is to reinforce inventory accuracy, errors in cycle counting are essential for defining the root cause of the existing inventory problems. Simply correcting inventory errors can fix the inventory problems once, but cannot change the overall inventory performance in the long run. Therefore, utilizing errors found from the cycle counting is an approach to explore further into the root cause for the errors. Instead of adjusting numbers for the inventory, changing the behavior of managing the inventory will be a practical solution for fixing inventory mismatch and inaccuracy.

There are four commonly used cycle counting techniques: control group cycle counting, random sample cycle counting, ABC cycle counting, and process control cycling counting (Brooks & Wilson, 2007). Traditional ABC cycle counting and process control cycle counting are more focused on warehouses and distribution centers. Control group cycle counting and random sample cycle counting can be possible techniques to use for store level cycle counting; however, modified ABC cycle counting can do the same thing.

Control Group Cycle Counting

Control groups are typically used in the scientific community for things such as testing new drugs, examining new diet plans or learning different human behaviors. Control group cycle counting is based on the similar purpose to test new inventory processes or to detect problems within the current inventory management process. This method can be implemented based on the following five stages: identifying the control group, and making sure these items represent a cross section of the inventory; counting the control group; setting the inventory records equal to the counts; recounting the control group in exactly the same location after a three to five-day interval; and, comparing the recounts to the updated inventory records (Brooks & Wilson, 2007).

In order to identify the problem, it is critical to set the current actual quantity matches with the record quantity (computer system record) equal for the first time the group is counted. After certain counting intervals, by comparing the differences between the actual quantity and the record quantity, discrepancies that existed in the process can be identified. In addition, instead of fixing the mismatch immediately like the usual cycle counting process, for the control group cycle counting, counters need to leave the mistakes before the entire counting period ends. This is because issues with the current process can be found by investigating specific error patterns. However, there are some troublesome situations that occur during control groups cycle counting that require additional investigation. For example, an error may occur due to the fault of careless stock pickers, or system failure for the computer system. It will leave unequal matches between actual quantity and record quantity in the absence of any reported transaction records (Brooks & Wilson, 2007).

The main purpose of control group cycle counting is to test the performance of current cycle counting and to check on the efficiency and accuracy of the current operational system. Thus, it should be done prior to starting another type of cycle counting. Moreover, depending on the overall stock keeping unit (SKU), the control group for testing could be varied.

Random Sample Cycle Counting

Just like the name states, random sample cycle counting selects samples from the population at random. It increases the uncertainties for a testing result, but it provides equal opportunity for every product in the system to be in the sample counting group.

Table 1 is an example to demonstrate the equally distributed opportunity for random sample cycle counting:

	Sampled	*"Hits"*	*Accuracy (%)*
Monday	50	50	100
Tuesday	50	49	98
Wednesday	50	48	96
Thursday	50	48	96
Friday	50	49	98
TOTAL	250	244	97.6

Table 1 Sampling Fifty Part Numbers Per Day for Sample Accuracy

Visualize a population of 1,000 item numbers. A number is written on a Ping-Pong ball and placed in a large bucket, then the balls are mixed in the bucket. A blindfolded person will randomly draw fifty balls, and the fifty balls will be considered as the random sample. The figure above shows the five days of random sample cycle counting, and the total number 250 is the random sample for the overall population of 1,000. According to different tests, random sample cycle counting is generally accepted as the best measure of inventory record accuracy if the sample has stability and if it is sufficiently large (Brooks & Wilson, 2007). The above diagram shows the result for the 250 samples, and the 97.6 percent accuracy is trustworthy, because of the uncertainties among samples and the accuracy rate per each draw is relatively close with no outliers.

There also are two different ways to select the random sample: constant population technique and diminishing population technique. To explain the difference between these two random sampling techniques, the previous Ping-Pong example can be used. The constant population technique means when the first fifty Ping-Pong balls are selected they are put back into the basket and they will have an equal chance to be selected for the next draw round. As for the diminishing population technique, it has a similar drawing process to the constant population technique. The only difference is after the fifty balls get picked from the basket, they are not returned back to the basket. After the first draw for the fifty balls randomly, the next drawing will happen among the 950 balls instead of 1,000 balls as the overall population. This technique will ensure all products get selected for being in the sample group if time allows.

Figure 2 shows pros and cons between the constant cycle counting and diminishing population counting, which helps identify the purpose for each cycle counting method.

	Pros	Cons
Constant Population Cycle Counting	• Sufficient outcome • Stay with the same population	• Possibility that some parts may be repeatedly sampled whereas other may never be sampled
Diminishing Population Cycle Counting	• Ensure to count all parts • Avoid repeat counts	• Time consuming (if want to count all parts) • Each part is counted unevenly as the counter cycles through the entire population

Figure 2 Constant Population vs. Diminishing Population Counting

ABC Analysis

Many classical ABC classification methods are incomplete and are not suited for store level inventory management. The ABC classification's major approach is by assignment of the SKUs, figure 3 shows the general concept of ABC classification. The idea behind the classification is based on the 80/20 rule, which means eighty percent of the volume in the warehouse comes from only twenty percent of the SKUs. The concept is interchangeable at the store level, in which eighty percent of the revenues for the stores comes from the twenty percent of the SKUs. In this case, the SKUs that fall into the eighty percent revenue category will be graded as class A, from eighty percent to ninety-five percent will be graded as class B, and the rest will be class C. Based on the number value ratio, the “A” items will require a more frequent cycle count than the “B” and “C” items.

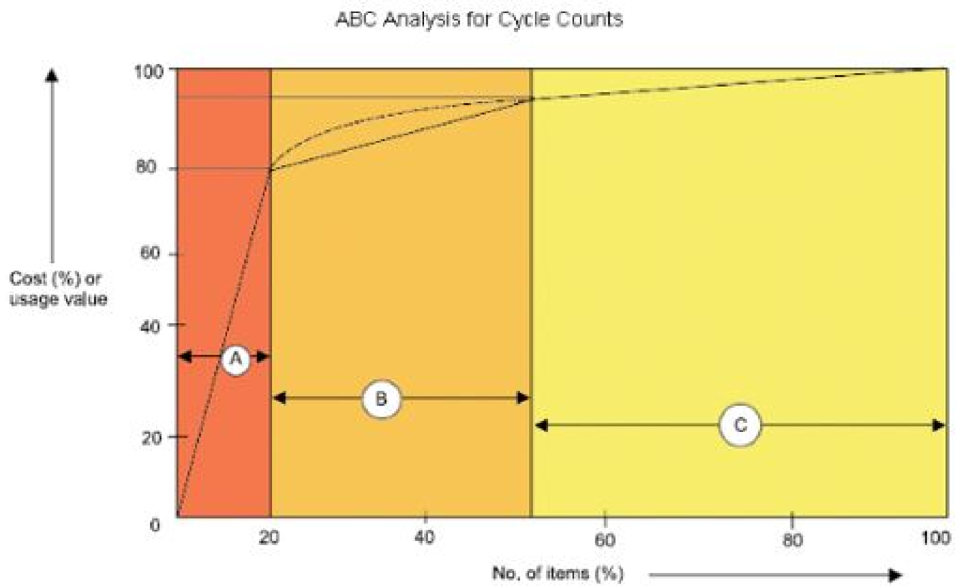

Figure 3 ABC Analysis for Cycle Counting

For the ABC cycle counting method, the best time to perform a cycle count is when the inventory is at its lowest level. Here are some guidelines for cycle counting time:

- A replenishment order is received
- The actual inventory record has a zero or negative balance
- Reorder is indicated by a computer system
- Cycle counting performed by counters

Counting in the low inventory level not only increases the speed for cycle counting, but also minimizes room for errors (REM, 1999).

Strategy and Framework

No matter what cycle counting method the company implements, it will be the most effective in a closed loop process as shown in figure 4, followed by the following steps according to the APICS Magazine, September/October 2016 edition

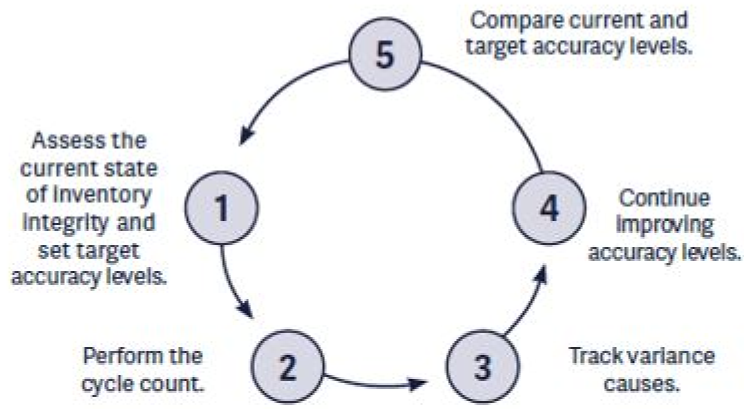

Figure 4 Cycle Counting Feedback Loop

1. *Assess the current state of inventory integrity and set target accuracy level*

Generally, the first step for cycle counting is to determine the accuracy level of the current inventory. Most computer systems will help generate the forecast to help determine the right level of accuracy and the real target accuracy level can be established based on the computer data. Inventory managers should validate key inventory control elements such as product shelf locations, inbound and outbound process, picking, restocking and transaction touches. After setting the parameters of inventory integrity, based on inventory type, operation managers should design a plan for which cycle counting method to use. Coming up with questions such as: who are the people to perform cycle counting? How many items are counted in a daily basis? What is the cycle counting criteria?

2. *Perform the cycle count*

After a comprehensive cycle counting process is designed, the cycle counting implementation occurs. Depending on the cycle counting criteria the team established prior, SKUs are picked from across categories to start the cycle counting.

3. *Track variance causes*

In most cases, the results for cycle counting will be submitted to the computer system that will perform the analysis automatically. People who are taking charge of the inventory management or cycle counting are responsible for assembling the results. They identify the acceptability of the counts and investigate and assign possible reason codes for these variances, and then perform reconciliation transaction updates. Most importantly, working with store managers and operation managers to troubleshoot the root causes of variances is critical.

4. *Continue improving accuracy levels*

As the cycle counting process proceeds through time, the store system must track the changes for cycle counting accuracy rates. As the cycle counting process takes firm root in the organization, hopefully, it shows an improvement in the inventory accuracy rate. However, if the rise is not significant or does not meet the standard goal, then it is possible to switch to a different cycle counting method and restart the process again.

5. *Comparing current and target accuracy levels*

Assuming all previous steps meet expectations, then the store will establish higher inventory accuracy targets. Theoretically, the higher the inventory accuracy rate, the lower the probability of variance. Moreover, due to high inventory accuracy rates, no matter which cycle counting method one applies, the number of items that needs to be counted will decrease incrementally (Ross, APICS 2016).

Chapter 3

Methodology

This thesis aims to develop a better store-level cycle counting process for company A in the grocery retail industry. The two main goals for the developed cycle counting process are increasing inventory accuracy and counting efficiency. The major constraint for the cycle counting process is the cost associated with the developed cycle counting process. Company A wants to improve its operational process by staying within the same budget.

According to the company's operational managers, the primary goal is to decrease mismatches between the current Computers Assisted Ordering system (CAO system) and the physical counting of the inventory on-hand quantities. Thus, the thesis will introduce different cycle counting approaches based on the sample data and system process map which is shown in figure 5.

Figure 5 Current System Process Map

The goal is to combine current company operational cycle counting systems with online research to generate a feasible cycle counting method for company A to test on a small amount of SKUs in several flagship stores. A control group cycle counting method can be applied in these stores to determine the SKUs for sample testing the new cycle counting method.

The current CAO system company A uses applies cycle counting records in nineteen different columns. From these nineteen columns, the "movement days," "no movement days," "average movement," "last low quantity," "last high quantity," and "quantity on hand "will be the leading data source for further analysis in order to determine the effectiveness of a different cycle counting approach.

Movement Days: Number of days the item had sales movement

No Movement Days: Number of days the item did not have sales movement

Average Movement: Average percentage of days the item had sales for all stores (e.g. >.333 would be items that sell at least every three days on average)

Last Low Quantity: low quantity on hand on last date in report range

Last High Quantity: high quantity on hand on last in report range

Quantity on hand: quantity on hand at the last current snapshot taken before the report was run

As mentioned in the earlier chapter, there are two cycle counting methods Company A is currently using: zero count which is the mandatory cycle counting at the store level, and high count as an optional cycle counting method for checking excessive inventories. Before explaining the cycle counting criteria, an assumption must be made: all items in the system have historical data from their last cycle count, and the data has been recorded as the "quantity on hand."

Based on the different "average movement" percentages, products can be classified as *quick movement products* and *slow movement products*. For example, if an item's average movement ratio is more than 0.274, then the product will be considered a quick movement product. It will require more attention on inventory check because it gives less lead-time after it goes out of stock. Conversely, if the product's average movement ratio is less than 0.1, it will require less attention on inventory check. This is because the product sells at least every ten days on average which provides enough lead-time for replenishment in general, especially with the quick turnover ratio company A has – on average 100 times a year (HBS, 2015). After dividing products into two rough categories, the "last low quantity," "last high quantity," "quantity on hand," and "shelf capacity" can be examined to identify quick movement products.

Calculating the differences between "quantity on hand" and "last low quantity," the products that have a mismatch between system data and physical counting data can be filtered out. This mismatch can be labeled as "quantity mismatch." Then the capacity ratio can be calculated as: $\frac{quantity\ on\ hand}{shelf\ capacity} = capacity\ ratio$ to identify the severity of out of stock. The smaller the ratio, the more problematic the product is. After several rounds of filtering, the products that are left are considered as category "A" products based on the ABC cycle counting concepts. In other words, these products require more frequent cycle counting compared to other products. For example, as seen in table 2 below:

Product	Avg_Movement	Last_Low_Qty	Last_High_Qty	Qty_On_Hand	Shelf_Capacity
X	0.525	4	4	3	16

Table 2 Example for the Cycle Counting Method Data

Product x has an "average movement" of 0.525 which means it sells at least two days on average which qualifies it to be a quick movement product because the out-of-stock risk is higher for the product. After comparing the difference between quantities on hand and last low quantity, it can be determined that there is a one inventory count difference between the computer system and physical counting. Then the absolute number of the mismatch quantity is used to divide by the quantity on hand value to exam the importance level for the mismatch and can be called "mismatch level." For this example, the importance of mismatch $\frac{1}{3} = 33.3\ percent$, which indicates the level of mismatch is not severe. After indicating the severe level of mismatch, the capacity ratio can be calculated: $\frac{3}{16} = 18.7$ percent, which indicates a bad shelf fulfillment and the counter needs to update the quantity in the CAO system in order to adjust the next shipment date to fulfill the customer needs.

Referring to the original ABC cycle counting method, table 3 shows three groups of items exist: “A” items are the top twenty percent that brings eighty percent of the revenues, “B” items are the middle thirty percent that bring fifteen percent of the revenues, and “C” items are the bottom fifty percent that only bring five percent of the revenues (NECS, 2013). Applying the same logic, a general rule can be inferred for determining the level of items followed by the previous data analysis. The detail determination will be explained in the later chapter of this thesis.

Category	**Range (Capacity ratio <20%)**
A	• Average movement >0.274 • Mismatch level> 20%
B	• 0.051<Average movement <0.274 • mismatch level<20%
C	• Average movement <0.051 • Mismatch level < 20%

Table 3 ABC Cycle Counting Criteria

From the example, a general idea can be determined about how product classification based on their recent cycle counting records will help the counters to narrow down products for the daily checking process, instead of walking down the aisles in the store to sight check all products. Theoretically, categorizing products into ABC categories will increase the efficiency of cycle counting, which will cause a decreased cycle counting cost.

After assigning products into different categories, the counter can apply the control group cycle counting method as a hybrid method with the modified ABC cycle counting method. The purpose for control group cycle counting is to insure the result for ABC cycle counting is effective comparing to the traditional cycle counting that company A is currently using. Divide the products on the floor into two different groups: control group and sample group; apply the modified ABC cycle counting for the sample group, and using the traditional cycle counting method for the control group; after one month of the testing period, comparing the inventory accuracy between these two groups will be able to tell the effectiveness of the new cycle counting method. Moreover, it will indicate the cost associated with these methods in order to indicate the applicability of the new cycle counting method.

Chapter 4

Analysis

The previous chapter listed the methodology to classify products into A, B and C categories based on the simple algorithms which will increase the efficiency and accuracy for further cycle counting process for company A in the retail grocery industry. This chapter will explain the logic behind these algorithms and practices for the partially innovated ABC cycle counting method.

The average movement ratio indicates the average percentage of days the item had sales for all stores, which is a good measurement for considering the severity of out of stock for the specific item based on the assumption that stores are operating 365 days in a year. According to the industry report for company A, the average turnover ratio for company A is 100 times a year which means company A replenishes its products 100 times in one year on average. This is much higher than the industry average of eighteen to twenty times per year (AG, 2015). Conducting the calculation based on the assumption $\frac{365}{100} = 3.65$ days, which means the Company A replenishes its products within an interval of average 3.65 days. Then applying $\frac{1}{3.65} = 0.274 = 27.4\, percent$ to get the upper acceptance limit for the average movement ratio. In other words, products with average movement ratios less than 27.4 percent will get less affected by the out of stock incidents, whereas the products with average movement ratios that are more than 27.4 percent will more likely get affected by the out of stock problems. Products with average movement ratios that are higher than 27.4 percent will require a closer look for its replenishment and cycling counting process because it is more likely to cause relentless inventory problems. Based on the same rationale, the lower acceptance limit for average movement ratio can be calculated by using the industry average turnover rate which is twenty. Average replenishment intervals will be $\frac{365}{20} = 18.25\ days$, then $\frac{1}{18.25} = 0.055 = 5.5\ percent$ as for the lower acceptance limit for the average movement ratio. Figure 6 below virtualizes the lower and upper acceptance limit for the average movement ratio.

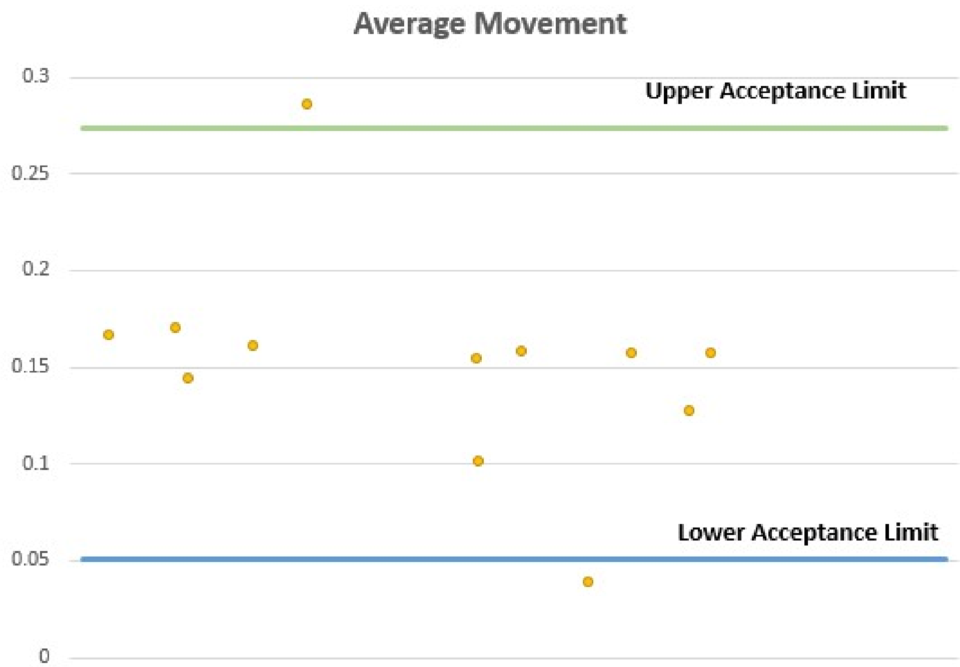

Figure 6 Average Movement Ratio Sample Graph

Applying the lower and upper acceptance limit concepts to the current CAO data report, company A will be able to categorize products into quick movement products and slow movement products. It also helps the company to classify product into A, B, C categories based on the average movement measurements.

However, the average movement ratio cannot be the only consideration for product classification. The mismatch ratio and capacity ratio mentioned in the previous chapter also need to be considered into the product classification with flexible boundaries. The capacity ratio from the previous CAO report will be the first checkpoint for considering whether the product needs to be classified into A, B or C categories for further cycle counting procedure. Based on the 20/80 rules, if the capacity ratio from the previous counting period for a product is below twenty percent then the product will be classified into category A, B or C, followed by average movement ratio, which will narrow down the importance of cycle counting for certain products. If the product falls under the quick movement product category, then it is necessary to calculate the mismatch scores. According to the general ABC analysis rule, if the mismatch score is more than twenty percent, which means an item has twenty mismatches among the 100 on hand quantities, then the product may contain serious process problems either in the ordering system or the cycle counting system. Thus, the item will be classified under category A that will require a more frequent checking and a more frequent cycle counting in the next counting period. If the item has less than twenty percent of the mismatch score, then it can be classified as category B or C based on its average movement ratio.

Based on the algorithms to classify products into different categories, it not only helps counters to save time by walking down the aisles to check for empty or low inventory shelves every day, but also increases the efficiency for counters from picking products to conduct cycle counting. After categorizing products into A, B or C categories based on the lower capacity ratio from previous report, counters do not need to walk down the aisle to check every single product. Instead, counters only need to focus on category A product on an every-day basis to secure the stock level. Counters then need only check category B and C products accordingly based on the replenishment schedule.

Note that products never stay in the same categories over time, counters or data analysts will reassign products into category A, B or C according to the previous performance report. This will not only help track the products and suppliers, but also help the store to identify problems in its replenishment process as a troubleshooting tool. For example, if a pickled olive A is currently under the category A because it has less than twenty percent capacity rate and the average movement ratio is more than 0.274, the counter will need to pay special attention for this product, and check this pickled olive A in a daily basis. After one month, based on the performance report, if the pickled olive A has a shelf capacity ratio more than twenty percent, then the product will be removed from category A. In other words, the counter will no longer need to walk down the aisle to check the pickled olive A everyday.

Comparing to the original cycle counting process, the modified ABC cycle counting will increase the time on analyzing the data, but make the on floor cycle counting more efficient in order to save more on manpower and overall cycle counting costs. Furthermore, combing the modified ABC cycle counting with the control group cycle counting, the hybrid cycle counting will help stores to test the efficiency and cost with this innovated cycle counting method.

Chapter 5

Conclusion and Future Research

This thesis is focused on increasing accuracy in inventory data in order to maintain a healthy inventory management system. Applying cycle counting is one of the methods to reduce mistakes in stores' inventory systems. Based on the current well-established cycle counting methods, a modified ABC analysis will provide the advantage for stores to minimize their cycle counting time and reduce costs associated with the cycle counting process.

By analyzing the computer assisted ordering data (CAO data) from Company A, there is no specific pattern indicating the faults between system and suppliers, thus the majority of inventory errors are human errors which are most likely caused by counters. The modified ABC cycle counting method will use historical data from the inventory system. Stores will be able to apply the algorithms to calculate the level of interest in cycle counting for certain products by organizing them into A, B, C categories. According to the original ABC cycle counting method, category A is required to have a more frequent cycle counting pattern and following by category B and category C.

For the testing stage, companies can combine revamped ABC cycle counting with control group cycle counting, to separate the entire floor SKUs into two groups: control group and sample group. This will help to indicate the effectiveness of the modified ABC cycle counting and mitigate risks by applying this new cycle counting method. This will reduce the time by sending counters to walk through the entire store's aisles to check for an empty shelf and minimize human errors during the counting process.

Future Research

There are many uncertainties and limitations during implementation of the modified ABC cycle counting method, which can suggest topics for future research. Uncertainties such as different SKUs held by different stores will bring challenges to apply the standard cycle counting, especially with the current standard algorithms. Stores make changes for products' SKUs based on different area needs, thus future research should include the customization feature for the ABC cycle counting. Before implementing the modified ABC cycle counting, determining sample size is critical. With a ninety-five percent level of confidence and the overall number of SKUs, the number of samples can be calculated. However different stores hold various numbers of SKUs, thus future research should include a template with SKU number ranges and their correlated sample sizes. It will help set a standard testing process with the current modified ABC cycle counting.

In addition to including sample size templates into future research, developing a counting frequency chart for different category products will be another research scope. After testing the modified ABC cycle counting method multiple times, the stores will gather enough data to do further analysis on how many times each category requires to conduct a cycle counting. Since the current cycle counting frequencies are based on assumptions, thus backing up the recurrence of cycle counting with real-time data will provide a more applicable and accurate number.

As outlined through this thesis, grocery stores can apply the modified ABC cycle counting method to decrease the number of unnecessary cycle counting attempts by analyzing the computer generated historical inventory data. Theoretically, this cycle counting method will bring improvement for floor inventory management and decrease human errors, but there is still space for future research to enhance the efficiency and accuracy of the cycle counting process.

APPENDIX A

Current Computer Assisted Ordering System Terms:

Column Name	Description
PL_DEPT_NAME	P&L Department Name
LOCATION_NAME	Unique store number and name
CATEGORY_NBR	Category Number
CATEGORY_NAME	Filtered for selected categories
ITEM_COUNT	Count of total occurances
UNIQUE_ITEM_COUNT	Count of unique items
COUNTED_STORE_QTY	Qty counted by store (backroom qty + sales floor)
MAGIC_QTY	System's qty on hand
ABSOLUTE_DIFF	Sum of absolute value of MAGIC_QTY - COUNTED_STORE_QTY
NET_DIFF	Sum of MAGIC_QTY - COUNTED_STORE_QTY
Absolute % Variance	(ABSOLUTE_DIFF / COUNTED_STORE_QTY) * 100
Net % Variance	(NET_DIFF / COUNTED_STORE_QTY) * 100
Count 0 Cycle Counts	Count of instances where COUNTED_STORE_QTY = 0
Count 0 Difference	Count of instances where ABSOLUTE_DIFF = 0 (i.e. the inventory was accurate)

BIBLIOGRAPHY

Lao, Guoling, and Lei Xing. "Supply Chain System Integration in Retailing: A Case Study of LianHua." *IFIP — The International Federation for Information Processing Research and Practical Issues of Enterprise Information Systems II Volume 1* (2004): 519-28. Print.

Hurlbut, Ted. "Cycle Counting." *Inc.com*. Inc., 01 June 2005. Web. 02 Apr. 2017.

Murray, Martin. "Inventory Classification in the Warehouse." *The Balance*. The Balance, 16 July 2016. Web. 02 Apr. 2017.

Ross, David. "Cycle Counting by the Probabilities." *Cycle Counting by the Probabilities*. APICS, Sept.-Oct. 2016. Web. 02 Apr. 2017.

REM. "Cycle Counting." *SpringerReference* (n.d.): n. pag. REM, 1999. Web. 2 Apr. 2017.

Wild, Antony. *Improving Inventory Record Accuracy*. Routledge, 2004. EBSCO*host*, ezaccess.libraries.psu.edu.02 Apr.2017

SoftTechinics. "Computer Assisted Ordering." *Www.groceryretailonline.com*. Grocery Retail Online, 2017. Web. 02 Apr. 2017.

McTaggart, Jenny, Ians, and Indiaretailing Bureau. "How Technology Is Helping Grocers Get a Better Handle on Out-of-stocks at the Store Level." *Indiaretailing.com*. Progressive Grocer, 08 Mar. 2017. Web. 02 Apr. 2017.

McTaggart, Jenny. "Visible Touch." *Progressive Grocery* June 2016: 184-87. *PSU Library*. Web. 3 Mar. 2017.

MuÌller, Max. *Essentials of Inventory Management*. New York: AMACOM, 2011. Print.

Bureau of Business Research, Harvard University. *Management Problems in Retail Grocery Stores*. Vol. IV. 4 Harvard Business, 1919.Print.

Anes, Vitor, Luis Reis, Bin Li, and M.de Freitas. "New Cycle Counting Method for Multiaxial Fatigue." *International Journal of Fatigue*. Vol. 67. N.p.: n.p., 2014. 78-94. Print.

Brooks, Roger B., and Larry W. Wilson. *Inventory Record Accuracy: Unleashing the Power of Cycle Counting*. Hoboken, NJ: Wiley, 2007. Print.

"Solving Inventory Management Problems." *Introduction to Logistics Systems Planning and Control* (2005): 121-55. *Reliant Confidence Counts*. Reliant Inventory Service. Web. 02 Apr. 2017.

Campany, Sarah O., and Martin E. Personick. "Profiles in Safety and Health: Retail Grocery Stores." *Monthly Labor Review* 115.9 (1992): 9-16. Safety and Health in Grocery Store, Sept. 1992. Web. 2 Apr. 2017.

Six Success Factors For A Tough Marke. *Retail Operations: Six Success Factors for a Tough Market* (n.d.): n. pag. *EY Retail Operations*. EY, 2013. Web. 2 Apr. 2017.

Kourouthanassis, Panos, Leda Koukara, Chris Lazaris, and Kostas Thiveos. *Grocery Supply-Chain Management: MyGROCER Innovative Business and Technology Framework*. Thesis. Athens University of Economics& Business, Athens, Greece, n.d. Athens: n.p., n.d. Print.

AG. "Wegmans: The New Frontier in Grocery." *Technology and Operations Management*. Harvard Business School, 9 Dec. 2015. Web. 03 Apr. 2017.

Lee, Quarterman. "Cycle Counting and Physical Inventory." *Hands-On Inventory Management* (2007): 49-54. *Strategosinc.com*. Strategosinc.com, 2007. Web. 4 Apr. 2017.

"Life Cycle Inventory Analysis." *Life Cycle Assessment (LCA)* (2014): 63-180. *Gallina LLP*. Gallina LLP, 2014. Web. 4 Apr. 2017.

Kok, A. Gurhan, and Kevin H. Shang. *European Journal of Operational Research*. 1st ed. Vol. 237. N.p.: Elsevier, n.d. 91-105. *ScienceDirect*. ScienceDIrect, 16 Aug. 2014. Web. 4 Apr. 2017.

"Cycle Counting." *Google Book*. Google, n.d. Web. 4 Apr. 2017.

Fritsch, Emilie. "Best Practices for Performing Cycle and Physical Counts of Your Inventory."*SkuVault Warehouse Management System · Home*. SkuVault, 11 Aug. 2014. Web. 04 Apr. 2017.

"A Guide to Implementing a World-Class Cycle Counting Program." *A Guide to Implementing a World-Class Cycle Counting Program* (n.d.): n. pag. *Tompkins*. Tompkins. Web. 4 Apr. 2017.

ItascaBlogPro. "Inventory Optimization." *Itasca Retail*. Itasca Retail, 17 Aug. 2016. Web. 04 Apr. 2017.

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