ATLAS COPCO MAFI-TRENCH CO. INVENTORY MANAGEMENT

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ABSTRACT

This Senior Project Report includes three areas of focus pertaining to the inventory management practices of Atlas Copco Mafi-Trench Company (ACMTC) - cycle counting, ergonomics, and material purchasing.

Various literature reviews as well as an analysis of the current state led to the project objectives. First, reduce time spent on the non-value added process of cycle counting. Second, eliminate the ergonomic hazard presented by the heavy inventory bins. Lastly, diminish the totals costs associated with inventory (ordering + carrying).

The project objectives spurred numerous alternatives and a few specific deliverables:

The creation of a 'Small Parts Cycle Count' Excel file led to a decrease in the counting and recording step by ~85%, and brought the total cycle counting process down from two hours to just over one.

After an economic and feasibility analysis, an investment in Akro-Mils Divider Bins is believed to be a better financial and operational decision than an RFID alternative in reducing cycle counting time and eliminating ergonomic risk in relation to medium sized purchased finished material. Divider bins have the potential to yield annual savings in excess of $8000 by eliminating company liability with employee injuries and reducing cycle counting time significantly.

Lastly, the 'ACMTC Order Quantity' Excel file provides an automatic and manual order quantity calculator to aid in the comparison of total costs associated with inventory when using different ordering algorithms. When comparing value receipts from 2017 to the minimum output of the order quantity algorithms, savings are estimated to be roughly $500 per SKU per year. Considering greater than 20 SKUs are consistently purchased year to year, total savings are estimated to be greater than $10k per year.

Table of Contents

List of Tables…………………………………………………………………..3

List of Figures………………………………………………………………….4

Introduction……………………………………………………………………5

Background…………………………………………………………………….6

Literature Review………………………………………………………………8

Design…………………………………………………………………………14

Methods……………………………………………………………………….21

Results……………………………………………………………………....22

Economic Analysis…………………………………………………………….24

Recommendations…………………………………………………………..27

Conclusions…………………………………………………………………..28

References…………………………………………………………………..30

Appendix………………………………………………………………….....33

List of Tables

Table 1: Original Cycle Counting Process

Table 2: IRA and Subsequent Value

Table 3: Excess Inventory Data Collection

Table 4: Cycle Counting Process Time Study Comparison

Table 5: Summary Chart of Current vs. Proposed Ergonomic Risk

Table 6: Potential Reduction in Operating Expenses

Table 7: Financial Figures for RFID Implementation

Table 8: Financial Figures for Divider Bins Implementation

Table 9: Financial Figures for Order Quantity Algorithms

List of Figures

Figure 1: Excess Inventory Covering Up Manufacturing Problems

Figure 2: Fishbone Diagram for Root-Cause Analysis

Figure 3: Ordering Algorithms Savings Potential

Introduction

The following senior project report has been written about and for Atlas Copco Mafi-Trench Co. (ACMTC) in Santa Maria, CA.

The subject, as alluded to in the title of the report, is inventory management for ACMTC. Initial visits to the Material Control Department at ACMTC consisted of observation and data collection of the current state within the department, specifically in regards to cycle counting, material purchasing, and ergonomics. These visits resulted in the following problem statement which will be elucidated further in the bulk of this report:

> The Material Control Department at ACMTC suffers from an excessive waste of time and resources spent on the non-value added process of cycle counting inventory. Furthermore, the inherent volatility of the oil and gas industry impels the Material Control Supervisor to purchase an excessive amount of inventory. Additionally, many of the inventory bins are extremely heavy and present an ergonomic hazard to employees.

In response, the objectives then became to reduce time spent cycle counting inventory, to cutback on costs associated with inventory, and to eliminate the ergonomic risk associated with counting heavy inventory items. The objectives were tackled by utilizing engineering tools, such as process improvement, time studies, statistical analysis, ergonomic risk assessment, order quantity algorithms, historical data analysis and more. Not included in the scope of our project are the departments and work stations outside of Material Control. Due to the overall size and complexity of ACMTC production, we maintained a scope within the inventory management practices of the Material Control Department and when it was necessary to gather information regarding the flow into and out of Material Control, the Material Control Supervisor as well as the internal SAP data were consulted.

In the next section of this report, a background of Atlas Copco Mafi-Trench Company is given as well as insight into the responsibilities of the Material Control Department and their current inventory management practices. Following some background, the research that was necessary to complete our project in the form of literature reviews is discussed. Literature reviews aided in identifying methods used by industry experts to solve problems related to those we identified in this project. Literature reviews naturally lead towards the generation of alternatives, which are then compared and contrasted with respect to operational performance, economic justification, and implementation feasibility in order justify the eventual recommendation. The section titled ‘Methods’ then breaks down the ways in which the generated designs were tested, including additional time studies, historical data comparison, and the WISHA Lifting Calculator. Finally, a breakdown of results and financial consequences are discussed and the report concludes with a summary of findings, a self-review, and recommendations for action.

Background

Atlas Copco Mafi-Trench Company (ACMTC) is an industrial supplier of hydrocarbon turboexpanders and compressors for the gas-processing industry. Turboexpanders and compressors are mounted on modular process skids, which act as the foundation for the end item. The finished product incorporates hundreds of raw and purchased-finished materials. These materials are stored in a designated inventory section of the warehouse and maintained by the Material Control Department.

The inventory area separates material into three sub-areas: small parts (e.g. nuts, bolts, washers), raw material (e.g. metal bar stock), and purchased-finished (e.g. metal flanges). This project focuses on small parts and small-medium sized purchased-finished materials. Small parts are stored in Akrobins, which are placed on shelves, and each bin contains anywhere from a few dozen to a thousand parts, depending on the size of the part. Purchased-finished materials are stored in plastic totes, which are placed on larger shelves, and each bin contains a few dozen parts. ACMTC designates small parts as Class C inventory and small-medium sized purchased-finished materials as Class B inventory.

The Material Control Department, in coordination with Shipping and Receiving, is responsible for the intake, identification, storage, and management of material; basic material cutting; and distribution of material across the production floor. Thus, Material Control acts as a feeder line to the entire production floor. A primary responsibility of Material Control is to maintain inventory record accuracy, a measure of how closely official inventory records match the physical inventory [Lee]. To do so, Material Control does periodic cycle counts and compares physical inventory levels with their Material Requirements Planning (MRP) software, SAP. Currently, cycle counting is a cumbersome, manual process requiring hours of tedious, non-value added labor.

ACMTC employs two methods of cycle counting. On a weekly basis, spot checks are performed on a handful of materials. Once a year, the entire inventory is accounted for. The process of cycle counting small parts is incredibly tedious. First, a bin of parts is removed from the shelf. A sample of the parts is removed from the bin and placed in a separate bin on a scale to obtain a sample weight. Once the sample weight is obtained, the remainder of parts are dumped into the bin and the scale returns the count. This count is compared to SAP inventory records and any discrepancies are investigated. The process of cycle counting small-medium sized purchased-finished materials is not necessarily tedious, but requires ample coordination and manpower. Each row on a shelf holds three bins. Due to poor foresight and spacing limitations, the middle bin must be removed before the left or right bin can be removed. Additionally, the weight of the bins requires extreme strength to lift, and in some instances more than one employee is needed. The process of cycle counting proves to be an excessive waste of time and resources, and in some instances poses a hazard to employees safety. At least one Material Control employee has suffered a work-related back injury in the past few years. The injury forced the employee out of work for a year and a half. ACMTC was partially responsible for the injury-related workers compensation.

According to Knowledge Leaders Capital, the energy sector, which includes the oil and gas industry, has historically ranked among the most volatile sectors [KLC]. Ongoing changes in volatility can drastically alter the incentives to invest in gas and oil inventories and facilities for production [Pindyck]. ACMTC is directly affected by the cyclical nature of the oil and gas industry. Specifically, it is difficult to forecast demand needs, which in turn trickles down to inventory levels. Material Control carries an excess amount of inventory on hand incase of a sudden boom in production. They also carry an excess amount of maintenance parts to prepare for field maintenance service and aftermarket repairs. However, this methodology fails to consider the costs associated with high levels of inventory. Speaking with the Master Scheduling and Production Control Manager shed light on how ACMTC is addressing this problem. Just a few years ago they dedicated a new position to Material Requirements Planning (MRP) and are considering the use of different ordering algorithms. It was also discovered that ACMTC uses a carrying cost of 3% per part per year and an ordering cost of $180 when calculating optimal order quantities.

A strong business case can be made for improving the Material Control Department's practices and procedures. First, employees must either dedicate time during the day to cycle counting instead of to more value-added activities, or work overtime to cycle count while the manufacturing floor is not operating. Cycle counting during the day results in ACMTC paying employees for non-value added work and working overtime costs the company, as well. Second, excess on-hand inventory implies excess funds tied down in inventory, which the company could be spending/investing elsewhere. Lastly, the ergonomic risk associated with cycle counting has already and can continue to cost the company tens of thousands of dollars in workers compensation.

Literature Review

Cycle Counting

In regards to the Theory of Constraints, it is important to think about the effects of reducing the time required for a cycle count [Goldratt]. Does reducing the time spent cycle counting directly lead to an increase in value-added work? Even in a more general sense, will increasing the rate of production in the Material Control Department lead to an increase in production for the company as a whole - or will it just lead to more work backed up at the next work center? These are important questions to ask when exploring areas of improvement to focus on. A case study of Hitachi Tool Engineering reveals that it is common in manufacturing environments for workers to be rewarded based on production. In practice, this leads to overproduction, excess WIP, and excessive inventory costs. The takeaway is that the rate of production should be regulated to match the level of demand rather than blindly increased to the work center capacity [Umble].

The underlying principle management must follow when choosing which areas to focus their attention towards is whether or not that area, department, and/or process acts as a bottleneck to the company's production. If it is not a bottleneck, time is being wasted focusing on it. That being said, the Master Scheduler at ACMTC relayed to us through email that the Material Control Department occasionally acts as a bottleneck in production. Therefore, the reduction in time spent cycle counting has the potential to lead to value added work and an increase in production for not only the Material Control Department, but for the company as a whole.

Another opportunity for ACMTC to benefit from a reduction in cycle counting time is to reduce operating expenses. Currently, Material Control employee(s) come in at 5 am every Wednesday to conduct cycle counts. With a reduction in time spent cycle counting, these employee(s) may not need to come in to work as early, and because they are paid by the hour this would be a direct reduction to operating expenses.

That being said, there do exist financial and operational reasons for conducting cycle counts. If demand for an item completely exceeds expectations or if a company does not maintain suitable inventory record accuracy (IRA) it may result in a stockout, or inventory dropping to zero, which can then delay production, lead to back-order costs, lost sales, and even lost customers. Due to this fear as well as for taxation purposes, many companies, including ACMTC, choose to conduct periodical cycle counts to maintain a high inventory record accuracy and thus a high confidence in the amount of inventory on hand at any moment. In *The Limitations of Cycle Counting,* the author discusses the advantages and disadvantages of cycle counting as a measurement system and as a control system. As a measurement system, cycle counting done on sufficiently random samples ensures satisfactory IRA, lessens the chance of a stockout, and gives accounting an accurate assessment of cash in the form of on-hand inventory. However, cycle counting is ineffective as a control system as it does not inherently seek and eliminate sources of error in inventory record accuracy. The article also discusses the importance of maintaining IRA for all classes of inventory. It is a common fallacy to accept higher tolerances and to cycle count less for Class C inventory due to its low cost per item, however Class C inventory items are usually just as critical to successful operations as Class A items and the cost of a stockout is usually fixed without regard to the Class of inventory [Graff]. Although there is merit to this statement, it must also be taken into consideration that most small part inventory items at ACMTC have nearly non-existent lead times and therefore present a very low-risk scenario in terms of a stockout. A visual kanban system would effectively eliminate the need for the non-value added process of cycle counting.

Currently, ACMTC replenishes their inventory based on predetermined reorder points in SAP. A visual kanban system would eliminate the need for both cycle counting and the altering of reorder points. An example of a solution for ACMTC would be to use plastic dividers in the low-value inventory bins to separate the amount of items representing the reorder point from the excess. In this scenario, once the inventory diminished to the point of reorder, the front half of the bin would be empty and the amount of inventory remaining behind the plastic divider would represent the demand during lead time plus an arbitrary amount of safety stock. The main advantage of this inventory tracking system is its ability to limit on-hand inventory, promote JIT manufacturing, and eliminate cycle counting time. Thus, the trade-off between IRA and cycle counting expenses should be on the forefront of the decision to continue cycle counting small part inventory items or not [Khojasteh].

Ergonomics

Ergonomics is defined as the science of designing the job to fit the worker, rather than physically forcing the worker's body to fit the job [OSHA]. Ergonomics are largely at play throughout ACMTC's facility. The Material Control Department, specifically, faces ergonomic risks on a daily basis because they are manually handling material. A few of the primary risk factors that ACMTC faces include awkward postures (e.g. bending), repetitive motions (e.g. frequent lifting), and forceful exertions (e.g. lifting heavy loads) [CDIR]. These three factors are common for Material Control employees who cycle count small-medium sized purchased-finished materials because the bins of materials are extremely heavy. A study conducted by Industrial Engineering Faculty at a Malaysian University examines musculoskeletal symptoms stemming from ergonomic hazards associated with material handling. The study found that, among those who self-reported symptoms, 89.1% reported lower back symptoms and 67.4% reported upper back symptoms [Rahman]. These results imply that back injuries are frequent among material handlers. According to the Spine Research Institute at The Ohio State University, the average cost of workers compensation for a back injury is between $40,000-$80,000 per employee [OSU]. Although companies invest in insurance to cover the cost of injuries, the insurance does not always cover the entire cost. As of 2017, the National Safety Council estimates the cost per medically consulted work-related injury at $31,000 [NSC].

The *Ergonomic Guidelines for Manual Material Handling* sheds light on various reasons to improve workplace ergonomics including injury prevention, reduction in effort by reducing forces in lifting, reduction in risk for musculoskeletal disorders, increasing productivity, and lowered costs by reducing workers' compensation claims following an injury [CDIR]. In terms of lifting heavy materials, the NIOSH or WISHA Lifting Equation can be used to determine if the lift puts the worker at risk of developing back pain or suffering a back injury. If the lift is indeed hazardous, there are several improvement options to mitigate the risk. In the case of ACMTC, the ideal improvement is to eliminate the need for manual handling of heavy bins altogether.

RFID

In researching alternatives for cycle counting and ergonomic mitigators, we found Radio Frequency Identification System (RFID) technology to potentially be a suitable alternative because it can serve the dual purpose of automating the cycle counting process for small-medium sized purchased-finished materials and eliminating manual material handling. RFID provides several benefits such as improving inventory management, reducing labor costs, and eliminating non-value added process times. If the RFID system is linked to ACMTC's MRP software, then the MRP system can be updated simultaneously and trigger appropriate reorder messages [Ghelichi].

There exist obvious correlations to the level of automation in manufacturing industries and beyond to the state of ergonomics. To validate this common sense, a particular academic paper written by a team at Universidad de Sonora in regards to a specific manufacturing company, concludes that automated systems most often benefit not only production and performance, but also ergonomics [Chan-Amaya]. With that in mind, RFID technology has the potential to increase the level of automation in the Material Control Department and mitigate the current ergonomic hazards that exist.

RFID systems involve an interrogator and a transponder, more commonly known as readers and tags, respectively. The reader emits radio waves which are sensed by the tag antenna. The tag contains data relevant to the item it is adhered to. The tag antenna transmits the information via radio waves back to the reader, which converts the waves into data. However, the performance of an RFID system depends on the environment in which the reader and tag exists. When materials such as metals and liquids are in close proximity to the system, the system's performance can be jeopardized because metals and liquids reflect energy emitted from the reader and create interference for tag antennas [Qing]. This presents a major issue for implementation of an RFID system at ACMTC because the vast majority of their materials are metal. Furthermore, the thickness of metal affects the system's performance. Thicker metal has been proven to adversely affect the performance.

An experimental study conducted by the Department of Electrical Engineering at the Indian Institute of Technology in Mumbai found that with thicker metal the tag could be read in 45% of test points in space, whereas with thin metal the tag could be read in 77% [Arora]. The space in consideration includes the metal and the tag. These results are relative to the experimental design, the RFID equipment used in the experiment, and the type of metal. Nonetheless, the results indicate that metal thickness directly affects the performance. Another study also attempts to identify methods of improving RFID system performance in metal environments. 10mm and 5mm plastic spacers were placed between the metal surface and the tag. When using the 10mm spacer, 94.7% of test points in space were read while 91.6% of points were read when using the 5mm spacer, whereas without a spacer, 77.6% of points were read [Periyasamy]. It is apparent that the effect of metal on the tag is negatively correlated with the amount of space between them. Research conducted by the Department of Electronic Engineering at Dongguk University in Korea, adds to the evidence that spacers between the metal and tag increase the read range of RFID systems in metal environments. Foam spacers of thickness ranging from 1mm to 5mm were mounted on metal surfaces and the detection range between the reader and the tag was measured. The results show that the detection range is 1m with a 2mm thick spacer, and 2m with a 2.5mm or thicker spacer [Park]. Therefore, the foam spacer counteracted the performance degradation imposed by the metal surface.

Another study, focusing on the performance of Ultra High Frequency (UHF) passive RFID systems in metal environments, yielded results that contradict the claim that metal interferes with RFID system performance. The experiment tested the read range and tag read rate of a UHF RFID system when the tag was adhered to five types of metal. The results assert that none of the metals impacted the performance degradation of the system. The study concludes that the unaffected performance is due to the antenna's higher emitting power, which can penetrate any type of metal with low conductivity [Periyasamy]. Therefore, research suggests that UHF RFID is a combatant to interference in industries with high usage of metals.

Dividable Bins

Further research on alternatives to reduce ergonomic risk led to the discovery of Akro-Mils Slotted Divider Plastic Tote Boxes. Items in the bins can be compartmentalized by inserting Akro-Mils Short and Long Dividers. The purpose of these bins is to organize material in a manner that would allow employees to simply look at the bin and use simple mental math to determine the number of parts in the bin. This allows the Material Control employees to get an accurate count without removing the bin from the shelf and counting each individual part, thus a 'clean-hand cycle count' [Akro-Mils].

Material Purchasing

To begin, *Introduction to Materials Management* highlights various inventory fundamentals. The text lays out two main objectives of inventory management: minimize total cost associated with inventory, and maximize customer service. These two objectives are in direct contrast as customer service pertains to the ability of the company to meet customer demand in a competitive time-frame, while minimizing total cost refers to the ability of the company to order the optimal quantity of inventory in regards to the summation of carrying and ordering costs [Chapman].

The challenge for ACMTC, and for manufacturers in general, is to maintain the 'inventory balance', that is to maintain enough inventory as to not delay production while reducing inventory as to not waste precious capital [Jaber]. That being said, low priority inventory, can and should be ordered in large quantities to meet demand spikes as the they generally represent no more than 5% of total inventory value [Kavoosi]. However, the question for high-value inventory (>$25 per part) becomes how much inventory on-hand should the company carry to optimize 'inventory balance', or simply, how much to order and when.

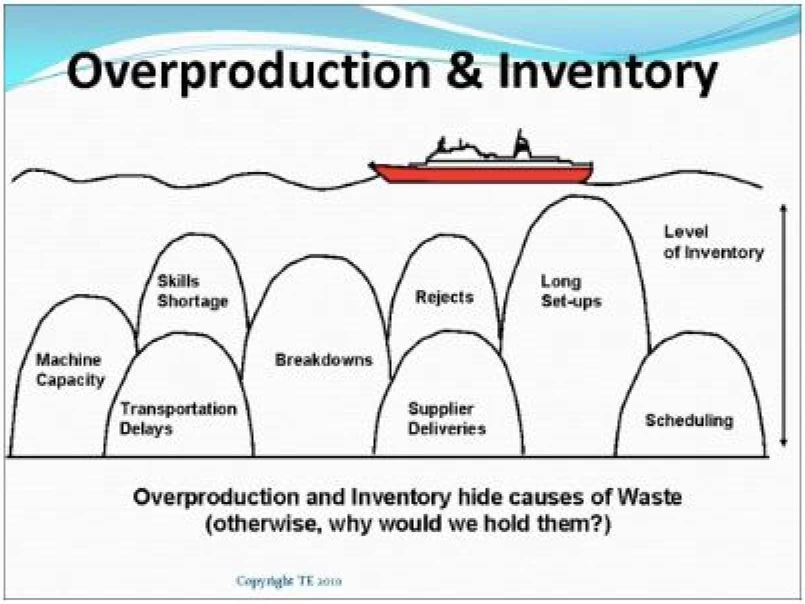
These questions are answered by various order quantity algorithms. The assumptions associated with Economic Order Quantity (EOQ) in particular include, a relatively constant and known demand, the item is purchased in lots, ordering costs and inventory carrying costs are constant and known, and replacement occurs all at once. The first assumption, in particular, is alarming, considering the demand ACMTC realizes is not constant. Hoon Jung in *Optimal inventory policies for an economic order quantity model with decreasing cost functions* extends the classical EOQ model to accommodate more realistic scenarios such as this. The article suggests that unit cost is indirectly affected by demand because if demand is increased, so is order quantity and a larger order quantity often results in a lesser cost per unit [Jung]. In other words, value ordering, bulk buying, must be considered a viable option and compared to other order quantity algorithms.

The Industrial and Manufacturing Department at the University of Iowa created a helpful PDF titled *Lot-Sizing Algorithms* in which the author dives into various order quantity algorithms to optimize order quantity when demand is highly variable. The algorithms considered, include Lot-for-Lot (L4L), EOQ, Period Order Quantity (POQ), and Part-Period Balancing (PPB). The technique of L4L is simply ordering a lot each period to meet that period's demand. Computing EOQ follows the formula: $Q = \sqrt{}((2*D*O)/C)$, where D is equal to annual demand, O is equal to the cost of creating and fulfilling an order, and C represents the cost to carry an inventory item for one year. Next, POQ is the EOQ expressed as a time supply, that is, an integer number of periods' supply per order. It is computed by dividing the EOQ by the average demand per month. Lastly, PPB is described by the number of periods covered by the replenishment is made so that the cumulative carrying cost is as close to the ordering cost as possible. The purpose of utilizing order quantity algorithms is to minimize the summation of ordering and carrying costs associated with inventory, this total cost follows the formula: $T = (Q/2)*C + (D/Q)*O$ [Bricker].

The L4L ordering technique is the most common among manufacturers relying on MRP software, however, fixed lot sizes, quantity discounts, and a seemingly low carrying cost often lead the Material Control Supervisor to order material in bulk as far as 6-12 months in advance of demand.

Prior to advancing into design, further research into the given ordering and carrying costs was completed. The given ordering and carrying cost used by ACMTC are $180 per order and 3% per part per year respectively. Ordering cost consists of the operating expense involved with making an order quantity decision with a trusted supplier and creating the actual purchase order. $180 represents two hours of Material Supervisor work per order. Carrying cost, on the other hand, depends on the price per part, and is made up of: taxes on land and building, insurance on building and equipment, estimated loss of return on capital tied up in inventory, insurance on inventory, average yearly loss stemming from material obsolescence and pilferage, cost of labor to receive, tag, and stock material, extra accounting hours necessitated by inventory control, as well as top management time spent on solving inventory related problems. For these reasons, CFPIM and President of Proaction Consulting Group, George Miller, states that it is common for mid to large size manufacturers such as ACMTC to incur carrying costs of $0.25 to $0.30 on the dollar annually [Inventory Reduction Report]. This is in great contrast to the given carrying cost at ACMTC currently, and may suggest that ACMTC is not placing nearly enough emphasis on carrying costs as is standard in industry.

The lack of emphasis on carrying cost leads directly to an inability to identify inventory as waste. Taiichi Ohno, the Father of the Toyota Production System, identified overproduction and inventory as wastes that are often used as a buffer to cover up other problems that need to be addressed. Figure 1 displays this scenario as a metaphor; inventory is the sea in which your manufacturing ship floats upon, and when this sea is lowered, many manufacturing problems, represented by jagged rocks, are exposed and will sink the ship unless they are removed from the picture [Ohno].


Overproduction & Inventory

Overproduction and Inventory hide causes of Waste
(otherwise, why would we hold them?)

Copyright TE 2010

Figure 1: *Excess inventory covering up manufacturing problems*

Other inventory wastes highlighted by Ohno, and clearly present at ACMTC, are transportation and motion. The Material Control Department stores a majority of inventory in its silo. Inventory is ordered, received, tagged, and stocked in this silo before being transported (often in excess of 100 feet) to the specific work center on the manufacturing floor that needs the material. There exists a wasteful step here of transportation of material and motion of people to and from the MC Department and various work centers on the manufacturing floor. A point-of-use inventory management system has the potential to generate significant savings over time and aid in reducing inventory as well. As highlighted in a case study regarding medical inventory replenishment at a hospital, point-of-use inventory management in combination with kanban visual replenishment, promotes low inventory levels, improved inventory tracking, and significant reduction in motion and transportation depending on the previous state [Rosales].

Design

This section of the report provides an overview of the Material Control Department's current state and the problems at play. It also discusses the selection and design of alternatives that are investigated as potential solutions.

Cycle Counting

To identify the root-cause of wasted time spent cycle counting, a fishbone diagram is used. Because cycle counting is the cause of ergonomic risk, this assessment will also target ergonomics. Of the several causes, a few are identified as areas for improvement. The boxes with red font indicate an area for improvement for small-medium sized purchased-finished material, and the boxes with green font indicate an area for improvement for small parts. Boxes with green and red font indicate an area for improvement for both classes of inventory.

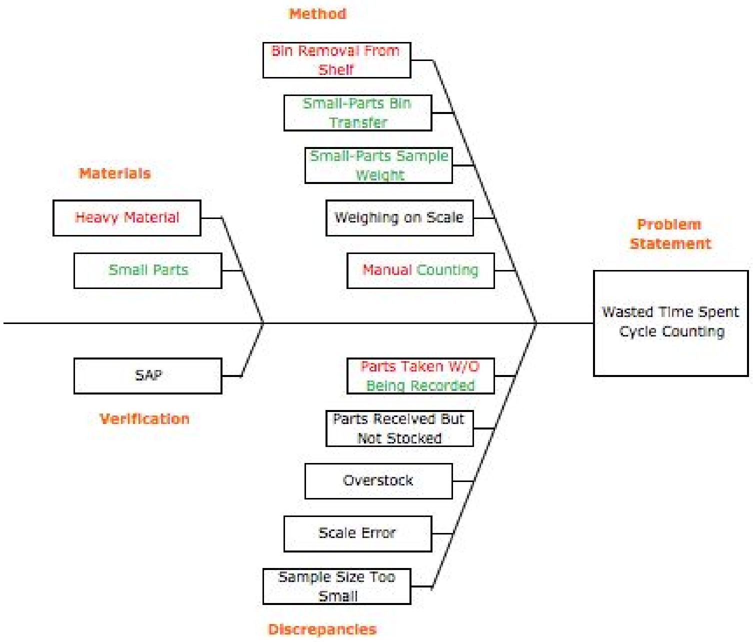


Figure 2: *Fishbone Diagram for Root-Cause Analysis*

To improve the current process of cycle counting, the current state must be known. Therefore, in combination with a root-cause analysis, time studies were conducted on the current counting and recording step of the cycle counting process for small parts inventory.

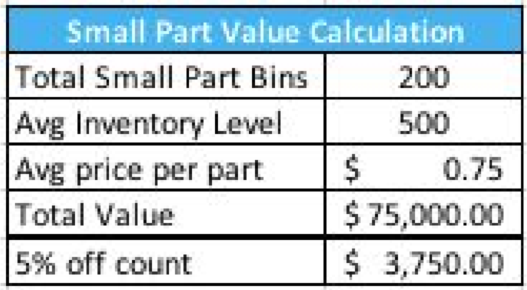
Part #	Sample Size	Count	Time [sec]
1249039562	5	33	47
1249039584	5	54	87
1249036851	5	63	78
1249069139	5	87	64
1249069113	5	26	50
1249039588	5	26	55
1249039381	10	359	125
1249054993	20	511	47
1249054994	20	1135	68
1249055006	20	696	56
1249039617	20	87	73
1249201820	20	397	101
1249039379	20	181	83
1249037143	50	858	118
1249055510	50	1462	129
1249055511	50	849	134
1249054970	50	299	97
1249055489	100	658	121

Table 1: *Original Cycle Counting Process*

The data results in a 95% Confidence Interval of (70.15, 100.19) seconds. This time includes, finding the sample weight of the specific inventory item, adjusting the scale, pouring the rest of the inventory items from the bin to the separate container on the scale, and recording the inventory count - as highlighted in the flow process chart (*Appendix A-1*). The design created to expedite the current cycle counting process is a 'Small Parts Cycle Count' Excel file. A sample weight per part was cataloged for just under 200 small part inventory SKUs. After creating a few quick

Excel formulas, cycle counting for a Material Control employee is now as easy as selecting an inventory bin off the shelf and placing the bin directly on the scale. The Material Control employee can either scan the part number or enter it manually, and then enter in the total weight shown on the scale. The Excel file then computes the quantity by subtracting the bin weight and dividing by the average weight per part (sample weight) through a VLOOKUP function referring to the catalogued weight per part sheet (*Appendix A-2*). The resulting flow process chart displays these improvements (*Appendix A-3*).

Eventually, cycle counting small parts inventory should be eliminated. Due to the fact that this inventory is low value (represents roughly 5% of inventory value at ACMTC) and low risk (short lead times), it is not worth the time the Material Control employees are spending cycle counting it. Although cycle counting provides greater accuracy of inventory on-hand, the low value of small parts inventory justifies a move to a visual management system. The decrease in operating costs will undoubtedly outweigh the decrease in IRA. The figure to the right is a basic calculation displaying the average inventory value of low-value items to be roughly $75k. If SAP IRA were to deviate 5% from actual inventory levels, that would translate to under $4000 of value. With cycle counting operating expenses totaling $9000 per year ($90 per hour * 2 hours per cycle count * 50 weeks per year), moving to a kanban visual management system is worth it up to a ~ 12% deviation from actual inventory levels.



Small Part Value Calculation	
Total Small Part Bins	200
Avg Inventory Level	500
Avg price per part	$ 0.75
Total Value	$ 75,000.00
5% off count	$ 3,750.00

Table 2: *IRA and Subsequent Value*

Ergonomics

Material Control employees are subject to manual material handling when cycle counting small-medium sized purchased-finished materials. As mentioned in the literature review, manual material handling puts workers at risk of awkward postures, repetitive motions, and forceful exertions. These risk factors can subject workers to musculoskeletal injuries. To determine the current level of ergonomic risk, the WISHA Lifting Calculator is utilized. This calculator is an ergonomic assessment tool adapted from the NIOSH Lifting Equation and is based on scientific research on the main causes of work-related back injuries. The calculator takes into consideration the following inputs:

- **Actual Weight -** the actual weight of objects the employee lifts
- **Vertical Hand Position -** the vertical location of the employee's hands where they begin to lift/lower the object
    - **Criteria:** above shoulder, waist to shoulder, knee to waist, below knee

- **Horizontal Hand Position -** the horizontal location of the employee's hands where they begin to lift/lower the object; determined by measuring the midpoint between the hands from the midpoint between the toes
    - **Criteria:** near (<7"), mid (7"-12"), extended (>12")
- **Lifts per Minute -** the number of lifts the employee performs per minute
    - **Criteria:** 1 lift/2-5 minutes, 1 lift/minute, 2-3 lifts/minute, etc.
- **Hours per Day -** the number of hours per day the employee spends lifting
    - **Criteria:** <1 hour, 1-2 hours, >2 hours
- **Twisting -** the number of degrees the employee twists while performing the lift
    - **Criteria:** <45 degrees, >45 degrees

In ACMTC's case, the following inputs are applicable:

- **Actual Weight** = 50 & 100 lb
- **Vertical Hand Position** = above shoulder, waist to shoulder, knee to waist, below knee
- **Horizontal Hand Position** = near (<7"), mid (7"-12"), extended (>12")
- **Lifts per Minute** = 1 lift/2-5 minutes
- **Hours per Day** = <1 hour
- **Twisting** = <45 degrees, >45 degrees

Note that ACMTC must use all of the vertical hand positions because of the shelving design. There are six rows on the shelves, stretching about eight feet from the floor. At various times, they also use all of the horizontal hand positions and twists. Therefore, a single Lifting Index cannot fit the entirety of lifts. Instead, a risk assessment has been made for all possible conditions. The majority of bins weigh on average 100lb, but some exceed this. The heaviest bins are in the 150-200lb range. To account for this, a risk assessment was conducted at 100lb (*Appendix A-4*).

The outputs of the calculation are Weight Limit, Lifting Index, and Risk. If the Actual Weight matches the Weight Limit, the Lifting Index is 1.00. A Lifting Index less than or equal to 1.00 is a "safe" lift. A Lifting Index greater than 1.00 and less than or equal to 1.50 is a "potential" risk lift. A Lifting Index greater than 1.5 is a "risk" lift.

Out of 24 possible lifts at 100lb, 0 are "safe", 4 are "potential", and 20 are "risk". These findings indicate that greater than 80% of lifts put employees at risk of an injury (*Appendix A-4*).

There is a clear need for an alternative to the current method of cycle counting small-medium sized purchased-finished materials, which requires strenuous manual lifting and poses an ergonomic hazard to employees. In monetary terms, the associated risk of a back injury is on average $40,000-$80,000 per employee [OSU], with ACMTC being responsible for as much as $31,000 [NSC].

A possible alternative to the current shelving system is to install a roll-out track underneath each bin. In turn, employees could simply slide the bin out from the shelf and avoid ever lifting the bin to remove it. However, this alternative poses a problem. Each row on a shelf holds three bins. The middle bin can be removed without a problem, but, due to poor shelf design, the left and right bins cannot be removed without first removing the middle bin because the outside bins are blocked by the sides of the shelf. So, an entirely new shelving system would need to be bought in addition to the roll-out tracks. One industrial shelf costs a couple hundred dollars. To replace the entire shelving system, ACMTC is looking at a cost of a couple thousands dollars. Additionally, replacing the shelving system and installing the roll-out tracks would require moving all of the materials and basically halting the material flow to the entire production floor for a few days. ACMTC cannot afford to halt production for that long. Furthermore, the sheer weight of bins would require extreme structural support for the tracks, and even the most structurally-sound solution might not hold the weight of a 200lb bin hanging off the shelf on the track. Therefore, alternate solutions must be investigated.

The ergonomic problem stems directly from the process of manual cycle counting, which is another tenet of our project. Therefore, the ideal ergonomic alternative will coincide with a cycle counting alternative, effectively killing two birds with one stone. In the next part of this section, an investigation into dual-purpose alternatives is described.

The Material Control Supervisor expressed his distaste for the current process of cycle counting small-medium sized purchased-finished material, which is a cumbersome process requiring excessive coordination and manpower. Additionally, he expressed an interest in the possibility of implementing RFID technology for an automated cycle counting process. As the Material Control Supervisor and his team are the end users of this project, it is in accordance with his interests that an evaluation of RFID is conducted.

As discussed in the literature review, the metal environment of ACMTC's Material Control Department poses a hindrance to RFID implementation because metal interferes with the performance of the system. Research suggested that a spacer be placed between the metal and the tag to decrease the interference and increase performance in a metal environment. However, this idea is only viable if the metal items are arranged in a way so that one item does not obstruct the line of sight between the RFID reader and another item. The bins at ACMTC contain 20-30+ items stacked on top of each other in no particular organized fashion. Therefore, alternatives to spacers must be investigated.

The initial idea was to place RFID/barcode combination tags on the front of the bins. Corresponding barcode labels would be adhered to the metal items in the bins. During a cycle count, the reader would be able to identify the RFID/barcode tags on the front of the bin. When an item is removed from the bin, the worker would identify the barcode label on the item and remove the corresponding RFID/barcode tag from the front of the bin. Thus, during the next cycle count, the reader would identify one less item. After researching RFID readers, the PHYCHIPS Arete Pop Dongle UHF Reader seemed the best fit. The device costs a mere $50, compared to other RFID readers costing thousands of dollars. It plugs directly into the audio jack on a mobile device and the Arete Pop application is free for download and use on any Android or iOS device. A demonstration of the RFID system was performed for the Material Control Supervisor, but he countered our idea with a glaring problem. Occasionally, workers from the production floor take materials without consent of a Material Control employee. Therefore, for the system to work properly, the production floor employees themselves would have to remove the RFID/barcode tag from the front of the bin. Realistically, the production employees would forget to remove the tag, rendering the system inaccurate and ineffective. The Material Control Supervisor deemed it necessary for the tags to be adhered to the material so that in the case of an item being taken off the record, the system would still work because the reader simply would not identify the taken item. Unfortunately, RFID systems are severely disrupted by metal interference. Recent advancements in RFID technology has led to the creation of metal-mounted RFID tags, but no such tag exists that is powerful enough to withstand the interference from several metal parts stacked on top of each other. Instead, standard operating procedures (SOPs) can be created and given to the production floor employees, instructing them to remove the RFID/barcode tags when they take a material or not to take certain materials without the direct consent of a Material Control employee who can remove the RFID/barcode tag.

The solution to metal interference is to reorganize the materials in a manner that would allow each individual part to be readable by the RFID reader. One idea for reorganization is to compartmentalize the parts in bins with dividers so that each part is visible at the top of the bin. Akro-Mils Slotted Divider Plastic Tote Boxes are an ideal suit. However, if the parts are to be reorganized in these new bins, why not just reorganize the parts in a manner that allows for simple, "hands-free" counting? For example, if a bin is 10" tall and divided into four compartments, and each part in the bin is 2" tall and the parts are stacked on top of each other, then each compartment (when parts are stacked to the top of the bin) would contain five parts, and the entire bin would contain 20 parts. Bins could be marked in increments to further ease the visual count. If one compartment was filled only to the 8" mark, but every other compartment was filled to 10", then the employee would see that there is one part missing in one compartment and the bin contains 19 parts (*Appendix A-6*). In doing so, the process of cycle counting would be simplified and the ergonomic risk would be eliminated. Now, two alternatives - RFID and Dividable Bins - exist. Both alternatives kill two birds with one stone.

Material Purchasing

In accordance with the literature reviews conducted on the subject matter, it was determined that a carrying cost of 27%, rather than the originally given 3%, is appropriate for ACMTC material. The break down of this is as follows:

1) (1%) Taxes on land and building
2) (1%) Insurance on building and equipment
3) (2%) Average yearly loss stemming from material obsolescence and pilferage
4) (3%) Insurance on inventory
5) (3%) Extra accounting hours necessitated by inventory control
6) (5%) Cost of labor to receive, tag, stock, move and maintain inventory
7) (5%) Yearly cost of top management time spent on inventory related problems
8) (7%) Yearly loss of return on capital tied up in inventory

The goal of creating an order quantity calculator based on sound algorithms is to aid the Material Control Supervisor in placing more of an emphasis on carrying costs and to reduce the waste they are currently experiencing of excess inventory. Figure 4 highlights the waste that ACMTC is currently experiencing, and demonstrates they are currently not identifying excess inventory as waste.

PN	Quantity	Price Per Part	Total $
1249063610	36	19.31	$ 695.16
1249057284	16	18.49	$ 295.84
1249063654	17	15	$ 255.00
1249063671	50	19.16	$ 958.00
1249064460	15	21	$ 315.00
1249063624	22	16.07	$ 353.54
1249063625	25	27.61	$ 690.25
1249063626	13	40.97	$ 532.61
1249089353	7	5594.4	$ 39,160.80
1249137367	15	2963.94	$ 44,459.10
1249063717	15	15.73	$ 235.95
On-Hand Inventory Not Touched For Over 19 Months:			$ 87,951.25

Table 3: *Data Collected on 7 May 2018*

In designing an order quantity calculator, fixed lot sizes and ACMTC previously determined safety stocks were considered. So, the order quantity calculator that was created allows for the Material Control Supervisor to first enter a part number, and once this is done, the associated fixed lot size, safety stock and price per part number data will be automatically pulled into the interface through another VLOOKUP function in order to aid in the calculations. Also, the carrying cost and ordering cost are shown at the top of the Excel file and can be manipulated if desired. Just below these inputs is the yearly demand schedule, which is also manipulated by the Material Control Supervisor. As the MRP schedule is inputted into the demand table, a graph to the right will simultaneously be updated to give the MC Supervisor the ability to visualize the yearly demand (*Appendix A-7*).

Following the material requirements visual, is the automatic order quantity calculator based on three ordering algorithms: bulk buying, L4L, and EOQ. The order receipt from each month is calculated using a series of logical IF statements in Excel. The carrying cost per month is calculated by multiplying the inventory on-hand by the monthly carrying cost (27% divided by 12 months) by the price per part. The ordering cost column is a simple IF function, stating if the order receipt is greater than zero, the ordering cost equals $180, else it equals zero. These monthly carrying and ordering costs are summed together to compute the total yearly cost associated with inventory. To the right of the order quantity calculator is another helpful visual, which displays demand and inventory levels along with order receipt values on a monthly basis (*Appendix A-8*).

Also included in this material purchasing design, is a manual order quantity calculator. This means that the MC Supervisor, or whomever is using this Excel file, has to enter in the monthly order receipts manually. The calculator has a drop down list including those algorithms listed in automatic calculator, and the POQ and PPB ordering algorithms. When an ordering algorithm is chosen, a description of the algorithm will be shown below to give the user an idea of when and in what quantity an order receipt should be made. With respect to the POQ algorithm, the periods per order, is automatically calculated for the user by dividing the EOQ by the average monthly demand; this results in the number of periods that an order receipt should satisfy. With respect to the PPB algorithm, an example is given to the right of the manual calculator, showing how to compute cumulative carrying costs. The order receipt should then be made to satisfy the number of periods in which the cumulative carrying cost up to that month is as close to the ordering cost of $180 as possible (*Appendix A-9*).

Methods

This section of the report describes the manner in which alternatives are tested and analyzed. Since implementation of certain alternatives can not be completed during this project, this section describes how testing of those alternatives can be simulated.

Cycle Counting

To test the process improvement alternative which had us gather standard weight per part measurements, time studies were completed on a sample of ~18 inventory bins which had previously been recorded using the current process of cycle counting. With time studies completed for the new process and old process for the same inventory item bins, statistical comparisons can be made. In this experiment, the time measurements act as the variable outputs, the cycle counting processes are the inputs which are manipulated, and the inventory item bins act as the control to the experiment.

Ergonomics

To test the alternatives of RFID and Dividable Bins, a second WISHA Lifting Calculator assessment can be conducted. In the first WISHA assessment, a weight of 100 lbs was used to account for the weight of a bin with all of its parts inside. This time, the weight is 50 lbs. The reason for this reduced weight is because both RFID and Dividable Bins eliminate the need to remove the bin from the shelf. Instead, lifting occurs only when an employee is removing a single part from a bin for use on the manufacturing floor. This drastically reduces the weight per lift. Every part in question weighs less than 50lb. However, we use an exaggerated weight of 50lb to account for parts of all weights and hyperbolize the theoretical maximum weight of a single lift (*Appendix A-5*).

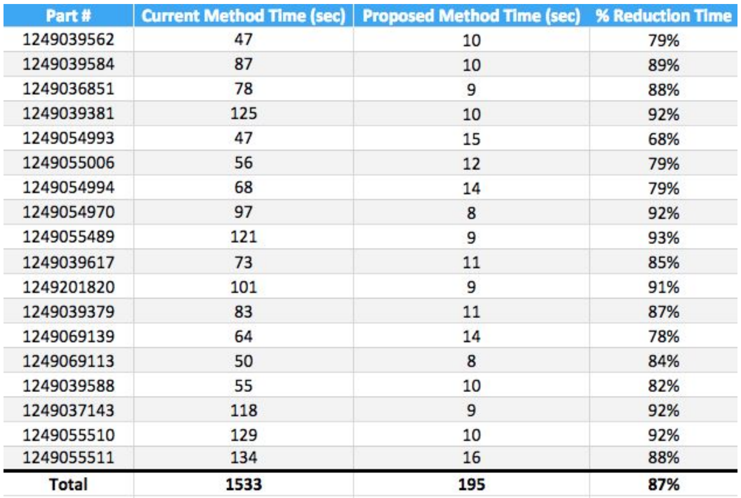
Material Purchasing

To determine the benefit of the order quantity algorithms versus the current method of ordering, a historical data analysis is completed over the year of 2017. To analyze the total costs associated with inventory of various SKUs during 2017, the value receipts from 2017 are broken down into a quantity ordered by dividing the value receipt per month by the moving average price for that specific SKU. To find the demand schedule realized in 2017, the quantity stock issued was used. With this same demand schedule transferred to the ACMTC order quantity calculator, the total costs associated with inventory can be calculated using the various ordering algorithms to find the optimal ordering technique. The minimum total cost calculated by the group of ordering algorithms can then be compared to the total cost calculated from the value receipts placed by ACMTC over the year of 2017 to determine ACMTC's potential savings.

Results

This section of the report details the findings of the testing methods described above.

Cycle Counting



Part #	Current Method Time (sec)	Proposed Method Time (sec)	% Reduction Time
1249039562	47	10	79%
1249039584	87	10	89%
1249036851	78	9	88%
1249039381	125	10	92%
1249054993	47	15	68%
1249055006	56	12	79%
1249054994	68	14	79%
1249054970	97	8	92%
1249055489	121	9	93%
1249039617	73	11	85%
1249201820	101	9	91%
1249039379	83	11	87%
1249069139	64	14	78%
1249069113	50	8	84%
1249039588	55	10	82%
1249037143	118	9	92%
1249055510	129	10	92%
1249055511	134	16	88%
Total	1533	195	87%

Table 4: *Cycle Counting Time Study Comparison*

Using the ‘Small Parts Cycle Count’ Excel file, the 95% Confidence Interval for the same counting and recording step timed previously has a 95% Confidence Interval of (9.63, 12.03) seconds; a statistically significant improvement. The current cycle counting process takes roughly two hours (employees arrive at 5 am to finish by 7am). This means that under the current method the counting and recording step for 50 inventory items accounts for about one hour (50 items * 85 seconds per item), and under the proposed method the counting and recording step under the same assumptions accounts for about 10 minutes (50 items * 11 seconds per item).

Ergonomics

The results of the second WISHA Lifting Calculator assessment can be seen in Appendix A-5. Out of 24 possible lifts at 50lb, 11 are “safe”, 10 are “potential”, and 3 are “risk”. These findings indicate that only 12.5% of lifts put employees at risk of an injury.

	Current (Lifting Calculator @ 100lb)	**Proposed (Lifting Calculator @ 50lb)**	**% Change**
Safe	0	11	∞
Potential	4	10	150%
Risk	20	3	-85%

Table 5: *Summary Chart of Current vs. Proposed Ergonomic Risk*

The results of the ergonomic risk assessment will be the same for RFID and Dividable Bins, as both alternatives accomplish the same goal of mitigating ergonomic risk by eliminating human interaction with heavy bins. Both alternatives provide greater an 85% reduction in ergonomic risk, as the number of “risk” lifts reduced from 20 to 3. Keep in mind that these results simulate an exaggerated lift weight of 50lb. In reality, employees will not have to lift anything above 20-30lb, theoretically reducing the ergonomic risk to 0.

Material Purchasing

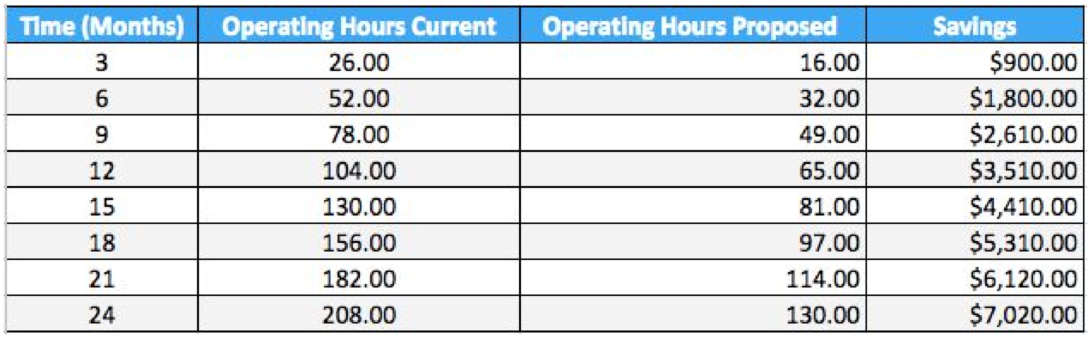
After comparing the value receipts from 2017 for several SKUs to the use of ordering algorithms, significant savings are realized as seen in Figure 3.

Figure 3: *Ordering Algorithms Savings Potential*

Economic Analysis

Cycle Counting

The reduction in time to the counting and recording step of the cycle counting process reduces the overall cycle counting process from two hours to just over one hour. The potential for savings here lies in the opportunity for employees conducting the cycle count to come in to work at 5:45 am now rather than at 5:00 am as they do currently.



Time (Months)	Operating Hours Current	Operating Hours Proposed	Savings
3	26.00	16.00	$900.00
6	52.00	32.00	$1,800.00
9	78.00	49.00	$2,610.00
12	104.00	65.00	$3,510.00
15	130.00	81.00	$4,410.00
18	156.00	97.00	$5,310.00
21	182.00	114.00	$6,120.00
24	208.00	130.00	$7,020.00

Table 6: *Potential Reduction in Operating Expenses*

If a reduction in operating hours isn't viable, the time savings generated also allow for an opportunity to find additional value-added work to contribute to the throughput of the manufacturing floor.

RFID

In performing a cost-benefit analysis of implementing an RFID system, several considerations need to be made, since there are several factors affecting the cost of the system. These costs can be categorized into three main groups: hardware costs, software costs, and other costs. Hardware consists of the reader, tags, and printer. Software consists of computer, reader, and printer setup. The other costs consists of buying and building the necessary infrastructure, and employee training. These costs can be broken down further into initial and recurring annual costs. Initial costs consist of material, setup, and labor (*Appendix A-10*).

There are many costs associated with employee injuries. The obvious, direct cost is insurance premiums. However, there are several indirect costs which are often overlooked. Among these are: uninsured costs not covered by insurance, cost of overtime to pick up slack of the injured worker, time-cost of safety professional for injury investigation, and time-cost of human resources to manage the injury [Douphrate]. As of 2017, the National Safety Council estimates the cost per medically consulted work-related injury at $31,000 [NSC]. This large amount includes estimates of wage losses, medical expenses, administrative expenses, and employer costs. This estimate will be used as an assumption for the following cost-benefit analysis, in which net present value (NPV), internal rate of return (IRR), return on investment (ROI), and payback period (PBP) will be examined (*Appendix A-11*). Additionally, an integral assumption is that an injury occurs once every five years.

10 YEAR INVESTMENT OUTLOOK	Passive RFID
Initial Investment	$20,495
Annual Cost	$4,400
NPV	$20,033.95
IRR	31%
ROI	217%
PBP	4.1 years

Table 7: *Financial Figures for RFID Implementation*

The financial figures shown above indicate that an investment in RFID is cost effective for the company. The IRR indicates a good investment because it is greater than the assumed discount rate of 10%. The PBP is under five years, which is the assumed timeframe for the occurence of an injury.

Dividable Bins

The cost-benefit analysis of reorganizing materials into compartmentalized Akro-Mils Divider bins consists of material, assembly, and material move costs (*Appendix A-12*).

10 YEAR INVESTMENT OUTLOOK	Akro-Mils Divider Bins
Initial Investment	$6,100
Annual Cost	0
NPV	$45,821.59
IRR	139%
ROI	1285%
PBP	0.79 years

Table 8: *Financial Figures for Divider Bins Implementation*

The financial figures shown above indicate that an investment in Akro-Mils Divider Bins is cost effective for the company. The IRR is greater than the assumed discount rate of 10% and the PBP is far less than the timeframe for an injury to occur. There are zero recurring annual costs because the system needs to be purchased and assembled only once.

Material Purchasing

Assuming two hours of training per month for new employees to understand order quantity algorithms, two hours per month of updating inventory counts, and savings of $500 for about twenty SKUs per year, the yearly cash flow is estimated to be over $5500. With upfront costs as low as $180 to accommodate a couple of hours for the MC Supervisor to learn and understand the 'ACMTC Order Quantity' Excel file, investing into the consideration of order quantity algorithms when purchasing material is clearly more than worthwhile (*Appendix A-13*).

10 YEAR INVESTMENT OUTLOOK	Order Quantity Algorithms
Initial Investment	$180
Annual Cost	$4320
Annual Cash Flow	$5680
NPV	$34,721.14
IRR	3156%

ROI	31456%
PBP	0.03 years

Table 9: *Financial Figures for Order Quantity Algorithms*

Recommendations

The research completed, alternatives created, and testing analyzed have led us to the following recommendations that we advise Atlas Copco to act on.

Cycle Counting

We recommend that ACMTC continue to use the 'Smalls Parts Cycle Counting' Excel file. With the time savings generated, it is up to management to make a decision whether to reduce operating expenses by having the employee(s) conducting the cycle count come in to work later, or to find value-added work to fill in during this time. Also, in regards to the issue of cycle counting and material purchasing, we recommend that ACMTC conduct further research into a point-of-use in combination with kanban inventory management system. Specifically, ACMTC should determine where inventory items should be placed on the manufacturing floor based on usage rates to minimize motion and transportation on the manufacturing floor. The use of a kanban visual replenishment system promotes the reduction of inventory and the elimination of the wasteful cycle counting process.

Ergonomics

Based on the data and financial findings of this project, ACMTC should invest in Akro-Mils Divider Bins to mitigate the ergonomic risk associated with cycle counting heavy materials and reduce the time spent cycle counting. This proposed solution effectively serves a dual purpose by solving the problem of cycle counting and ergonomics.

Both RFID and Dividable Bins can accomplish the same goal of mitigating ergonomic risk and reducing cycle counting time, however we recommend Dividable Bins after completing a cost analysis. RFID costs $20,495 up front and comes with an additional burden of around $4,400 per year. Comparatively, Dividable Bins cost a mere $6,100 to implement with negligible upkeep costs. Therefore, ACMTC should invest in reorganizing inventory shelving in a standardized fashion to allow for visual, "clean hands" cycle counting.

Material Purchasing

Lastly, we recommend that the MC Supervisor take the time to learn and understand the 'ACMTC Order Quantity' Excel file. An understanding of how carrying cost is compiled and the subtleties between the ordering algorithms discussed, will lead to improved material purchasing decision making as well as significant savings.

One specific area for decision making will occur between the decision to place a value-order (bulk buying) or to follow one of the other ordering algorithms. For example, bulk buying may result in a higher total cost of inventory (carrying + ordering) on the year, but if the savings generated on a per part basis when purchasing are greater than that of the savings generated by using another ordering algorithm, a bulk buy should be made. This will occur more often for SKUs with a price per part less than about $50.

Conclusions

Cycle Counting

The problem identified associated with cycle counting was that it is a non-value added activity, yet it is taking an excessive amount of time and resources in the Material Control Department. Employees have to come in an hour early every Wednesday and conduct cycle counts for roughly two hours, even on low-value SKUs. The objective was to reduce or eliminate this process completely, and this objective was met with two recommendations: continue to utilize the 'Small Parts Cycle Count' Excel file which reduces the time for a smalls parts cycle count by nearly 50%, and conduct further research into a point-of-use kanban inventory management system to not only eliminate cycle counting, but to also reduce motion of people and transportation of material on the manufacturing floor.

Unfortunately, our research did not lead us to the point-of-use alternative until nearly the end of our project timeline. That being said, if more time was available, we would map out the current transportation of material from the receiving area to the MC Department to the specific workstation on the manufacturing floor. After gathering data on the current state, the potential for improvement by implementing point-of-use could be estimated more accurately.

Ergonomics

The WISHA Lifting Calculator made it clear that ACMTC's Material Control department is at severe risk of injury while performing cycle counts on heavy materials, with greater than 80% of lifts considered risky. Based on the second Lifting Calculator assessment, the reduction in ergonomic risk that accompanies an invest in Dividable Bins makes cycle counting heavy materials greater than 70% safer. Additionally, this recommended solution cuts the time it takes to cycle count a single bin by 50%. Drawing this reduction in time out across several bins counted each week leads to an annual cost savings of $2,250, on top of the $6,200 annual cost savings associated with mitigating ergonomic risk.

Material Purchasing

The data collected and displayed in Table 3 highlights the waste of excess inventory at ACMTC. There is nearly $90,000 of inventory that has been sitting on the shelves for over 19 months, this demonstrates a clear lack of emphasis on carrying costs. This is common in manufacturing: inventory is often not seen as a problem unless a stockout occurs and this leads to the problem of excess inventory. Based on our analysis of various ordering algorithms, such as bulk-buying, L4L, EOQ, POQ and PPB, there are significant savings to be had. These savings stem from the total costs associated with carrying and ordering inventory. In our calculations, a carrying cost of 27% was used to reflect the many components of carrying inventory, which is drastically greater than the carrying cost originally given of 3%.

Even when being ultra-conservative, our findings suggest that there is an opportunity for savings in excess of $5000 per year just by considering the ordering algorithms displayed in the ‘ACMTC Order Quantity’ Excel file when making material purchasing decisions.

References

"Akro-Grid 33220." *How to Organize | Medical Supply Room | Inventory | Storage Bins,* https://akro-mils.com/Products/Types/Plastic-Storage-Containers/Akro-Grid/Akro-Grid-33220. See also: Akro-Mils Short Divider for Akro-Grid Box 33220, 6 Pack, Black (41220). See also: Akro-Mils Long Divider for Akro-Grid 33220, 6 Pack, Black (42220)

Arora, Kanik, et al. "IEEE Wireless Communications and Networking Conference." IEEE, The Practical Feasibility of Using RFID in a Metal Environment, 2007, pp. 1681–1685. Engineering Village.

Bricker, Dennis. *Lot-Sizing Algorithms*. IME Dept - University of Iowa , 21 Jan. 2010, user.engineering.uiowa.edu/~dbricker/stacks_pdf1/lot-sizing.pdf.

CDIR - Ergonomic Guidelines for Manual Material Handling. Vol. 2007-131, California Department of Industrial Relations, 2007.

Chan-Amaya, Alejandro. "A Methodology to Determine the Level of Automation to Improve the Production Process and Reduce the Ergonomics Index." Journal of Physics: Conference Series, ser. 885, 2107. 885, doi:10.1088/1742-6596/885/1/012013.

Chapman, Stephen N., et al. *Introduction to Materials Management*. Pearson Education Limited, 2017.

Douphrate, David & Rosecrance, John. (2004). THE ECONOMICS AND COST JUSTIFICATION OF ERGONOMICS.

Ghelichi, A., and A. Abdelgawad. "IEEE IEEM." A Study on RFID-Based Kanban System in Inventory Management, 2014. Engineering Village.

Goldratt, Eliyahu M. *The Goal*. The North River Press, 2004.

Graff, Richard T. " THE LIMITATIONS OF CYCLE COUNTING." *Production and Inventory Management Journal*, 1987.

IOMA - "Inventory Reduction Report." Institute of Management and Administration, Aug. 2001. http://www.business.unr.edu/faculty/ronlembke/463/1-ICC.pdf

Jaber, M., S. Zanoni, L. Zavanella, 2014. Economic order quantity models for imperfect items with buy and repair options. International Journal of Production Economics, pp: 126-131.

Jung, Hoon, and Cerry M. Klein. "Optimal Inventory Policies for Profit Maximizing EOQ Models under Various Cost Functions." *European Journal of Operational Research*, vol. 174, no. 2, 2006, pp. 689–705., doi:10.1016/j.ejor.2004.06.041.

Kavoosi, Mohammad, and Amanollah Rahpeima. "Using EOQ model, the most favorable economic order to increase productivity (Case study: Parto Industrial Manufacturing Company)." *Advances in Environmental Biology*, 2014, p. 1121+. *Academic OneFile*

Khojasteh, Yacob. *Production Control Systems a Guide to Enhance Performance of Pull Systems*. Springer Japan, 2016.

KLC - "Energy And Utilities Have Been The Most Volatile Sectors." Knowledge Leaders Capital Blog, Knowledge Leaders Capital LLC, 4 Mar. 2015, blog.knowledgeleaderscapital.com/?p=130.

Lee, Quarterman. *Strategos Guide To Cycle Counting & Inventory Accuracy*. Strategos, Inc., 2006.

NSC - National Safety Council. (2017). Injury Facts®, 2017 Edition . Itasca, IL: Author. Library of Congress Catalog Card Number: 99-74142

Ohno, Taiichi, and Norman Bodek. *Toyota Production System: beyond Large-Scale Production*. Productivity Press, 2008.

OSHA United States, Congress, Occupational Safety and Health Administration. 3125, 2000. www.osha.gov/Publications/osha3125.pdf.

OSU - "Addressing The High Corporate Costs of Back Pain (and Other MSDs)." *Spine Research Institute*, The Ohio State University, 15 Aug. 2014

Park, Chong Ryol, and Ki Hwan Eom. "RFID Label Tag Design for Metallic Surface Environments." Sensors, no. 11, 2011, pp. 938–948. Engineering Village, doi:10.3390/s110100938.

Periyasamy, M., and R. Dhanasekaran. "IEEE International Conference on Communications and Signal Processing." IEEE, Evaluation of Performance of UHF Passive RFID System in Metal and Liquid Environment, 2015, pp. 0404–0417. Engineering Village.

Pindyck, Robert S. "Volatility in Natural Gas and Oil Markets." The Journal of Energy and Development, vol. 30, no. 1, 2004, pp. 1–19.

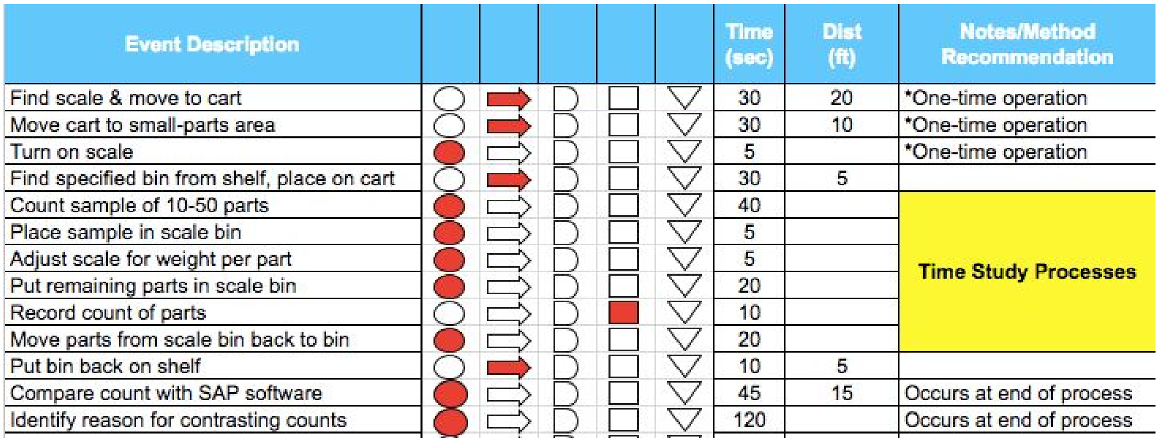
Qing, Xianming, and Zhi Ning Chen. "Proximity Effects of Metallic Environments on High Frequency RFID Reader Antenna: Study and Applications." IEEE Transactions on Antennas and Propagation, vol. 55, no. 11, Nov. 2007, pp. 3105–3111. Engineering Village.

Rahman, Mohd Nasrull Abdol, and Muhammad Fareez Ahmad Zuhaidi. "International Research and Innovation Summit." IOP Publishing, Musculoskeletal Symptoms and Ergonomic Hazards among Material Handlers in Grocery Retail Industries, 2017. Engineering Village.

Rosales, Claudia R., et al. "The 2Bin System for Controlling Medical Supplies at Point-of-Use." *European Journal of Operational Research*, vol. 243, no. 1, 16 May 2015, pp. 271–280., doi:10.1016/j.ejor.2014.10.041.

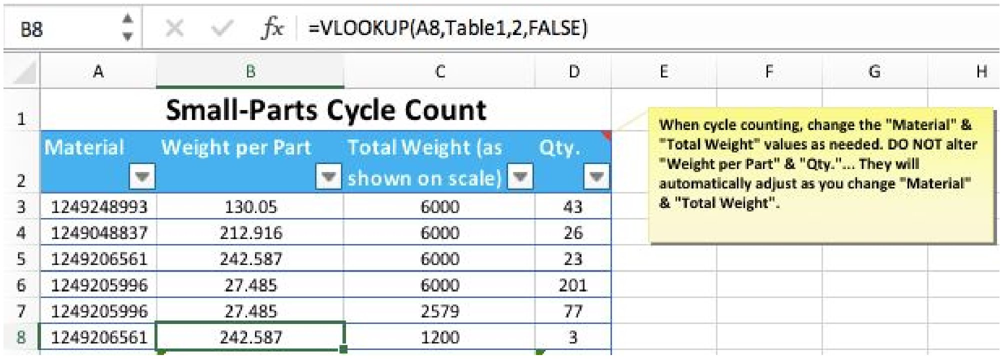
Umble, M., et al. "Implementing Theory of Constraints in a Traditional Japanese Manufacturing Environment: The Case of Hitachi Tool Engineering." *International Journal of Production Research*, vol. 44, no. 10, 2006, pp. 1863–1880.

Appendix A



Event Description						Time (sec)	Dist (ft)	Notes/Method Recommendation
Find scale & move to cart	○	➡	D	☐	▽	30	20	*One-time operation
Move cart to small-parts area	○	➡	D	☐	▽	30	10	*One-time operation
Turn on scale	●	⇨	D	☐	▽	5		*One-time operation
Find specified bin from shelf, place on cart	○	➡	D	☐	▽	30	5	
Count sample of 10-50 parts	●	⇨	D	☐	▽	40		Time Study Processes
Place sample in scale bin	●	⇨	D	☐	▽	5		
Adjust scale for weight per part	●	⇨	D	☐	▽	5		
Put remaining parts in scale bin	●	⇨	D	☐	▽	20		
Record count of parts	○	⇨	D	🟥	▽	10		
Move parts from scale bin back to bin	●	⇨	D	☐	▽	20		
Put bin back on shelf	○	➡	D	☐	▽	10	5	
Compare count with SAP software	●	⇨	D	☐	▽	45	15	Occurs at end of process
Identify reason for contrasting counts	●	⇨	D	☐	▽	120		Occurs at end of process

A-1: *Flow Process Chart of Original Cycle Counting Process*



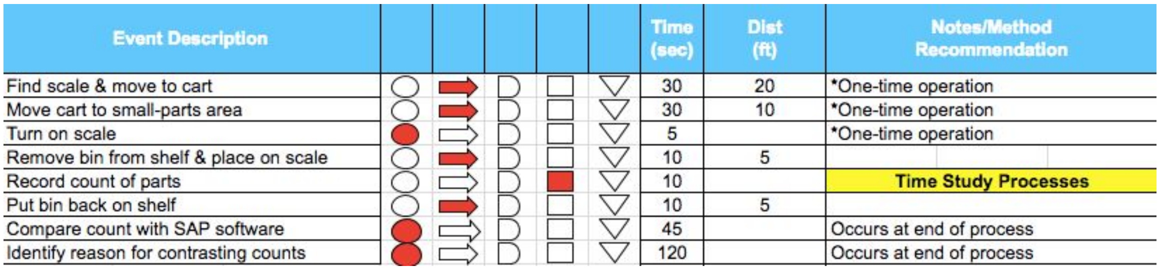
B8 =VLOOKUP(A8,Table1,2,FALSE)

Small-Parts Cycle Count

	Material	Weight per Part	Total Weight (as shown on scale)	Qty.
3	1249248993	130.05	6000	43
4	1249048837	212.916	6000	26
5	1249206561	242.587	6000	23
6	1249205996	27.485	6000	201
7	1249205996	27.485	2579	77
8	1249206561	242.587	1200	3

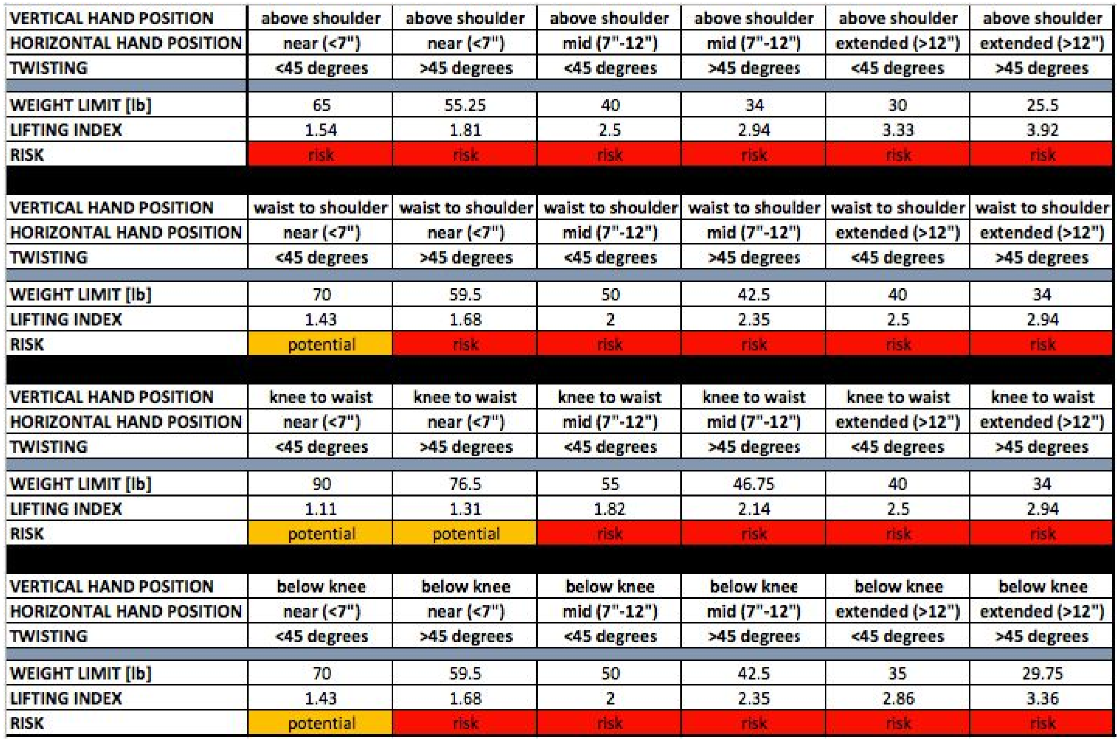
When cycle counting, change the "Material" & "Total Weight" values as needed. DO NOT alter "Weight per Part" & "Qty."... They will automatically adjust as you change "Material" & "Total Weight".

A-2: *Screenshot from 'Small Parts Cycle Count' Excel File*



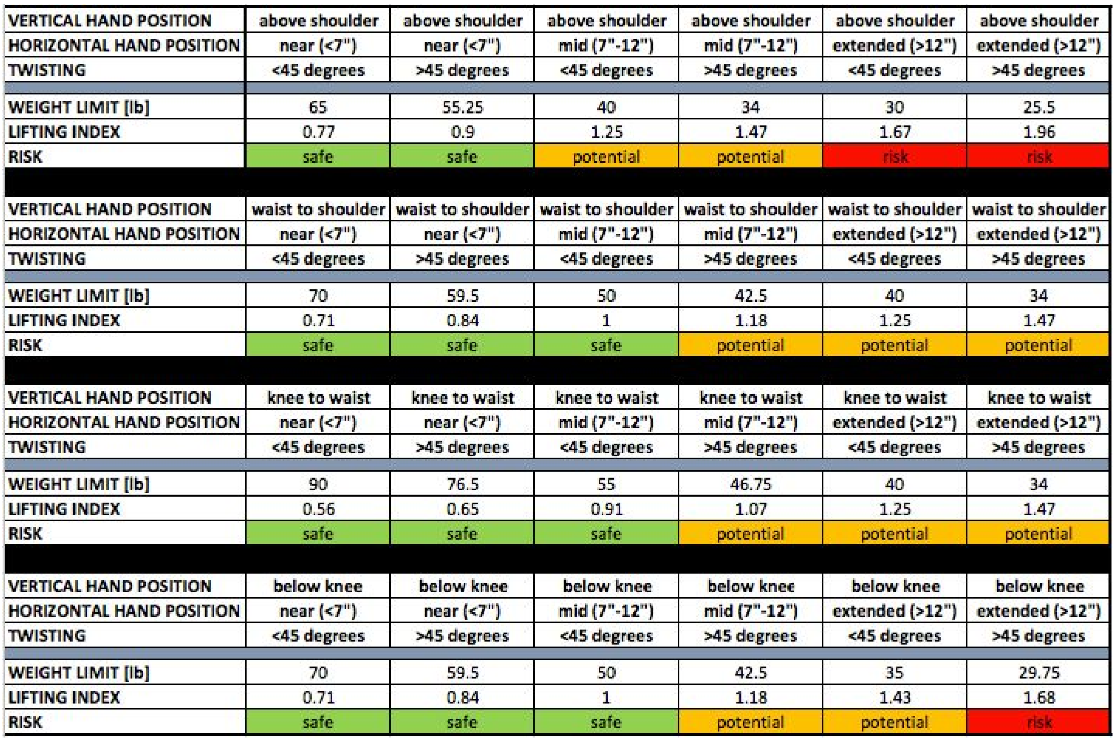
Event Description						Time (sec)	Dist (ft)	Notes/Method Recommendation
Find scale & move to cart	○	➡	D	☐	▽	30	20	*One-time operation
Move cart to small-parts area	○	➡	D	☐	▽	30	10	*One-time operation
Turn on scale	●	⇨	D	☐	▽	5		*One-time operation
Remove bin from shelf & place on scale	○	➡	D	☐	▽	10	5	
Record count of parts	○	⇨	D	🟥	▽	10		Time Study Processes
Put bin back on shelf	○	➡	D	☐	▽	10	5	
Compare count with SAP software	●	⇨	D	☐	▽	45		Occurs at end of process
Identify reason for contrasting counts	●	⇨	D	☐	▽	120		Occurs at end of process

A-3: *Flow Process Chart of Improved Cycle Counting Process*



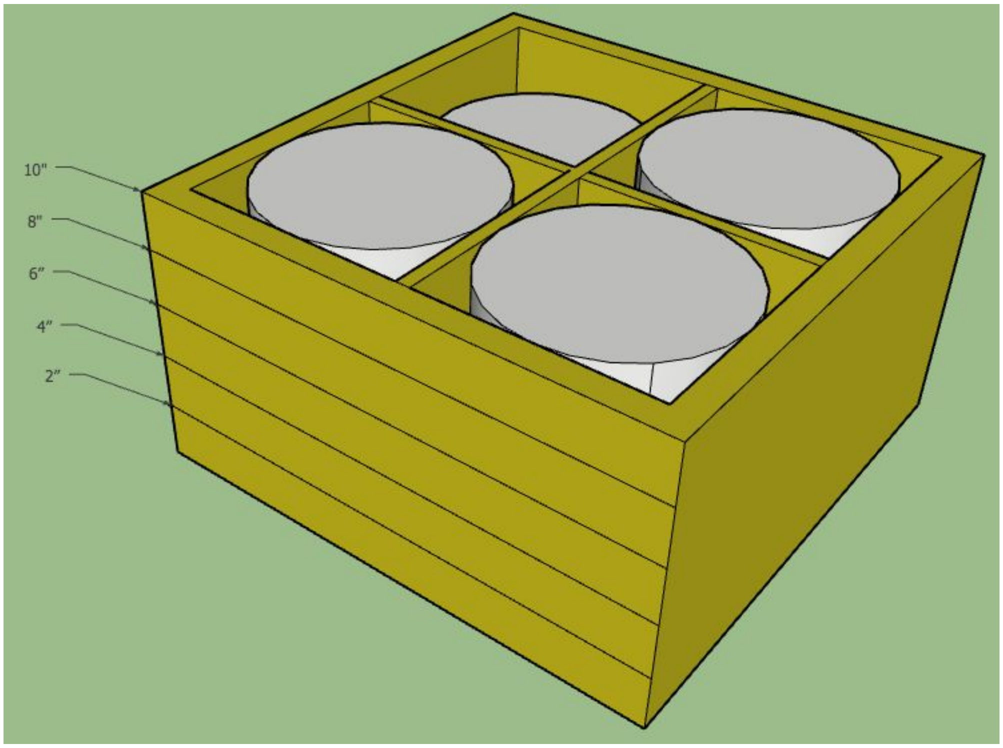
VERTICAL HAND POSITION	above shoulder	above shoulder	above shoulder	above shoulder	above shoulder	above shoulder
HORIZONTAL HAND POSITION	near (<7")	near (<7")	mid (7"-12")	mid (7"-12")	extended (>12")	extended (>12")
TWISTING	<45 degrees	>45 degrees	<45 degrees	>45 degrees	<45 degrees	>45 degrees
WEIGHT LIMIT [lb]	65	55.25	40	34	30	25.5
LIFTING INDEX	1.54	1.81	2.5	2.94	3.33	3.92
RISK	risk	risk	risk	risk	risk	risk
VERTICAL HAND POSITION	waist to shoulder	waist to shoulder	waist to shoulder	waist to shoulder	waist to shoulder	waist to shoulder
HORIZONTAL HAND POSITION	near (<7")	near (<7")	mid (7"-12")	mid (7"-12")	extended (>12")	extended (>12")
TWISTING	<45 degrees	>45 degrees	<45 degrees	>45 degrees	<45 degrees	>45 degrees
WEIGHT LIMIT [lb]	70	59.5	50	42.5	40	34
LIFTING INDEX	1.43	1.68	2	2.35	2.5	2.94
RISK	potential	risk	risk	risk	risk	risk
VERTICAL HAND POSITION	knee to waist	knee to waist	knee to waist	knee to waist	knee to waist	knee to waist
HORIZONTAL HAND POSITION	near (<7")	near (<7")	mid (7"-12")	mid (7"-12")	extended (>12")	extended (>12")
TWISTING	<45 degrees	>45 degrees	<45 degrees	>45 degrees	<45 degrees	>45 degrees
WEIGHT LIMIT [lb]	90	76.5	55	46.75	40	34
LIFTING INDEX	1.11	1.31	1.82	2.14	2.5	2.94
RISK	potential	potential	risk	risk	risk	risk
VERTICAL HAND POSITION	below knee	below knee	below knee	below knee	below knee	below knee
HORIZONTAL HAND POSITION	near (<7")	near (<7")	mid (7"-12")	mid (7"-12")	extended (>12")	extended (>12")
TWISTING	<45 degrees	>45 degrees	<45 degrees	>45 degrees	<45 degrees	>45 degrees
WEIGHT LIMIT [lb]	70	59.5	50	42.5	35	29.75
LIFTING INDEX	1.43	1.68	2	2.35	2.86	3.36
RISK	potential	risk	risk	risk	risk	risk

A-4: *WISHA Lifting Calculator Results for 100lb bins.*

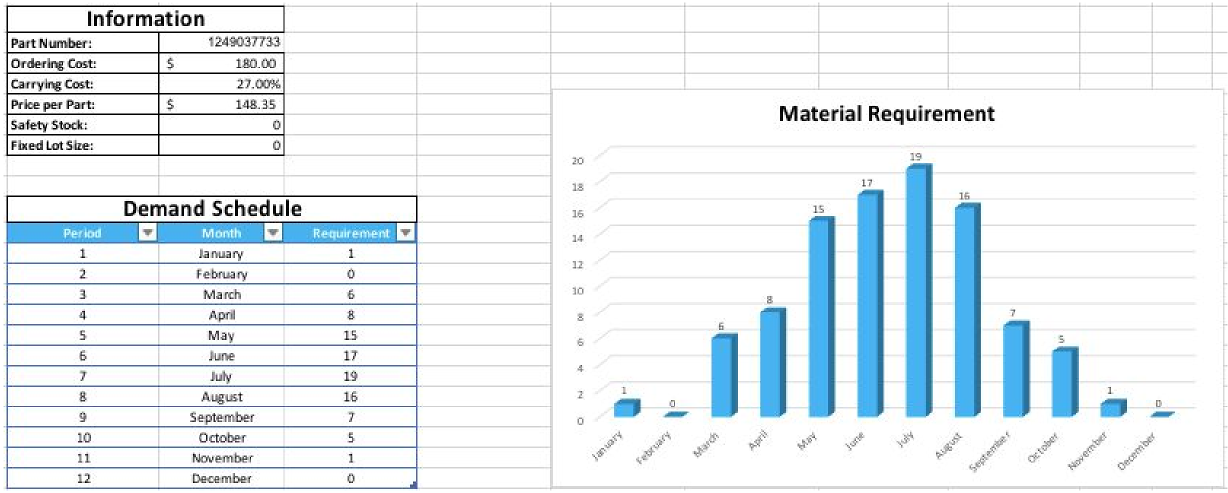


VERTICAL HAND POSITION	above shoulder	above shoulder	above shoulder	above shoulder	above shoulder	above shoulder
HORIZONTAL HAND POSITION	near (<7")	near (<7")	mid (7"-12")	mid (7"-12")	extended (>12")	extended (>12")
TWISTING	<45 degrees	>45 degrees	<45 degrees	>45 degrees	<45 degrees	>45 degrees
WEIGHT LIMIT [lb]	65	55.25	40	34	30	25.5
LIFTING INDEX	0.77	0.9	1.25	1.47	1.67	1.96
RISK	safe	safe	potential	potential	risk	risk
VERTICAL HAND POSITION	waist to shoulder	waist to shoulder	waist to shoulder	waist to shoulder	waist to shoulder	waist to shoulder
HORIZONTAL HAND POSITION	near (<7")	near (<7")	mid (7"-12")	mid (7"-12")	extended (>12")	extended (>12")
TWISTING	<45 degrees	>45 degrees	<45 degrees	>45 degrees	<45 degrees	>45 degrees
WEIGHT LIMIT [lb]	70	59.5	50	42.5	40	34
LIFTING INDEX	0.71	0.84	1	1.18	1.25	1.47
RISK	safe	safe	safe	potential	potential	potential
VERTICAL HAND POSITION	knee to waist	knee to waist	knee to waist	knee to waist	knee to waist	knee to waist
HORIZONTAL HAND POSITION	near (<7")	near (<7")	mid (7"-12")	mid (7"-12")	extended (>12")	extended (>12")
TWISTING	<45 degrees	>45 degrees	<45 degrees	>45 degrees	<45 degrees	>45 degrees
WEIGHT LIMIT [lb]	90	76.5	55	46.75	40	34
LIFTING INDEX	0.56	0.65	0.91	1.07	1.25	1.47
RISK	safe	safe	safe	potential	potential	potential
VERTICAL HAND POSITION	below knee	below knee	below knee	below knee	below knee	below knee
HORIZONTAL HAND POSITION	near (<7")	near (<7")	mid (7"-12")	mid (7"-12")	extended (>12")	extended (>12")
TWISTING	<45 degrees	>45 degrees	<45 degrees	>45 degrees	<45 degrees	>45 degrees
WEIGHT LIMIT [lb]	70	59.5	50	42.5	35	29.75
LIFTING INDEX	0.71	0.84	1	1.18	1.43	1.68
RISK	safe	safe	safe	potential	potential	risk

A-5: *WISHA Lifting Calculator Results for 50lb bins.*



A-6: *3D Model of Compartmentalized Bin System for Visual, "Hands-Free" count.*



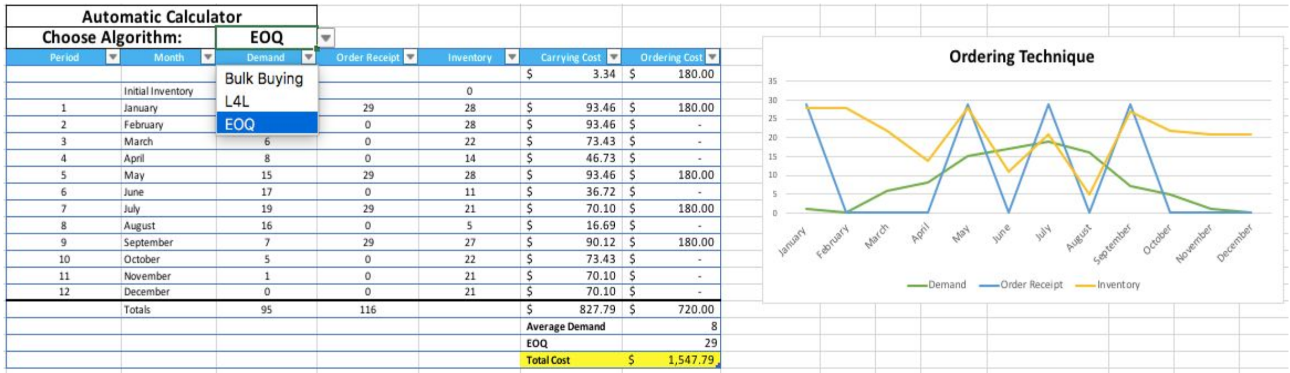
Information

Part Number:	1249037733
Ordering Cost:	$ 180.00
Carrying Cost:	27.00%
Price per Part:	$ 148.35
Safety Stock:	0
Fixed Lot Size:	0

Demand Schedule

Period	Month	Requirement
1	January	1
2	February	0
3	March	6
4	April	8
5	May	15
6	June	17
7	July	19
8	August	16
9	September	7
10	October	5
11	November	1
12	December	0

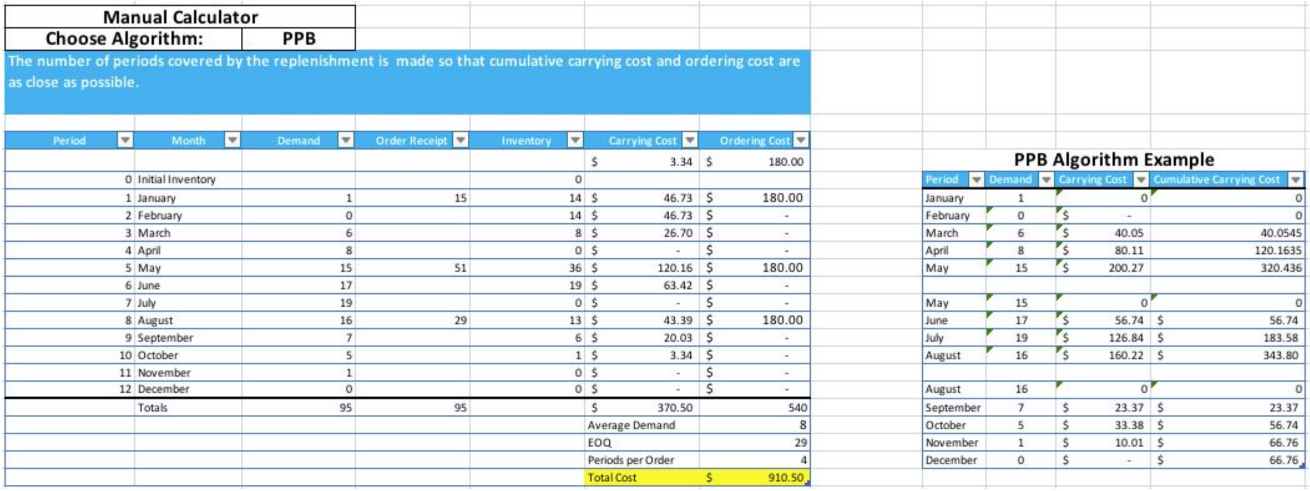
A-7: *Top Half of ACMTC Order Quantity Excel File with Material Requirement Visual*



Automatic Calculator						
Choose Algorithm:		EOQ				
		Bulk Buying L4L EOQ				

Period	Month	Demand	Order Receipt	Inventory	Carrying Cost	Ordering Cost
					$ 3.34	$ 180.00
	Initial Inventory			0		
1	January		29	28	$ 93.46	$ 180.00
2	February		0	28	$ 93.46	$ -
3	March	6	0	22	$ 73.43	$ -
4	April	8	0	14	$ 46.73	$ -
5	May	15	29	28	$ 93.46	$ 180.00
6	June	17	0	11	$ 36.72	$ -
7	July	19	29	21	$ 70.10	$ 180.00
8	August	16	0	5	$ 16.69	$ -
9	September	7	29	27	$ 90.12	$ 180.00
10	October	5	0	22	$ 73.43	$ -
11	November	1	0	21	$ 70.10	$ -
12	December	0	0	21	$ 70.10	$ -
	Totals	95	116		$ 827.79	$ 720.00
					Average Demand	8
					EOQ	29
					Total Cost	$ 1,547.79

***A-8:** Automatic Order Quantity Calculator*



Manual Calculator	
Choose Algorithm:	PPB

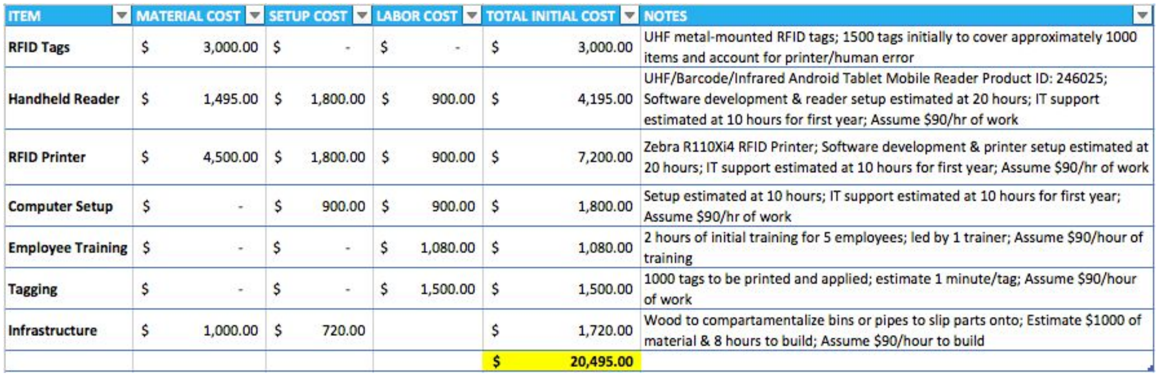
The number of periods covered by the replenishment is made so that cumulative carrying cost and ordering cost are as close as possible.

Period	Month	Demand	Order Receipt	Inventory	Carrying Cost	Ordering Cost
					$ 3.34	$ 180.00
0	Initial Inventory			0		
1	January	1	15	14	$ 46.73	$ 180.00
2	February	0		14	$ 46.73	$ -
3	March	6		8	$ 26.70	$ -
4	April	8		0	$ -	$ -
5	May	15	51	36	$ 120.16	$ 180.00
6	June	17		19	$ 63.42	$ -
7	July	19		0	$ -	$ -
8	August	16	29	13	$ 43.39	$ 180.00
9	September	7		6	$ 20.03	$ -
10	October	5		1	$ 3.34	$ -
11	November	1		0	$ -	$ -
12	December	0		0	$ -	$ -
	Totals	95	95		$ 370.50	540
					Average Demand	8
					EOQ	29
					Periods per Order	4
					Total Cost	$ 910.50

PPB Algorithm Example

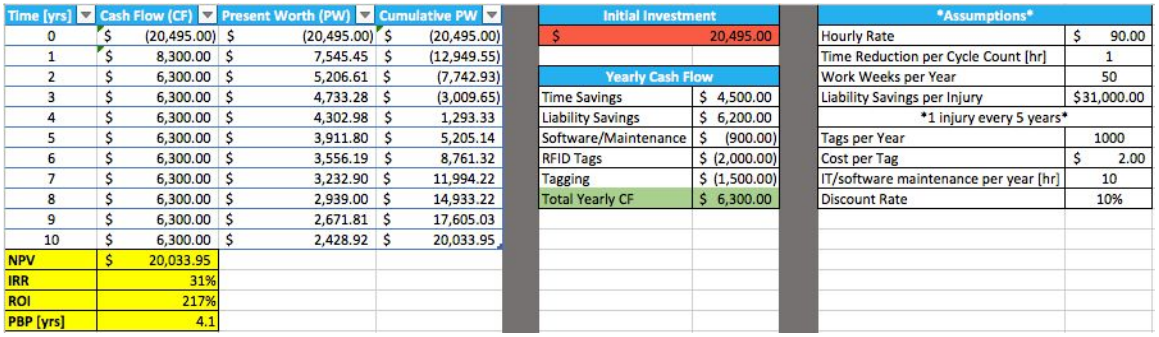
Period	Demand	Carrying Cost	Cumulative Carrying Cost
January	1	0	0
February	0	$ -	0
March	6	$ 40.05	40.0545
April	8	$ 80.11	120.1635
May	15	$ 200.27	320.436
May	15	0	0
June	17	$ 56.74	$ 56.74
July	19	$ 126.84	$ 183.58
August	16	$ 160.22	$ 343.80
August	16	0	0
September	7	$ 23.37	$ 23.37
October	5	$ 33.38	$ 56.74
November	1	$ 10.01	$ 66.76
December	0	$ -	$ 66.76

***A-9:** Manual Order Quantity Calculator with PPB Algorithm Example*



ITEM	MATERIAL COST	SETUP COST	LABOR COST	TOTAL INITIAL COST	NOTES
RFID Tags	$ 3,000.00	$ -	$ -	$ 3,000.00	UHF metal-mounted RFID tags; 1500 tags initially to cover approximately 1000 items and account for printer/human error
Handheld Reader	$ 1,495.00	$ 1,800.00	$ 900.00	$ 4,195.00	UHF/Barcode/Infrared Android Tablet Mobile Reader Product ID: 246025; Software development & reader setup estimated at 20 hours; IT support estimated at 10 hours for first year; Assume $90/hr of work
RFID Printer	$ 4,500.00	$ 1,800.00	$ 900.00	$ 7,200.00	Zebra R110Xi4 RFID Printer; Software development & printer setup estimated at 20 hours; IT support estimated at 10 hours for first year; Assume $90/hr of work
Computer Setup	$ -	$ 900.00	$ 900.00	$ 1,800.00	Setup estimated at 10 hours; IT support estimated at 10 hours for first year; Assume $90/hr of work
Employee Training	$ -	$ -	$ 1,080.00	$ 1,080.00	2 hours of initial training for 5 employees; led by 1 trainer; Assume $90/hour of training
Tagging	$ -	$ -	$ 1,500.00	$ 1,500.00	1000 tags to be printed and applied; estimate 1 minute/tag; Assume $90/hour of work
Infrastructure	$ 1,000.00	$ 720.00		$ 1,720.00	Wood to compartamentalize bins or pipes to slip parts onto; Estimate $1000 of material & 8 hours to build; Assume $90/hour to build
				$ 20,495.00	

***A-10:** Cost Breakdown of RFID*



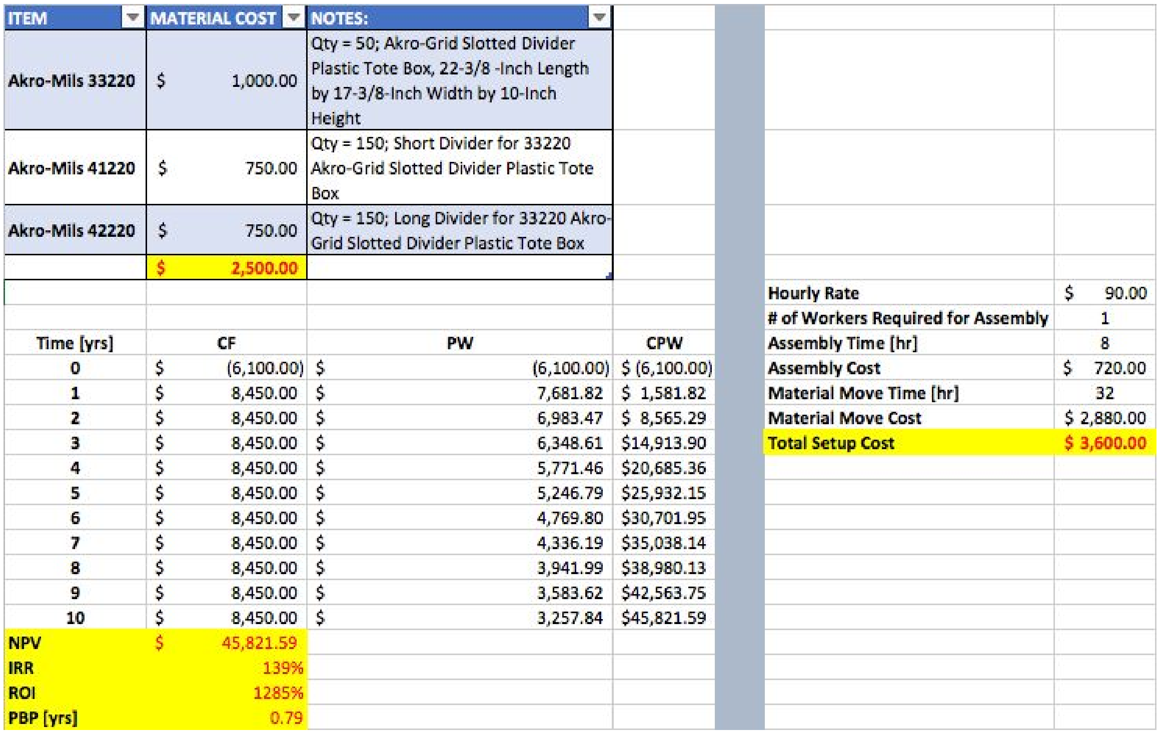
Time [yrs]	Cash Flow (CF)	Present Worth (PW)	Cumulative PW
0	$ (20,495.00)	$ (20,495.00)	$ (20,495.00)
1	$ 8,300.00	$ 7,545.45	$ (12,949.55)
2	$ 6,300.00	$ 5,206.61	$ (7,742.93)
3	$ 6,300.00	$ 4,733.28	$ (3,009.65)
4	$ 6,300.00	$ 4,302.98	$ 1,293.33
5	$ 6,300.00	$ 3,911.80	$ 5,205.14
6	$ 6,300.00	$ 3,556.19	$ 8,761.32
7	$ 6,300.00	$ 3,232.90	$ 11,994.22
8	$ 6,300.00	$ 2,939.00	$ 14,933.22
9	$ 6,300.00	$ 2,671.81	$ 17,605.03
10	$ 6,300.00	$ 2,428.92	$ 20,033.95
NPV	$ 20,033.95		
IRR	31%		
ROI	217%		
PBP [yrs]	4.1		

Initial Investment	
$ 20,495.00	

Yearly Cash Flow	
Time Savings	$ 4,500.00
Liability Savings	$ 6,200.00
Software/Maintenance	$ (900.00)
RFID Tags	$ (2,000.00)
Tagging	$ (1,500.00)
Total Yearly CF	$ 6,300.00

Assumptions	
Hourly Rate	$ 90.00
Time Reduction per Cycle Count [hr]	1
Work Weeks per Year	50
Liability Savings per Injury	$31,000.00
1 injury every 5 years	
Tags per Year	1000
Cost per Tag	$ 2.00
IT/software maintenance per year [hr]	10
Discount Rate	10%

A-11: *RFID Annual Costs & Financial Figures*



ITEM	MATERIAL COST	NOTES:
Akro-Mils 33220	$ 1,000.00	Qty = 50; Akro-Grid Slotted Divider Plastic Tote Box, 22-3/8 -Inch Length by 17-3/8-Inch Width by 10-Inch Height
Akro-Mils 41220	$ 750.00	Qty = 150; Short Divider for 33220 Akro-Grid Slotted Divider Plastic Tote Box
Akro-Mils 42220	$ 750.00	Qty = 150; Long Divider for 33220 Akro-Grid Slotted Divider Plastic Tote Box
	$ 2,500.00	

Hourly Rate	$ 90.00
# of Workers Required for Assembly	1
Assembly Time [hr]	8
Assembly Cost	$ 720.00
Material Move Time [hr]	32
Material Move Cost	$ 2,880.00
Total Setup Cost	$ 3,600.00

Time [yrs]	CF	PW	CPW
0	$ (6,100.00)	$ (6,100.00)	$ (6,100.00)
1	$ 8,450.00	$ 7,681.82	$ 1,581.82
2	$ 8,450.00	$ 6,983.47	$ 8,565.29
3	$ 8,450.00	$ 6,348.61	$14,913.90
4	$ 8,450.00	$ 5,771.46	$20,685.36
5	$ 8,450.00	$ 5,246.79	$25,932.15
6	$ 8,450.00	$ 4,769.80	$30,701.95
7	$ 8,450.00	$ 4,336.19	$35,038.14
8	$ 8,450.00	$ 3,941.99	$38,980.13
9	$ 8,450.00	$ 3,583.62	$42,563.75
10	$ 8,450.00	$ 3,257.84	$45,821.59
NPV	$ 45,821.59		
IRR	139%		
ROI	1285%		
PBP [yrs]	0.79		

A-12: *Dividable Bins Cost Breakdown & Financial Figures*

Time (Years)	Cash Flow (CF)	PW	Cumulative PW
0	$ (180.00)	$ (180.00)	$ (180.00)
1	$ 5,680.00	$ 5,163.64	$ 4,983.64
2	$ 5,680.00	$ 4,694.21	$ 9,677.85
3	$ 5,680.00	$ 4,267.47	$ 13,945.32
4	$ 5,680.00	$ 3,879.52	$ 17,824.84
5	$ 5,680.00	$ 3,526.83	$ 21,351.67
6	$ 5,680.00	$ 3,206.21	$ 24,557.88
7	$ 5,680.00	$ 2,914.74	$ 27,472.62
8	$ 5,680.00	$ 2,649.76	$ 30,122.38
9	$ 5,680.00	$ 2,408.87	$ 32,531.26
10	$ 5,680.00	$ 2,189.89	$ 34,721.14
Discount Rate	10%		
NPV	$ 34,721.14		
IRR	3156%		
ROI	31456%		
PBP	0.03		

Total Upfront costs	
2 Hours Taining/Learning	$ 180.00
Total Upfront Costs	$ 180.00

Yearly Cash Flow	
Yearly Inventory Cost Savings	$ 10,000.00
Training Other Employees	$ (2,160.00)
Inventory Updating	$ (2,160.00)
Yearly Cash Flow	$ 5,680.00

*Assumptions------>	
Training Hours per Month	2
Inventory Updating Hours per Month	2

A-13: *Order Quantity Algorithms Annual Costs & Financial Figures*