

AIR COMMAND AND STAFF COLLEGE

DISTANCE LEARNING

AIR UNIVERSITY

AUTOMATED MEDICAL SUPPLY CHAIN MANAGEMENT:

A REMEDY FOR LOGISTICAL SHORTCOMINGS

by

Brendan E. McQuown, Captain, USAF

A Research Report Submitted to the Faculty

In Partial Fulfillment of the Graduation Requirements

Proposal Adviser: Dr. Gregory Williams

Project Advisor: Dr. Andrew Niesiobedzki

Maxwell AFB, AL

August 2016

DISTRIBUTION A. Approved for public release: distribution unlimited.

Disclaimer

The views expressed in this academic research paper are those of the author(s) and do not reflect the official policy or position of the US government or the Department of Defense. In accordance with Air Force Instruction 51-303, it is not copyrighted, but is the property of the United States government.



Table of Contents

	Page
Disclaimer	ii
Table of Contents	iii
List of Figures	v
List of Tables	vi
Acknowledgements	vii
Abstract	viii
Introduction	1
Overview of the Study	1
Problem Background	1
Nature of the Problem	2
Purpose of the Study	3
The Research Question	3
Definition of Terms	4
The Anticipated Significance of the Study	4
Research Methodology	5
Literature Review	6
Research to Date	7
The Significance of Inventory Management in Business	9
Types of Inventory Management	11
A Manual Inventory Control Method	12
Automated Inventory Control Methods	12
Coca-Cola Company: An Industry Vanguard in Automated Inventory Management	13
The Significance of Inventory Management in Healthcare	14
Challenges of Supply Management in Healthcare	15
Barriers to Automated Supply Management in Healthcare	16
Military Medical Supply Chain Management	18
Inventory Management at Eglin Hospital's Inpatient and Surgical Units	19
Analysis	20
Cost-Benefit Analysis	20
The Numbers	21
Examination and Findings	22
The Case For Automation	24
Analysis of Pyxis	25

Conclusion	26
Limitations and Future Research.....	26
Recommendation.....	27
Endnotes	28
Bibliography	31



List of Figures

Figure 1. Simple Illustration of Inventory System Process Flow Diagram	10
Figure 2. Illustration of Manual Barcode Technology Workflow and RFID Workflow.....	13
Figure 3. Defense Medical Logistics Standard Support High-Level Operational Model.....	18
Figure 4. The Cost-Benefit Analysis Eight Step Process.....	21



List of Tables

Table 1. CBA of Manual (Visual) Inventory Management.....	22
Table 2. CBA of Automated (Perpetual/Pyxis) Inventory Management.....	22



Acknowledgements

First and foremost I would like to thank my wingman in life – my wife. Without your endless support, I would not have been able to accomplish this mass undertaking. You watched and cared for our children while I escaped on the weekends to complete this research paper and other course work. Thank you!

I would also like to thank my Research Electives I and Research Electives II course instructors Dr. Greg Williams and Dr. Robert Niesiobedzki. Dr. Williams guided me toward a viable research question. I had to change my research topic entirely during the Research Elective I course. Dr. Williams' support through the chaos of coming up with a new topic and research question saved this project. Originally I was going down a dead road. And, Dr. Niesiobedzki, thank you for your candid feedback, your helpful guidance, and your understanding of the military member's uncertain schedule. You made this doable.

Abstract

Inspired by the 2013 “Every Dollar Counts” campaign, this research evaluated whether automated inventory management practices would be more efficient than manual inventory management practices within the 96 Medical Group (MDG), Eglin Hospital. It was known that the Defense Medical Logistics Standard was used at Eglin Hospital but was not fully integrated down to the unit level. Casual manual inventory management practices were used explicitly resulting in inventory overstock and expiration, and supply shortages. Furthermore, inventories on multiple units were dispersed making it difficult to find needed supplies. Appropriately, automating the supply chain seemed like a logical solution to fix these flawed management practices, and so the question was asked: How will an automated supply management solution in the 96 MDG’s inpatient and surgical units impact efficiency?

This study utilized an evaluation methodology applying a cost-benefit analysis and mixed methods approach to posit how automation will increase efficiency at Eglin Hospital. The results of the study show good reasons to invest in automation. There is a strong amount of qualitative and quantitative data from the merchandise and manufacturing fields of business. There is limited data in healthcare; however, the correlation is made that best practices are universal to all business types. Thus there is a strong valuation placed on the non-quantifiable benefits within the cost-benefit analysis of automated inventory management practices. As a result, the study concludes automation will increase efficiency at the 96 MDG and is recommended for hospital-wide use. Bias cannot be completely ruled out within this study. The study realizes there are limitations and areas for future research.

Introduction

Overview of the Study

This research paper will assess the impact of an automated supply management system in the 96 MDG inpatient and surgical units using an evaluation methodology. A cost-benefit analysis using the influence of the Air Force's "Every Dollar Counts" campaign will help establish criteria for the appraisal of manual and automated supply chain management practices. Comparative analysis of the results will assist the facilities leadership and Medical Service Corps personnel in determining which inventory management SCM practices will best serve the 96 MDG moving forward.

Problem Background

The Military Health System (MHS) is facing extraordinary cost pressures to budget their money better. As most are already aware, healthcare costs are only climbing. According to the Congressional Budget Office, healthcare spending is projected to account for 11 percent of the Department of Defense's (DoD) base budget by 2028.¹ This healthcare spending projection is significant because healthcare accounted for 6 percent of the DoD's base budget in 2000.² As a result, the leadership of the 65 military hospitals, 412 clinics, and 414 dental clinics within the MHS are challenged with the creation of cost reduction strategies while maintaining the highest standards of patient care.³ One area of cost reduction lies within the logistical capacity of supply chain management (SCM) because 40 percent of a typical hospital's operating budget is its supply chain.⁴

SCM is not a new concept. Businesses of all types (i.e. services, merchandise, and manufacturing) utilize the concepts of SCM to meet consumer demands all the while reducing unnecessary costs. The United States military is no exception. In fact, the US military has in a

large sense streamlined the many processes of modern SCM. However, they have not fully expounded upon the implications of good SCM throughout all their provided services. Globally, the healthcare industry has been slow to embrace SCM. At the 96 MDG, a lot of money is being lost “despite [the] well-documented evidence of cost reduction resulting from good SCM practices” in other types of business.⁵ Consequently, this research will focus on the implications of an automated supply inventory management system within the inpatient and surgical units of the 96 MDG.

Nature of the Problem

Supply/inventory management research in healthcare has become a hot topic within the healthcare-logistical world. Nationally, this problem stems from poor “price transparency” strategies employed by healthcare facilities.⁶ Insurance companies see one hospital charging one thing for a service and another hospital charging something wildly different for the same service. They want more price transparency and are now reimbursing less for healthcare provided services rendered than they have in the past. As a result, healthcare facilities are not receiving the money they see necessary to support all costs; accordingly, they are looking at all areas for cost savings.

The military services are not immune to budgetary constraints. On the contrary, in the not so distant past (2013), Airmen of all career fields found themselves in positions of doing more with less due to big budget cuts and sequestration. Air Force (AF) leadership from the beginning realized this circumstance was not a viable means to any one end. They knew they needed to focus on Airmen’s time and intellect rather than finding ways to get more with less.⁷ As a result, in 2013, Deborah Lee James, Secretary of the AF and General Larry O. Spencer, USAF retired, and former Vice Chief of Staff of the AF, came up with the “Every Dollar

Counts” campaign in response to budget sequestration. The objectives of the campaign were to cultivate a culture of innovation, efficiency, and savings to lessen the financial impacts caused by budget cuts.⁸ Its creation marked a cultural shift in how the AF viewed and handled money and challenged the way things were done in the past – it marked a new culture of fiscal stewardship.⁹

Though created in 2013, the “Every Dollar Counts” campaign remains one the Secretary of the AF’s top three priorities to this day. To date, of the 6,791 ideas stemming from this initiative, 192 have been approved by AF leadership and have accumulated \$121.3 million in projected savings.¹⁰ The challenge to save money is ongoing; more innovative ideas and solutions are waiting to be discovered.

Purpose of the Study

The purpose of this study is to find out whether or not the investment in an automated supply management system will increase efficiency at the 96 MDG. Are automated supply management principles better than manual supply management principles? Appropriately, the biggest indicator of efficiency is cost savings. Evidence in merchandise and manufacturing businesses alike suggest automation can improve inventory control and increase cost savings; thus, automation increases business efficiency. A few healthcare related studies have similar findings. Can it be true that the principles of automated supply inventory management principles are universal across all businesses?

Research Question

The days of military, financial freedom are gone. All the military services continue to face the budgetary constraints and the threat of work stoppages due to budget sequestration. In response to budget caps and the threat of sequestration penalties, the AF is challenging all its Airmen to be better stewards of military property and taxpayer dollars. All ideas and solutions

are plausible. Therefore, the research question for this study is: How will an automated supply management solution in the 96 MDG's inpatient and surgical units impact efficiency?

Definition of Terms

Inpatient and Surgical Units. Loose terminology used to include all inpatient units: medical-surgical unit, intensive care unit, labor and delivery unit; and, all surgical units: preoperative, intraoperative, and postoperative units.

Supply Chain Management. "The process of efficiently integrating suppliers, manufacturers, warehouses, and stores so that merchandise is produced and distributed in right quantities, to the right location, and at the right time to minimize system-wide costs while satisfying service-level requirements."¹¹

Inventory. "The tangible personal property held for sale in the ordinary course of business or an asset on a balance sheet."¹²

Inventory Management. "The process of monitoring and controlling the goods and materials that are held in inventory to ensure that appropriate levels are maintained."¹³

Bayesian Inference. "An approach to statistics in which all forms of uncertainty are expressed regarding probability."¹⁴

Cost-Benefit Analysis. "A method used to help appraise, or assess, the case for a proposal; the process involves weighing the total expected costs against the total expected benefits of one or more actions to select the best or most profitable option."¹⁵

The Anticipated Significance of the Study

Currently the medical and surgical inpatient units of the 96 MDG have loosely controlled inventories, require staff to use a whiteboard to indicate the need for re-supply, and occasionally eyeball stock levels and expiration dates. As a result of casual SCM practices, items are

overstocked, not stocked, expired, or lost.¹⁶ An automated supply solution could potentially eliminate these issues by securing inventory, automating inventory refill counts, managing expiration dates, and keeping healthcare providers out of the SCM process. The 96 MDG's investment in such a system could essentially pay for itself, reduce future costs, improve patient safety outcomes, and increase workplace satisfaction.

Research Methodology

This research paper will use the evaluation framework to assess the efficacy of the 96 MDG's current manual SCM practices in comparison to a proposed automated SCM solution. Appropriately, the research will start with the provision of the MDG's current SCM policies and infrastructure to include a brief summary of the Defense Medical Logistics Standard Support System to give readers a background of military medical logistics. The background will then be examined within the context of the AF's "Every Dollar Counts" campaign – a campaign created in 2013 challenging U.S. Airman to come up with innovative money-saving ideas to maximize efficiency. The ensuing discussion will highlight manual SCM practices logistical inefficiencies such as loose inventory control, the impact of the healthcare providers managing stock, and the potential for a patient safety event. Next, the alternative concept of automation will be introduced. Evaluation of manual and automated SCM solutions will then be performed using a convergent parallel mixed methods approach.

The assessed criteria between the two systems will be cost, speed, accuracy/report quality, reliability (i.e. human error), time savings, maintenance/support requirements, limitations (i.e. security). Examined data from services (i.e. medical), merchandise, and manufacturing businesses will yield the quantitative and qualitative data necessary to provide a comprehensive appraisal of manual and automated SCM practices. The data will then be

scrutinized using a cost-benefit analysis (CBA) method to grade efficiency. All data will be graded against the limitations: perceived reliance on technology, upfront costs associated with new systems integration, continual maintenance and support fees, and super user and staff training. Finally, based on this paper's research findings, a well-informed recommendation to either upgrade to automation or continue with manual methods of SCM practices on the medical and surgical inpatient units will be provided to the 96 MDG leadership and Medical Service Corps (MSC) personnel.

Literature Review

Over the last two and a half decades SCM has greatly evolved. Essentially the focus of SCM has shifted from a generalized cost reduction philosophy to a more holistic lean practices philosophy. Yes, cost reduction has always been the focus, but the ways in achieving were not articulated well. Nowadays, businesses understand they can decrease SCM costs with real-time material and information flow, or decision support, and increase profitability by having the right products in place at the right time.¹⁷

In healthcare, there is a need for increased visibility, efficiency, and gathering of data around relevant interactions. Researching automated inventory management in healthcare yields moderate results; its significance is slowly being realized. Most open source searching using the Air Command and Staff College's Muir S. Fairchild Research Information Center search database and Google Scholar returned articles predominantly covering inventory management in merchandise and manufacturing businesses. The research available in the merchandise and manufacturing business segments is abundant. However, no search results truly investigate inventory management within the Air Force Medical Service (AFMS). In fact, only one paper titled, "Material Management of Medical-Surgical Items at Military Healthcare Facilities," has

been written in the AF within the last seven years that researched AFMS best SCM practices. Overall, inventory management within healthcare search inquiries are limited. Those that are related to healthcare are mostly case studies.

As a result, to successfully answer this research question, primary and secondary sources are used. Tertiary sources are only used to highlight the necessity for better SCM practices, specifically inventory management, within the medical field. Secondary sources explicitly include peer-reviewed journals and case study white papers. These sources provide additional insights into SCM best practices in all types of businesses. Furthermore, this will fill in the gaps that we may find in our primary sources. Finally, transferability of best inventory management practices into the medical business can then be assessed.

Research to Date

In 2009, Major Christopher Estridge, USAF, wrote his AFIT graduate research paper titled, “Material Management of Medical-Surgical Items at Military Healthcare Facilities.” His research project looked to find the optimal inventory policy that provided the lowest total relevant cost while still providing an acceptable service level to the end customer for the AFMS to adopt. The overall focus of his research is geared toward stock ordering. It assesses the efficacy of the Defense Medical Logistics Standard (DMLSS) compared to two other ordering processes. His results are rather inconclusive as a multitude of variables come into play. Additionally, his work focused on an ideal stock procurement system across all branches of the military and not specifically best inventory management strategies at the unit level within a defined hospital.

In 2015, Haiyan Xie and Ranathunga Sarathchandra conducted research titled, “Empirical Study of an Automated Inventory Management System With Bayesian Inference Algorithm.” It

addresses the inefficiency and inconsistency associated with asset tracking and inventory management within large organizations. Specifically, it investigates two asset-tracking practices: manual inventory management versus automated inventory management. The authors used the Bayesian Inference Algorithm to come to the conclusion that there is practicability in organizations pursuing the implementation of an automated inventory management system.¹⁸ This research is valuable because it provides quantitative data that will support the implementation of an automated supply system at the 96 MDG.

Three case study white papers published by Becton and Dickinson (BD) yield substantial evidence for the use of automated inventory practices. BD is a leading solutions company in healthcare whose vision is, “We envision a world where our solutions for Enterprise IT, Surveillance and Analytics facilitate decisions, Infection Prevention reduces infections, Medication Management improves medication safety, Procedural Solutions optimize workflow and Respiratory Care enhances lung support.”¹⁹ An area of expertise they specialize in is inventory management for which they offer Pyxis supply technologies. Pyxis is a configurable supply technology consisting of programmed cabinetry and shelving units that enable perpetual inventory management and easy access to supplies. It is designed to help hospitals reduce costs, streamline workflow and support compliance.

Case study one is a 2012 Munroe Regional case study where the hospital compared its utilization of automated inventory management technologies (Pyxis) to previous SCM practice in the operating room to determine its efficacy. The findings of this study indicated automation helped save the hospital \$2.7 million in the first nine months of Pyxis utilization.²⁰ Case study two is a 2013 St. John’s Medical Center case study. It is a more focused case study looking at the improvements Pyxis technologies created in their perioperative units. Findings included

reduced supply stock-outs, increased staff satisfaction that in turn decreased a number of calls unit managers were receiving due to supply stock-outs and enabled clinicians to focus more on patient care, and increased work/charge capture. The case study concluded Pyxis technologies helped save St. John's perioperative units \$71,859 in the first year of use.²¹ Lastly, case study three is a 2014 Parrish Medical Center case study. It revealed Pyxis automated technologies reduced hospital supply spending by 11% (\$474,000) and increased revenue by approximately \$4 million throughout their hospital campus.²²

Most importantly, these case studies include several of the measurables (e.g. cost, speed, accuracy/report quality, reliability, time savings, maintenance and support requirements, and limitations) being examined in this research study. Analysis of all these sources will allow us to draw some conclusions about which SCM (automated or manual) practices are more efficient and which will best serve the 96 MDG. Ultimately the sum of data will be used to analyze trends of supply costs over multiple years and how it impacts manpower. The three white paper case studies compare SCM practices before and after the introduction of automation within each of the respected hospital's logistical networks.

The Significance of Inventory Management in Business

The goal of SCM is to be as efficient as possible from supplier to the customer. Two areas largely account for the SCM fundamentals. They are inventory management and distribution. With our focus being on inventory management we need to understand why inventory is an important metric in business. According to inventory management experts Waller and Esper, inventory acts as a litmus test, which assesses the overall health of business.

Perhaps the most fundamental role that inventory plays in supply chains is that of facilitating the balancing of demand and supply. To effectively manage the forward and reverse flows in the supply chain, firms have to deal with upstream supplier exchanges and downstream customer demands. This puts an organization in the position of trying

*to strike a balance between fulfilling the demands of customers, which is often difficult to forecast with precision or accuracy, and maintaining adequate supply of materials and goods. This balance is often achieved through inventory.*²³

The scope of inventory management is primarily about specifying supply versus demand. Often, especially in big business, inventory management is necessary at different locations within a facility or multiple locations of a supply network. Having these multiple locations protects the regular and planned course of production against the random disturbance of running out of materials or goods for improved performance.²⁴ Furthermore, the scope of inventory management accounts for the fine lines between replenishment lead times, carrying costs of inventory, demand forecasting, inventory valuation, inventory visibility, and future inventory price forecasting.²⁵ All in all, too much inventory on the shelf creates waste; likewise, too little inventory on the shelf creates shortfalls. Demand forecasting is a critical component of profitable business; and, the way inventory is managed either positively or negatively contributes to demand forecasting.

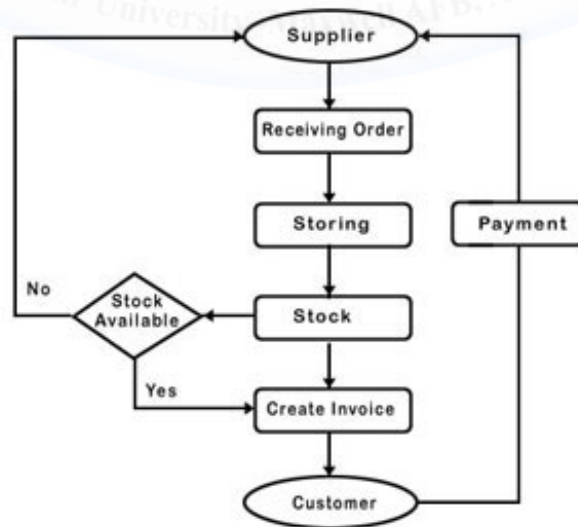


Figure 1. Simple Illustration of Inventory System Process Flow

Diagram²⁶

Types of Inventory Management

There are numerous ways to track inventory. The most popular methods in healthcare include the visual method, the periodic method, and the perpetual method.²⁷ The visual method is a manual method of tracking inventory. This method usually consists of inventory managers eyeballing stock levels to compare the stock visually on hand with a listing of the amount of products that should be carried.²⁸ The periodic method is another manual method that requires inventory managers to count stock with a list of minimum desired level of inventory on a regular basis at predetermined periods of time.²⁹ Then when quantities fall below the desired minimums, a resupply order is placed. These manual methods are time-consuming and often inaccurate of demand if the untrained is in charge of resupply. Lastly, there is the perpetual method. This method is the most commonly used in industrialized countries because it involves a computer system that monitors the inventory on a continuous basis and automatically subtracts quantities when supplies are removed.³⁰ The perpetual method is thought to be superior because it provides inventory managers with real-time stock levels.³¹ The real-time data component helps determine the demand. When inventory managers have knowledge of demand levels, they are better able to forecast supply needs.

A Manual Inventory Control Method

Typically a good inventory manager utilizing both visual and periodic manual methods of inventory management uses an algorithm to calculate a number of needed supplies. As an example in healthcare, there are some pharmacies (especially in developing countries) that use the most basic yet most all-encompassing algorithm for stock items expected to stay the same for the foreseeable future. It consists of seven steps. The first step is to calculate the average monthly consumption (AMC); this is the number of units used in a given month. Second, add

the number of units dispensed to patients during the last three to six months to account for seasonal changes. Third, divide the total number of units dispensed to patients by the number of months counted. Fourth, calculate the maximum stock level; this is the AMC x 3. Note, the industry's recommended maximum stock level for an item that is delivered monthly is three times the AMC of the item. Fifth, calculate the minimum stock level; this is the AMC x 1. Sixth, the inventory manager needs to decide how much to order; this is when they visually check the balance in stock against that item's maximum stock level. Seventh, if the balance is less than the maximum stock level, it is time to order the item.³²

Automated Inventory Control Methods

The industry standards for automated inventory management methods are barcodes and radio frequency identification (RFID) tracking methods. RFID could be considered an evolutionary jump of the barcode. Both have significance in business.

A barcode is an optical machine-readable representation of data relating to the object to which it is attached.³³ The system consists of the barcode and a scanner. They are widely used in all types of businesses. Most popularly they are used in point-of-sale management and in logistical SCM. Barcoding items allow businesses to monitor merchandise. For example in grocery stores, fast-selling items can be quickly identified and automatically reordered and slow-selling items can be identified preventing inventory buildup.

Radio-frequency identification (RFID) uses electromagnetic fields to identify automatically and track tags attached to objects.³⁴ Tags contain electronically stored information; and, unlike using a barcode, the tag does not need to be within the line of sight of the scanner. As a result, the tag may be embedded in the tracked object. It is a faster hands-off

method of automatic identification and data capture. It takes the manual scanning of each individually barcoded items out of the equation.

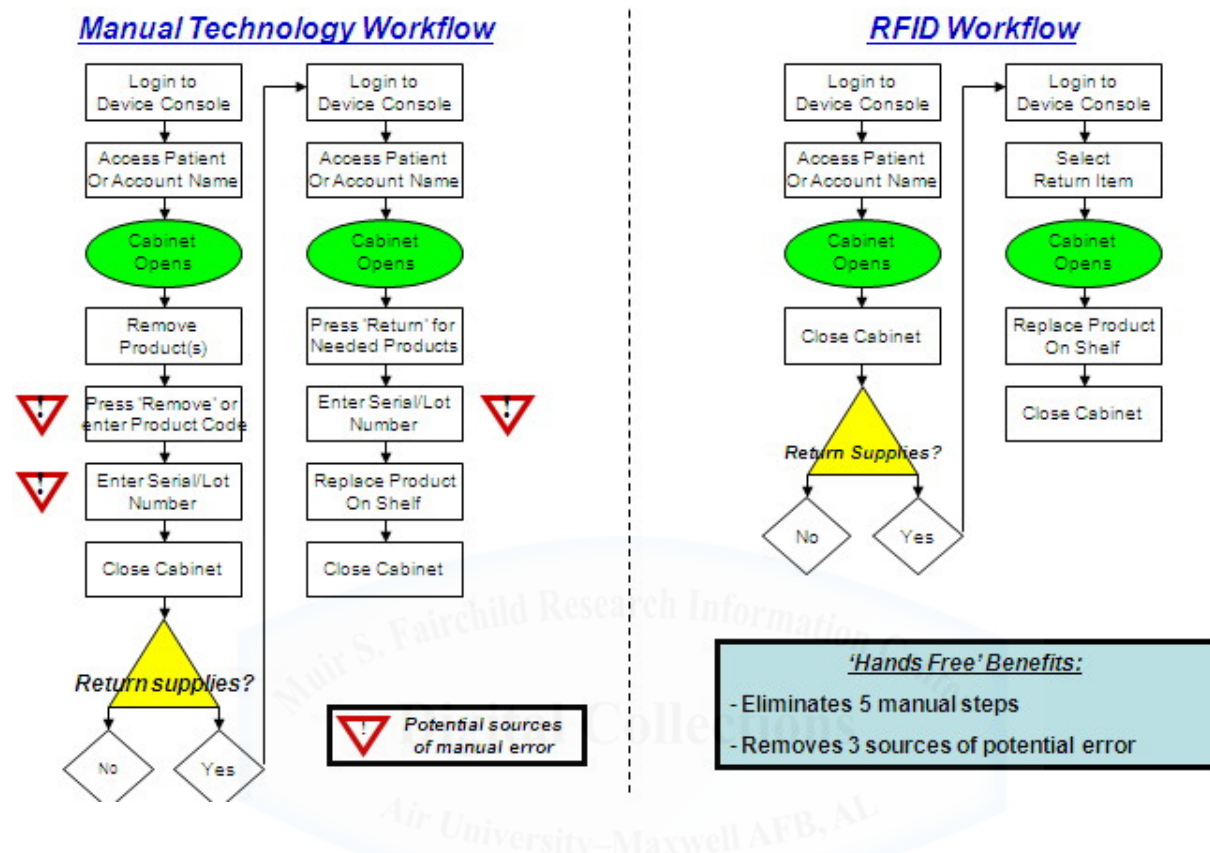


Figure 2. Illustration of Manual Barcode Technology Workflow and RFID Workflow³⁵

Coca-Cola Company: An Industry Vanguard in Automated Inventory Management

The Coca-Cola Company has been refining SCM practices from the beginning. Today, they invest heavily in automation to provide the most accurate real-time data necessary to prevent stock-outs and keep their consumers filled up with their line of drink products at all times. More recently, in 2009, Coca-Cola has introduced Coca-Cola Freestyle. It is a touch-screen soda fountain that allows users to customize the flavors of their beverage; customers now have over 100 drink options built into a single machine.³⁶ Users, using a touch screen, select from mixtures of flavors of Coca-Cola branded drink products that are then individually dispensed to create their uniquely flavored beverage.

Coca-Cola Freestyle is redefining business intelligence. This is accomplished through the many cabinetry technologies packed into the machines. Pertaining specifically to the supply versus demand and inventory management aspect, these machines use cartridges that store concentrated ingredients in the dispenser cabinet that are RFID enabled. The machine uses RFID chips to detect its supplies and to radio resupplying needs to other units.³⁷ The machines transmit supply and demand data to both Coca-Cola and the machine owner to prevent stock-outs and maximize profitability. For an example, Moe's Southwest Grill now requires all new franchises to have Coca-Cola Freestyle after testing the machines in Florida, Georgia, and North Carolina saw profitability increase by 9 percent.³⁸

The Significance of Inventory Management in Healthcare

The importance of inventory management in healthcare is evident when supplies (i.e. pharmaceuticals, medical-surgical procedure kits such as wound care products, and implants and tissues) account for approximately 40 percent of a hospital's typical operating budget.³⁹ However, even more impactful is the unavailability of a product when needed on demand for patient care. This situation may adversely affect a patient's wellbeing in hospital settings, especially when the product is an essential lifesaving one. An example of a situation like this would be antibiotic therapy for an aggressive infection. In some instances, certain infections only have sensitivity to one particular antibiotic. In the scenario where there was no available alternative antibiotic, the infection would worsen causing a life-threatening situation. The patient will either require transfer to a different facility (which creates additional costs) or die.

Challenges of Supply Management in Healthcare

Some of the major challenges of supply management in healthcare are a diversity of procedures, provider preferences, past practices, limited data, and duplication of supplies.⁴⁰ Each uniquely stresses the inventory management system.

First, concerning the diversity of procedures and provider preferences; everyday there are thousands of procedures performed across the US, and each requires a variety of supplies. Interestingly for duplicate procedures, there is little consistency in what is used from one provider to the other. The cost of supplies for a simple procedure can vary by hundreds of dollars depending on how the provider performed the procedure.⁴¹ Hospitals find it difficult to standardize procedures because no procedure is truly identical and each physician has their particular way of doing things. Rather than create a hostile work environment with providers and impose a procedural standardization that providers may be unfamiliar with, healthcare facilities regularly maintain “just-in-case” supplies for fear of not having something a provider might request.⁴² Consequently overstocking occurs and items often reach their expiration dates.

Second, regarding past practices, healthcare staff members are often the ones tasked with reordering supplies. Hospitals tend to think that managing their inventories completely in-house decrease costs because no processes are sourced out. Unfortunately, members of the healthcare team (i.e. doctors, nurses and medical technicians) are not well educated on inventory management practices; instead, their expertise lies in patient care. Healthcare providers neither have good information on usage and replenishment data nor are they familiar with units of measure.⁴³ As a result, tracking by exception occurs and inaccurate and inefficient overstocking procedures repeat. These practices have been largely overlooked because until recently insurance companies were willing to reimburse most hospital expenses.

Third, considering limited data, many healthcare facilities are struggling to find quantifiable data regarding supply usage, inventory levels, product duplication, and procedural costs to push for better SCM practices.⁴⁴ The data that does exist is retrospective and based on tracking items by exception, which does not provide accurate, current or prospective data sets. It is hard to convince healthcare providers and executive support to invest in new inventory management practices without actual supply usage data.

Fourth, and lastly, product duplication is a sizeable challenge that can drive up costs. On the one hand, constantly evolving technology creates new products; and, on the other hand, identical products come from vendors in different configurations. In the case of new products, evolving technology results in short product life cycles; however, there is little clinical evidence the new product improves patient outcomes.⁴⁵ Also, identical products with different configurations drive up costs. For example, different types of medical sutures need to be stocked in hospitals; however, it does not make good financial sense to stock different lengths of sutures of the same material and needle type. All in all, the reduction of product duplication reduces costs and improves inventory management.

Barriers to Automated Supply Management in Healthcare

The most evident barriers to automation are a lack of executive support, costs, misaligned department goals, and lack of education. Executive support is paramount with any new proposal. As with any business, executive buy-in for any change is needed to drive organizational change. Traditionally hospital executive focus has been tied with efforts to increase the revenue base rather than control costs.⁴⁶ Concerns regarding best SCM practices have not been a high priority item at board meetings across the healthcare industry. According to the McKone-Sweet research article interview findings, “The executive function team [often] lacked a representative with any

SCM knowledge or responsibilities.”⁴⁷ Top executives are largely unaware of cost savings opportunities with automated supply because SCM experts are not represented at board meetings. There has to be a top-down philosophy with an executive interested in supply chain issues and metrics put in place to measure and evaluate supply chain costs and overall performance to drive organizational SCM procedures.⁴⁸

The financial costs of adding automation to inventory management practices are not cheap. There are upfront hardware costs and recurring support/software costs. Cost becomes a major hurdle because of the lack of valid data to support the timely return of investment.⁴⁹

Misaligned department goals adulterate the overall hospital goals of cost reduction and are another barrier to automated inventory management practices. Recall, inventory management is necessary at different locations within a facility or multiple locations of a supply network. However, cost control and stock replenishment are left to the individual departments within the hospital – each department essentially does their own thing. Consequently, the logistical supply chain and individual departments are not fully integrated. As a result, poor inventory management practices occur within the individual departments.

Finally, the last barrier to implementation of automated supply is the lack of knowledge and skills about inventory management practices, both at the operational and executive levels. As previously mentioned, “many executives do not understand the importance of the supply chain and fail to track and monitor critical performance measures.”⁵⁰ Likewise, materials managers and clinicians lack the formal training to provide hospital executives the valid data to raise concern for the need to improve inventory management procedures. Understanding of the end-to-end supply chain, good communication and relationship skills, ability to develop contracting strategies, and financial and business skills need to be developed.⁵¹

Military Medical SCM

At the strategic level, the AFMS exclusively uses the DMLSS as the backbone of their SCM practices. DMLSS “is an automated information system for theater level III hospitalization units, including Army combat support hospitals, AF expeditionary medical systems, Navy hospital ships and Navy expeditionary medical force hospitals.”⁵² It delivers an automated and integrated information system with a comprehensive range of medical material, equipment, and war reserve materiel and facilities management functions for the MHS.⁵³ One of DMLSS’ many functions is to serve as the military’s electronic just-in-time inventory management system.

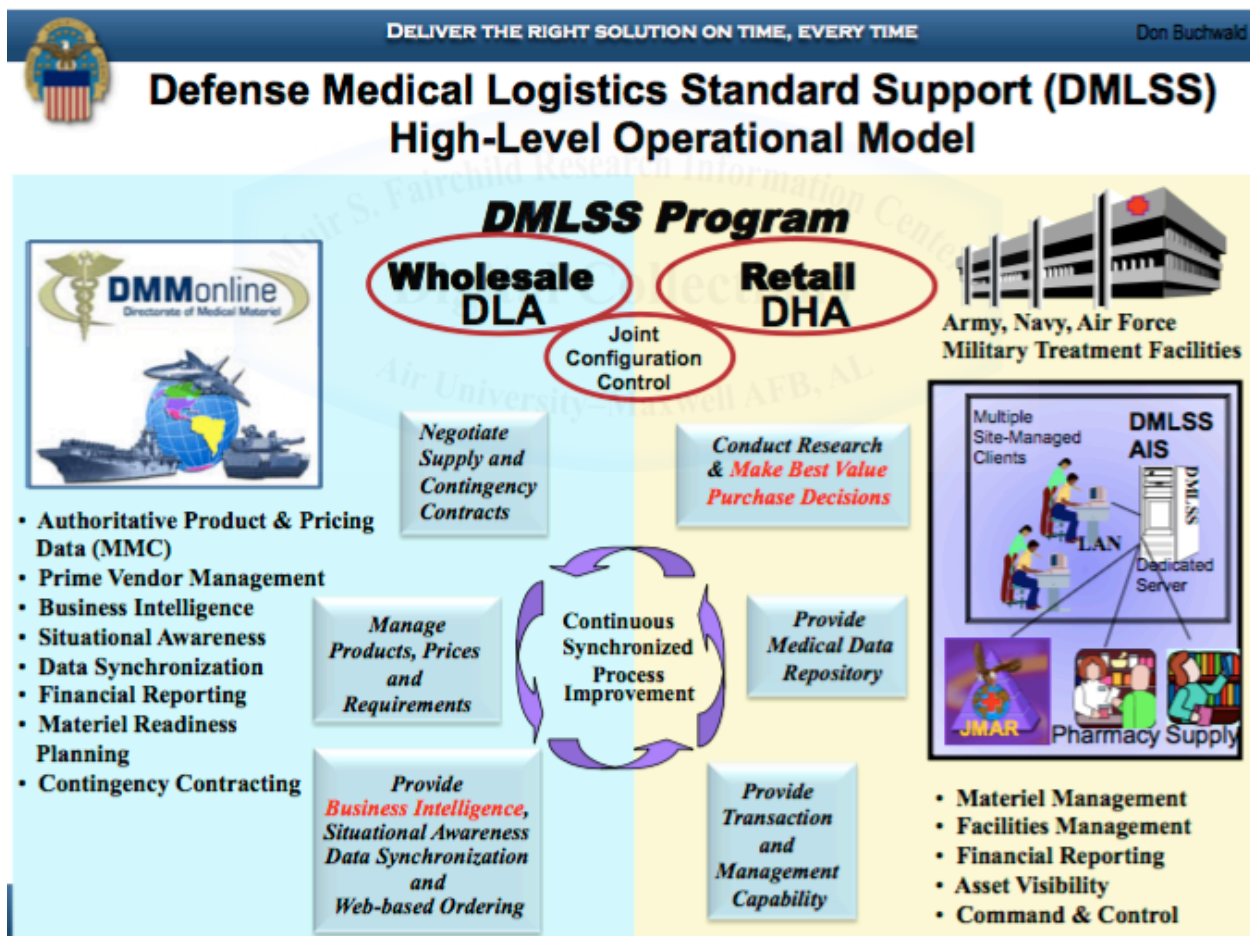


Figure 3. Defense Medical Logistics Standard Support High-Level Operational Model⁵⁴

An entire Air Force Instruction (AFI 41-216, DMLSS) totaling 86 pages exists; however

it contains almost no guidance on inventory management at the end user interface. It only states it needs to be done. DMLSS serves the AFMS enterprise well but it is not a one size fits all solution. It is too large a system to monitor accurately the unit level inventories in military treatment facilities. Missing is an efficient level of inventory management at the unit level.

Inventory Management at Eglin Hospital's Inpatient and Surgical Units

Currently the inpatient and surgical units utilize manual inventory management practices; specifically, they use the visual method. No algorithms are used in these units to determine adequate levels. Everything is tracked by exception or eyeballed. There is no defined periodic time where assets are routinely checked for minimum levels. Items are only restocked when staff members write on white boards to indicate a need for stock out or low counts. The information relayed on the white board is eventually seen by the unit's equipment custodian. The equipment custodian is a 4N0X1X or Aerospace Medical Technician by trade; and, according to the 4N0X1 Career Field Education and Training Plan, an Aerospace Medical Technicians job description is, "Plans, provides, and evaluates routine patient care and treatment of beneficiaries to include flying and special operational duty personnel. Organizes the medical environment performs and directs support activities in-patient care situations, including contingency operations and disasters."⁵⁵ Nowhere does it mention expertise in inventory management is a required skill. The equipment custodian duty is merely an additional duty; their primary duty takes precedence. After the equipment custodian goes into their DMLSS account, they can easily place orders. Orders typically arrive in two to three days to the warehouse where the logistical supply chain takes delivery and carts to the ordering units. Once on the unit, the supplies' cart is dropped off for staff to stock. At this point, there are unsecured supply items standing in the back hallways. Eventually, items are stocked.

The process mentioned above has many loopholes that create inefficiencies and unnecessary costs. Witnessed loopholes are logistical supply, and medical and surgical units are not integrated, the inexperienced and untrained are in charge of inventory management, and no data collection is being done. Consequently, 96 MDG leadership and MSC personnel are oblivious to the underlying condition of their inventory management practices; and it is not a problem because there have been no adverse events pinpointed to lack of supplies.

Analysis

Cost-Benefit Analysis

In this study, the evaluation of Eglin Hospital's manual (visual) inventory management practice was compared to Pyxis (a perpetual [automated] methods technology widely used in healthcare) using a CBA. Recall, a CBA is, "A method used to help appraise, or assess, the case for a proposal; the process involves weighing the total expected costs against the total expected benefits of one or more actions to select the best or most profitable option."⁵⁶ Furthermore, it is "A decision making tool accounting for the social costs and social benefits of a project over time to establish a net present value."⁵⁷ Note, a CBA considers quantifiable costs, non-quantifiable costs, quantifiable benefits, and non-quantifiable benefits; thus, it incorporates both costs and outcomes into the analysis. Outcomes are measured using a common scale; in this case it is increased efficiency of the staff. CBA "is appropriate when one of two standards are met: (1) when the processes being compared produce identical outcomes, and (2) when a single objective is easily measured. It attempts to define what should be, which requires an assessment of value, which in turn, cannot be divorced from value judgments."⁵⁸ Altogether, CBA attempts to understand whether the allocation of resources is efficient.



Figure 4. The CBA Eight Step Process⁵⁹

The Numbers

Data from the 96 MDG's intensive care unit (ICU) equipment custodian was obtained. The ICU stocks \$46,591 worth of inventory at minimum. This number was obtained by adding the listed inventory items on the ICU's 2016 customer catalog. The ICU also has a \$128,300 fiscal budget. On average, the ICU daily consumption rate is \$416.29 or \$151,945 a year. For the fiscal year 2016, the ICU is on track to be \$23,646 over budget. These metrics were obtained from the ICU DMLSS expense report print off. Additionally, a Becton and Dickinson (BD) Pyxis supply technology quote of \$116,168 for hardware costs and \$334/month for support costs were provided from a BD May 2016 Eglin Hospital site assessment. Keeping all these metrics in mind, the assessed criteria between the manual and automated inventory management methods will be costs, speed, accuracy/report quality, reliability, time savings, maintenance/support requirements, and limitations.

CBA Examination and Findings

Manual (Visual) Inventory Management	
COSTS	BENEFITS
Upfront: \$0	Simplicity
Recurring: \$0	Sense of Control
Unrealized Monetary Loss	Familiarity
Human Error	
Speed	
Accuracy/Report Quality	
Reliability	
Time Savings	
Maintenance/Support Requirements	

Table 1: CBA of Manual (Visual) Inventory Management

Automated (Perpetual/Pyxis) Inventory Management	
COSTS	BENEFITS
Upfront: \$116,168	Limits healthcare providers in the supply chain
Recurring: \$334/mo	Speed
System Manager	Accuracy/Report Quality
Maintenance/Support Requirements	Reliability
Security	Time Savings
Culture Change/Training	Better information for decision making
Technology Reliance	Easier to use

Table 2: CBA of Automated (Perpetual/Pyxis) Inventory Management

There is no quantifiable cost known and non-quantifiable costs outweigh the benefits 7:3 (Table 1). Casual supply management fosters unrealized monetary losses because of the inability to repeatedly produce accurate reports; this assertion is supported by the background case studies within the literature review. Compounding unrealized loss are expiration dates; manual practices do not track these dates. Additional loss is realized when expired supplies are stocked. It creates wasted space in the stockroom, which in turn, creates a delay in the acquisition of new supplies. An example of this is the monetary loss that occurs with Vacutainer blood collection tube expiration. When expired tubes need to be replaced the hospital absorbs the replacement costs.

New collection tubes have to be ordered, patient care delays may occur, and the potential for erroneous lab results increases. The result of erroneous lab results is the unnecessary treatment of patients, which also further compounds cost issues. Supply utilization is not captured by current manual methods. With manual methods there are human errors that add to the costs. Human errors result in the additional ordering of supplies, increasing the need for additional storage space and inventory expiration levels. Furthermore, inaccurate physical inventory counts potentially results in inadequate product procurement, meaning the ICU could possibly run out of a critically needed item at the wrong time. Speed, reliability, and support requirements all are inefficient with manual inventory management practices because it takes a long time to find items not often used. During these occurrences additional staff may have to discover this inventory, taking away time from patient care. Unfortunately all these costs metrics are noted as non-quantifiable because of the poor report quality data not being saved due to the constraints of manual practices. Regarding benefits, manual inventory management practices are all the ICU staff are familiar with which creates a false sense of simplicity and control.

The benefits of valuation outweigh the costs 9:7 (Table 2). The valuation of benefits can be argued because \$116,168 is a substantial quantifiable cost. In addition, other costs would be seen in recurring costs of \$334 per month, the recommended system manager costs, and maintenance costs. The valuation of benefits would have to be understandably substantial to advocate for the purchase of automation. However, the evaluation of benefits does present considerable increased efficiency potential. As the table depicts, automation will limit the amount of healthcare workers in the supply chain, will increase the speed of operations, report quality, and reliability, will create information for decision making, and is easier to use. All the

aforementioned represent an unknown cost savings at this time. Savings can only be realized if accurate records are kept and the information is shared.

The Case For Automation

The literature persistently highlights the fact that good inventory management practices are necessary to have an efficient workplace. Poor inventory management practices lead to increased costs and decreased employee productivity. It further identifies that speed, report quality, reliability, time savings, and system ease of use increase workplace efficiency.

Visual (manual) methods of inventory management can be effective, but the literature details visual practices being very time consuming and frequently unreliable – especially in large facilities. Furthermore, visual practices require a high degree of expertise in the area of inventory management. Remember, this research shows that logistical expertise does not always filter down to every level. The required inventory management at different locations within a facility is absent. As a result, visual inventory management practices are inefficient.

Quite the opposite of manual inventory management practices, the literature shows automated inventory management practices increase speed, improve report quality, improve reliability, recoup time savings benefits (i.e. increased clinical time for healthcare providers), and are easier to use. In large part, automation streamlines SCM and appropriately integrates the supply chain with individual departments. The three BD healthcare case studies in the literature review showed three different large healthcare facilities benefiting financially and economically from the efficiencies gained through automated inventory management practices. Ultimately, these facts paired with the CBAs of this research further support the practicability of automated inventory management systems in large organizations.

Analysis of Pyxis

Pyxis technology is not completely automated. Yes, it packs in many efficient features of automation like rapid access, accurate reporting, supply chain visibility, the ability to track supplies in real time, and help return healthcare workers to clinical activity; but it does require manual user inputs. It functions more like barcode technology as was discussed in the literature review. Instead of point-of-sale, Pyxis is push-to-take. Push-to-take means manual inputs still need to be made upon the removal of medical supplies. An implication for such technology utilization incorporates the possibility of human error. Figure 2, the “Illustration of Manual Barcode Technology Workflow and RFID Workflow,” highlights the fact RFID technology in inventory management eliminates five manual steps and removes three sources of potential human error. Fundamentally RFID technology is the more efficient of the two technologies because it removes the human element. In large part, this research has focused on making inventory management completely automated. However, removing all manual healthcare provider manual inputs is not a realistic option. RFID technology is considerably more expensive than barcode technology; it is not practical to place an RFID chip on small one-time use items. RFID is more practical for tracking high value items like medical stents. As a result, Pyxis is a more suitable option. Like RFID, Pyxis is also a perpetual method of asset tracking as discussed in the literature review. It is certainly more efficient than visual asset tracking methods. Still, for Pyxis to be completely successful in a large organization, workplace culture change and training would need to occur. Notably, as the literature has stated, integration of the supply chain and the department would need to happen. Pyxis would be the bridge to integration. Healthcare members in the different departments would need to correctly press the push-to-take button to create the accurate data needed for the medical logistician to correctly

resupply the Pyxis shelves. Appropriate utilization would make Pyxis a highly reliable and efficient inventory asset-tracking tool.

Conclusion

In conclusion, this evaluation determined automated inventory management would conceivably improve efficiency within the 96 MDG. Currently the organization's medical and surgical inpatient units do not use accurate inventory management practices. An unknown amount of money is being lost every fiscal year due to poor inventory management practices. As discussed in the literature review, DMLSS is too large a system to accurately track the smaller metrics; it is not effectively integrated within the individual hospital departments. The addition of automation will add the necessary inventory management within the supply network to complement the DMLSS system. As a result, real-time inventory will be realized and communicated to the larger DMLSS system; thus, efficiency will be increased at the 96 MDG.

Limitations and Future Research

The study recognizes that CBA and value judgment provides a rather subjective assessment that reflects the relative advantages and disadvantages of each of the criterion assessed. The research could have been made stronger by assigning numerical values to the criteria; doing so would allow the study to produce a scientific comparison. Furthermore, weighting the variables allows the rater the ability to express which variables are more or less important than other and is a subjective assessment that creates greater dispersion in-the numerical results and makes choices easier to differentiate.⁶⁰ Additionally, due to the limited sources (i.e. case studies) available, the use of the Becton and Dickinson white papers can be perceived as biased. However, this research takes the bias into consideration; and, while it

cannot dismiss it the facts remain that there is an overwhelming amount of evidence that supports automation in the supply chain.

Future research could be done at Medical Treatment Facilities (MTFs) (i.e. Wright-Patterson AFB) currently using Pyxis to capture the quantifiable data necessary to appropriately answer the research question. Those metrics were neither available to Becton and Dickinson nor to the author of this paper. A much stronger case for automation and standardization within the MTFs could potentially be realized in such a study.

Recommendation

It is the recommendation of this paper that automated inventory management practices be adopted at the 96 MDG's inpatient and surgical units. Yes, the upfront costs of converting to automation are substantial but the added efficiency gained is significant in ways that are non-quantifiable. However, validity of this recommendation is strongly supported by current literature in merchandise and manufacturing businesses and emerging literature in the healthcare industry. The CBA of this study further supports this recommendation. It will effectively remove the untrained and inexperienced healthcare providers currently managing inventory. It will allow for the integration of the logistical supply chain and the individual medical and surgical inpatient units. An investment in automated inventory management can and will improve the accuracy, efficiency, and reliability of the inventory management system. All-in-all, automated asset tracking practices are practical in large organizations like the 96 MDG.⁶¹

Endnotes

¹ “Approaches to Reducing Federal Spending on Military Health Care.” Congressional Budget Office, 16 January 2014, <https://www.cbo.gov/publication/44993>.

² Ibid., 2014.

³ “Military Treatment Facilities,” accessed 26 May 2016, <http://www.health.mil>.

⁴ Kathleen E. McKone-Sweet, Paul Hamilton, & Susan B. Willis, “The Ailing Healthcare Supply Chain: A Prescription for Change,” *Journal of Supply Chain Management*, Volume 41, Issue 1, 1 January 2005, 1.

⁵ Ibid., i.

⁶ Anna D. Sinaiko, and Meredith B. Rosenthal, “Increased Price Transparency in Health Care Challenges and Potential Effects,” *New England Journal of Medicine*, no. 364, 10 March 2011, 891.

⁷ Jamie M. Morin, “Making Every Dollar Count,” *Armed Forces Comptroller*, Spring 2013.

⁸ Deborah Lee James, Secretary of the Air Force, and General Larry O. Spencer, USAF Retired, and former Vice Chief of Staff of the Air Force, letter, subject: Every Dollar Counts Campaign, 13 May 2014.

⁹ Jamie M. Morin, Spring 2013.

¹⁰ Secretary of the Air Force Public Affairs, “Airman Powered by Innovation projected to save over \$120M,” 9 June 2016, <http://www.af.mil/News/ArticleDisplay/tabid/223/Article/795613/airmen-powered-by-innovation-projected-to-save-over-120m.aspx>.

¹¹ Matthew A. Waller and Terry Esper, “The Definitive Guide to Inventory Management: Principles and Strategies for the Efficient Flow of Inventory Across the Supply Chain,” Council of Supply Chain Management Professionals, New Jersey: Pearson Education, 2014, 4.

¹² Ibid., 3.

¹³ Margaret A. Camp and Donna Reeves, “Effective Operating Room Inventory Management,” Pfiedler Enterprises, 2014, 22, <http://www.pfiedler.com/ce/1265/files/assets/common/downloads/Effective%20Operating%20Room%20Inventory%20Management.pdf>.

¹⁴ Neal M. Radford, “Philosophy of Bayesian Inference,” <http://www.cs.toronto.edu/~radford/res-bayes-ex.html>.

¹⁵ Margaret A. Camp and Donna Reeves, 2014, 22.

¹⁶ Jasmine Pennic, “5 Ways Supply Chain Can Reduce Rising Healthcare Costs,” HIT Consultant, 13 May 2013, <http://hitconsultant.net/2013/05/13/5-ways-supply-chain-can-reduce-rising-healthcare-costs/>.

¹⁷ Kathleen E. McKone-Sweet, Paul Hamilton, & Susan B. Willis, 1 January 2005, 1.

¹⁸ Haiyan Xie and Ranathunga A.M. Sarathchandra. “Empirical Study of an Automated Inventory Management System With Bayesian Inference Algorithm.” *International Journal of Research in Engineering and Technology*. Volume 4, Issue 10, October 2015, 405.

¹⁹ “BD Values,” Becton and Dickinson, 2016, <https://www.bd.com/aboutbd/values/>.

²⁰ “Munroe Regional reduces costs and gives nurses more time for patient care using Pyxis supply technologies,” CareFusion (BD), 2012, accessed 14 July 2016, http://www.carefusion.com/Documents/case-studies/medication-supply-management/DI_Munroe-Regional-Medical-Center_CS_EN.pdf.

²¹ “St. John’s Medical Center improves efficiency using supply automation.” CareFusion (BD), 2013, accessed 14 July 2016,

http://www.carefusion.com/documents/brochures/medication-supply-management/DI_Pyxis-Perioperative-Solutions_BR_EN.pdf.

²² “Building a bridge between OR and Supply Management.” CareFusion (BD), 2014, accessed 14 July 2016, http://www.carefusion.com/Documents/case-studies/medication-supply-management/DI_Parrish-Medical-Center_CS_EN.pdf.

²³ Matthew A. Waller and Terry Esper, 4.

²⁴ Katherum Juma, “The Impact of Inventory Management and Performance of Private Organizations in Uganda. A Case Study of Coca-Cola Mbarara Plant in Mbarara Municipality,” Research Project, Bishop Stuart University, June 2013.

²⁵ Ibid., 2013.

²⁶ “Inventory Management,” Vns InfoSolutions Pvt. Ltd, 22 October 2009, slide 4, accessed 10 July 2016, <http://www.slideshare.net/sriprasoon/inventory-management-2316977>.

²⁷ Ali Ayad, “Inventory Management in Pharmacy Practice: A Review of Literature,” *Archives of Pharmacy Practice*. Volume2, Issue 4, 2011, 152.

²⁸ Ibid., 152.

²⁹ Ibid., 152.

³⁰ Ibid., 152.

³¹ Ibid., 152.

³² “How to Order Supplies Based on Past Use,” *World Health Organization, Operations Manual for Staff at Primary Health Care Centres*, (2008), Chapter 7.2, accessed 7 July 2016, <http://www.ncbi.nlm.nih.gov/books/NBK310913/>.

³³ “Barcode,” accessed 23 July 2016, <https://en.wikipedia.org/wiki/Barcode>.

³⁴ “RFID,” accessed 23 July 2016, https://en.wikipedia.org/wiki/Radio-frequency_identification.

³⁵ Nick Klein, “Manual Vs. RFID Technology Workflow,” 18 November 2011, accessed 10 July 2016, http://www.mobileaspects.com/blog/2011/11/18/evaluating-tissue-tracking-technology-solutions-part-2/manual_vs_rfid_tech_workflow/.

³⁶ Claire Swedberg, “RFID to Revolutionize Coca-Cola’s Dispensers,” *RFID Journal*, 10 June 2009, <http://www.rfidjournal.com/articles/view?4967>.

³⁷ Ibid., 2009

³⁸ David Winzelberg, “Everything You Need to Know About Coca-Cola Freestyle,” 16 October 2012, <http://www.coca-colacompany.com/stories/everything-you-need-to-know-about-coca-cola-freestyle>.

³⁹ Maj Christopher J. Estridge, “Material Management of Medical-Surgical Items at Military Healthcare Facilities,” Graduate Research Project no. AFIT/ILS/ENS-09C-01, Wright-Patterson AFB: Air Force Institute of Technology, 2009.

⁴⁰ Margaret A. Camp and Donna Reeves, 2014, 7.

⁴¹ Ibid., 7.

⁴² Ibid., 8.

⁴³ Ibid., 8.

⁴⁴ Ibid., 8.

⁴⁵ Ibid., 10.

⁴⁶ Kathleen E. McKone-Sweet, Paul Hamilton, & Susan B. Willis, 1 January 2005, 4.

⁴⁷ Ibid., 4.

⁴⁸ Ibid., 4.

⁴⁹ Margaret A. Camp and Donna Reeves, 2014, 11.

⁵⁰ Kathleen E. McKone-Sweet, Paul Hamilton, & Susan B. Willis, 1 January 2005, 5.

⁵¹ Ibid., 6.

⁵² “Defense Medical Logistics Standard Support,” accessed 14 June 2016, <http://www.health.mil>.

⁵³ Ibid., 2016.

⁵⁴ “DLA Troop Support Medical Supply Chain,” Defense Logistics Agency, 7 June 2016, accessed 14 July 2016, <http://www.ncmbc.us/docs/16MBB/ZOTOMAYOR.pdf>.

⁵⁵ Department of the Air Force, “Career Field Education and Training Plan Aerospace Medical Service AFSC 4N0X1X, Headquarters US Air Force, Washington, DC, 25 June 2014.

⁵⁶ Margaret A. Camp and Donna Reeves, 2014, 22.

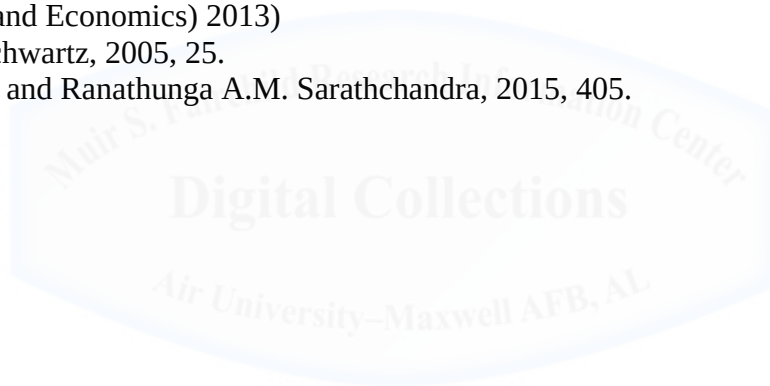
⁵⁷ Virang Dal, “Cost Benefit Analysis (CBA),” 31 May 2015, <https://www.youtube.com/watch?v=Su81VxqNklY>.

⁵⁸ Capt Jason D. Schwartz, “A Cost-benefit between Pyxis and Bar Coding for Brooke Army Medical Center Operating Room,” U.S. Army, Baylor University Graduate Program in Health Care Administration, Project no 03-05, 29 April 2005, 24.

⁵⁹ “U.S. Army Cost Benefit Analysis Guide,” Office of the Deputy Secretary of the Army (Cost and Economics), 3rd Edition, 24 April 2013. (Office of the Deputy Assistant Secretary of the Army (Cost and Economics) 2013)

⁶⁰ Jason D. Schwartz, 2005, 25.

⁶¹ Haiyan Xie and Ranathunga A.M. Sarathchandra, 2015, 405.



Bibliography

- "Munroe Regional reduces costs and gives nurses more time for patient care using Pyxis supply technologies." Case Study, CareFusion (Becton and Dickinson), 2012.
http://www.carefusion.com/Documents/case-studies/medication-supply-management/DI_Munroe-Regional-Medical-Center_CS_EN.pdf (accessed July 14, 2016).
- "Approaches to Reducing Federal Spending on Military Health Care." *Congressional Budget Office*. January 16, 2014. <https://www.cbo.gov/publication/44993> (accessed July 1, 2016).
- Ayad, Ali K. "Inventory Management in Pharmacy Practice: A Review of Literature." *Archives of Pharmacy Practice* 2, no. 4 (2011): 151-156.
- Barcode. <https://en.wikipedia.org/wiki/Barcode> (accessed July 23, 2016).
- "BD Values." Becton and Dickinson, 2016. <https://www.bd.com/aboutbd/values/> (accessed July 13, 2016).
- "Building a bridge between OR and Supply Management." Case Study, CareFusion (BD), 2014.
http://www.carefusion.com/Documents/case-studies/medication-supply-management/DI_Parrish-Medical-Center_CS_EN.pdf (accessed July 14, 2016).
- Camp, Margaret A., and Donna Reeves. "Effective Operating Room Inventory Management." Pfiedler Enterprises, 2014, 22.
<http://www.pfiedler.com/ce/1265/files/assets/common/downloads/Effective%20Operating%20Room%20Inventory%20Management.pdf> (accessed July 18, 2016).
- Dal, Virang. *Cost Benefit Analysis (CBA)*. May 31, 2015.
<https://www.youtube.com/watch?v=Su81VxqNkLY>.
- Defense Logistics Agency. "DLA Troop Medical Supply Chain." Report, 2016.
- Department of the Air Force. *Career Field Education and Training Plan Aerospace Medical Service AFSC 4N0x1X*. Washington DC, June 25, 2014.
- Estridge, Christopher J. "Material Management of Medical-Surgical Items at Military Healthcare Facilities." Graduate Research Project, Air Force Institute of Technology, 2009.
- James, Deborah Lee, and Larry O. Spencer. "Every Dollar Counts Campaign." May 13, 2014.
- Juma, Katherum. "The Impact of Inventory Management and Performance of Private Organizations in Uganda: A Case Study of Coca-Cola Mbarara Plant in Mbarara Municipality." Research Project, Bishop Stuart University, 2013.

- Klein, Nick. *Manual Vs. RFID Technology Workflow*. November 18, 2011.
http://www.mobileaspects.com/blog/2011/11/18/evaluating-tissue-tracking-technology-solutions-part-2/manual_vs_rfid_tech_workflow/ (accessed July 10, 2016).
- McKone-Sweet, Kathleen E., Paul Hamilton, and Susan B Willis. "The Ailing Healthcare Supply Chain: A Prescription for Change." *Journal of Supply Chain Management* 41, no. 1 (January 2005): 1.
- "Military Treatment Facilities." <http://www.health.mil> (accessed May 26, 2016).
- Morin, Jamie M. "Making Every Dollar Count." *Armed Forces Comptroller*. 2013.
- Office of the Deputy Assistant Secretary of the Army (Cost and Economics). *U.S. Army Cost Benefit Analysis Guide*. 3rd. 2013.
- Pennic, Jasemine. *5 Ways Supply Chain Can Reduce Rising Healthcare Costs*. May 13, 2013.
<http://hitconsultant.net/2013/05/13/5-ways-supply-chain-can-reduce-rising-healthcare-costs/> (accessed July 6, 2016).
- Radford, Neal. "Philosophy of Bayesian Inference." <http://www.cs.toronto.edu/~radford/res-bayes-ex.html> (accessed July 23, 2016).
- RFID*. <https://en.wikipedia.org/wiki/Radio-frequency-identification> (accessed July 23, 2016).
- Schwartz, Jason D. "A Cost-benefit between Pyxis and Bar Coding for Brooke Army Medical Center Operating Room." Health Care Administration, Baylor University Graduate Program, 2005, 1-57.
- Secretary of the Air Force Public Affairs. "Airman Powered by Innovation projected to save over \$120M." June 9, 2016.
<http://www.af.mil/News/ArticleDisplay/tabid/223/Article/795613/airmen-powered-by-innovation-projected-to-save-over-120m.aspx> (accessed July 6, 2016).
- Sinaiko, Anna D., and Meredith B Rosenthal. "Increased Price Transparency in Health Care Challenges and Potential Effects." *New England Journal of Medicine*, March 2011: 891.
- "St. John's Medical Center improves efficiency using supply automation." CareFusion (BD), 2013. http://www.carefusion.com/Documents/case-studies/medication-supply-management/DI_St-Johns-Medical-Center-CS_EN.pdf (accessed July 13, 2016).
- Swedberg, Claire. "RFID to Revolutionize Coca-Cola's Dispensers." *RFID Journal*, June 2009.
- Vns InfoSolutions Pvt. Ltd. *Inventory Management*. October 22, 2009.
<http://www.slideshare.net/sriprasoon/inventory-management-2316977> (accessed July 10, 2016).

- Waller, Matthew A., and Terry Esper. *The Definitive Guide to Inventory Management: Principles and Strategies for the Efficient Flow of Inventory Across the Supply Chain*. New Jersey: Pearson Education, 2014.
- Winzelberg, David. *Everything You Need to Know About Coca-Cola Freestyle*. October 16, 2012. <http://www.coca-colacompany.com/stories/everything-you-need-to-know-about-coca-cola-freestyle> (accessed July 23, 2016).
- World Health Organization. "How to Order Supplies Based on Past Use." 2008. <http://www.ncbi.nlm.nih.gov/books/NBK310913/> (accessed July 7, 2016).
- Xie, Haiyan, and Ranathunga A.M. Sarathchandra. "Empirical Study of an Automated Inventory Management System With Bayesian Inference Algorithm." *International Journal of Research in Engineering Technology IJRET* 04, no. 10 (2015): 398-405.

