REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
04/16/2018	Master's of Military Studies	JUN 2017 - APR 2018

4. TITLE AND SUBTITLE
AUTONOMOUS WAREHOUSING:
COMPETITIVENESS ON THE GLOBAL STAGE & ADVANTAGES TO MILITARY WAREHOUSING

5a. CONTRACT NUMBER
N/A

5b. GRANT NUMBER
N/A

5c. PROGRAM ELEMENT NUMBER
N/A

6. AUTHOR(S)
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5d. PROJECT NUMBER
N/A

5e. TASK NUMBER
N/A

5f. WORK UNIT NUMBER
N/A

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

USMC Command and Staff College
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2076 South Street
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)
MMS Mentor
Dr. Stowe, Christopher

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release, distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Through the combination of renewable energy resources, robotics within warehousing and artificial intelligence two benefits emerge. The first benefit is reducing warehouse operating costs, through the creation of an autonomous warehouse, leading to a greater competitive edge in the global marketplace of warehousing. The second benefit is to military warehousing in increasing efficiencies in energy sustainment of deployable information technology systems, increased productivity in light of workforce reduction, and the opportunity for a deeper analysis of inventory management via artificial intelligence.

15. SUBJECT TERMS
Renewable energy, Robotics, Artificial Intelligence, Warehousing, Military Warehousing

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			USMC Command and Staff
Unclass	Unclass	Unclass	UU	34	**19b. TELEPHONE NUMBER** *(include area code)* (703) 784-3330 (Admin Office)

United States Marine Corps
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MASTER OF MILITARY STUDIES

AUTONOMOUS WAREHOUSING: COMPETITIVENESS ON THE GLOBAL STAGE & ADVANTAGES TO MILITARY WAREHOUSING

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF MILITARY STUDIES

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AY 2017-18

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Executive Summary

Title: Autonomous Warehousing: Competitiveness on the Global Stage & Advantages to Military Warehousing

Author: Maj Nicholas S. Emig (CG-6)

Thesis:

Autonomous Warehouse development is a necessity to achieve the necessary cost savings to maintain a competitive edge in the operation of warehouses globally and has useful application to military warehousing.

Discussion:

Warehousing revolves around a set of reoccurring actions of receiving, storing, and issuing goods. These repetitive actions make it a prime environment for the implementation of robotic systems, with the overall intent of designing an entirely autonomous warehouse. Through the use of renewable energy resources for powering the physical building, robotics for the internal operations of the warehouse, and artificial intelligence for the overall supervision of warehouse actions, this demonstrates the possibility of creating an entirely autonomous warehouse.

The value of creating an autonomous warehouse is the cost savings generated. Warehousing is very competitive in the area of operating costs. Therefore, a reduction in labor costs and building expenses would create significant savings in cost, enough to propel warehousing to a new level of competition on the global stage.

In a parallel effort, the innovations of renewable energy, robotics, and artificial intelligence relate to military warehousing, specifically the storage of aviation support assets. Utilizing Marine Corps Aviation Supply, an application analysis will demonstrate how these technology improvements in warehousing benefit military warehousing operations.

Conclusion:

An autonomous warehouse is conceivable given the technologies of renewable energy, robotics, and artificial intelligence that a warehouse could operate in an independent state. The benefits that autonomous warehousing brings is a reduction in the costs to run a warehouse. This cost reduction enables warehouses to gain a higher level of competition globally.

The application of renewable energy resources, robotics, and artificial intelligence benefits military warehousing. It enables greater energy independence for deployed information technology systems, aids in reducing workforce requirements, and provides a deeper level of inventory analysis.

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Preface

With over ten years of experience in the tactical level operation of a Marine Aviation Supply Department, within a Marine Aviation Logistics Squadron, I have an appreciation for how the Naval Supply system is utilized to support Marine Corps Aviation readiness. The Aviation Supply Department utilizes a combination of paper-based processes, manual entries, and legacy computer systems to manage thousands of aviation parts to support flight-line readiness. With this experience, I wanted to know more about how commercial warehouses operated as a means of comparison.

As one reads this paper, only a surface application analysis exists on the comparison of advances within those technologies discussed and Marine Corps Aviation Supply. This action was done deliberately as the unique requirement to be deployable makes a comparison additionally complex.

Therefore, my intent in crafting this paper was to further develop my knowledge of how commercial warehouses operate and the latest technology used in industrial warehouses. The culmination of my research leads me to believe that a fully automated, independently operating warehouse is feasible and will likely come into fruition in the not-so-distant future. The same research has also led me to believe that there are numerous commercial, off-the-shelf products, such as a Warehouse Management System, Radio Frequency Identification Tags, and handheld wireless scanners, that would benefit military warehousing operations, Marine Corps Aviation Supply in particular.

Introduction

Warehousing is an adaptive occupation that continues to change in response to new technologies and methodologies. What was done by humans is now being accomplished by machines and technology. Therein lies the possibility of an entirely autonomous self-operating warehouse. This paper initially focuses on the following areas: renewable energy methods to operate a warehouse, implementation of robotics within a warehouse, and application of artificial intelligence as foundational technologies in achieving an autonomous warehouse. Traditionally warehouses have been massive, expansive structures that by their very nature consume an overwhelming amount of energy. However, there are numerous opportunities within a warehouse to minimize its energy consumption. Furthermore, the utilization of robotics within a warehouse can increase a warehouse's efficiency and production. Through the employment of robotics, the granularity of data available increases. Utilizing artificial intelligence to analyze this data can reveal new levels of insight into how to operate a warehouse. The combination of these areas will demonstrate the genuine possibility of autonomous warehousing. Autonomous warehousing is the means of achieving significant cost reduction in the pursuit of gaining greater economic competition on the global market. Autonomous warehouse development is a necessity to obtain the necessary cost savings to maintain a competitive edge in the operation of warehouses globally and has useful application to military warehousing.

In the pursuit of a fully autonomous warehouse, the more significant value lay in the opportunity to save money by reducing the cost of operating a warehouse. There are numerous additional benefits of autonomous warehousing such as lowering the cost of building expenses, improving inventory accuracy, and optimizing the functions within a warehouse. The primary

focus for moving in the direction of independent warehousing is the cost savings captured in the operation of a warehouse, such as reduced operating cost and reduction in labor costs. Warehouses operate within very tight competition of other warehousing activities. Reducing warehouse operating costs are critical to making it a competitive industry on the global scale. Implementing a fully autonomous warehouse would generate massive competitive advantage through costs savings.

In a comparable effort, the final section will connect the above areas of innovation to the military. This integration demonstrates how commercial best practices can have relevant and tangible benefits to the military. The term military in this context will relate specifically to the United States Marine Corps Aviation Supply. The intent of this analysis is not a deep-dive study, but rather a surface application of how the discussed technologies could benefit the military organization.

Renewable Energy, powering a Warehouse

The initial step in creating an autonomous warehouse is developing a building that can be powered by renewable energy resources. Operating a warehouse under its renewable power sources provides savings through reduced operating costs. These savings directly contribute to the competitiveness of warehousing globally. It also offers incentives to the corporation and benefits to the end consumer. To properly frame the discussion a brief look at the drivers changing warehouse energy consumption will be reviewed. Those drivers are public image, consumer's interest in renewable energy, energy conservation legislation, and areas to improve energy efficiency within a warehouse. The critical element of energy efficient warehousing will be supported by examining the real-world actions of two companies, Staples and Recreational Equipment Incorporated (REI). The summation of energy conservation and implementation of renewable energy sources demonstrates the costs savings that can be captured and leveraged for lowering building operating costs. It also demonstrates an advantage applicable to the deployability of military information technology systems.

A company's public image relates strongly to its ability to market its goods and services. In the world of warehousing, this image may not be as open facing as other service-orientated companies, but that does not degrade its importance. One of many ways that a warehouse company can show concern about its image is by its environmental actions. CO_2 emission is a consistent measurement that can be utilized to compare companies and their operations. Gwynne Richards, a 30-year practitioner of logistics, a fellow of the Chartered Institute of Logistics and Transportation, and graduate student of the University of West England, has written numerous books on warehouse management and logistical operations. Within these publications, he focuses on warehouses and its impact on the environment. He stated in 2010, "according to the Carbon

Trust Partnership (CTP), estimated that the warehousing industry in the UK represented approximately 3 percent of the UK's CO_2 emission."[1] In addition to this significant contribution of CO2, Gwynne Richards states, "The UK Department of Energy and Climate Change calculated that in 2012 warehouses consumed 12 percent of the total energy consumed by the UK service sector."[2] For a sector of commerce that does the essential function of storing items, it is consuming 12 percent of a countries total energy requirements and jettisoning off 3 percent of all of UK's CO_2 emission. All this for the simple act of receiving, storing, and issuing material. Warehousing becomes an easy target for public scrutiny, which adversely affects its public image. However, simple changes can go a long way in curbing the energy usage and CO_2 emissions of a warehouse. Another leading trend with consumers that affects a company's public image is their desire to purchase products from environmentally friendly companies.

Customers are becoming increasingly more interested in products created in a safe and environmentally friendly manner. Al Iannuzzi, in his book *Greener Products: The Making and Marketing of Sustainable Brands,* wrote that "A strong global demand for greener products was indicated by over 60 percent in all countries surveyed, indicating that they (the consumer) want to purchase products from environmentally responsible companies."[3] It is a combined effect of the public image, the voice of the customer, and legislation and that is driving companies to operate in a greener fashion. Warehouses become an easy target for this type of change since they are often large and consume many resources as part of their routine operation. Warehouses, however, are not isolated from change. Another vital driver to integrating renewable energy methods into warehousing was legislation.

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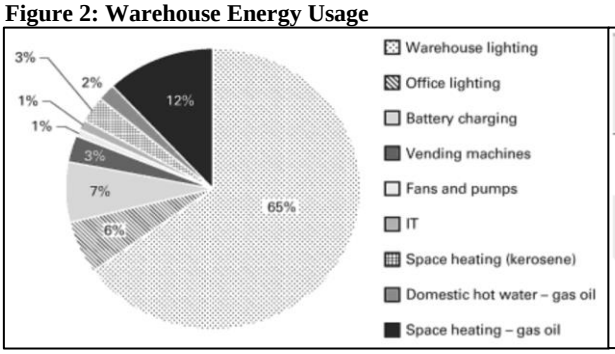
[1] Richards, Gwynne. *Warehouse Management: A Complete Guide to Improving Efficiency and Minimizing Costs in the Modern Warehouse*. Third Edition. Ed. New York, NY: Kogan Page, 2018. 438.
[2] Ibid. 437
[3] Iannuzzi, Al. Greener products: the making and marketing of sustainable brands. Boca Raton, FL: CRC Press, 2018. 11.

There are various pieces of legislation that have been the change agents for provoking companies to adjust their operations. Two prime examples are the European Union's 2020 Climate & Energy Package legislation and the European Union 2050 Low Carbon Economy roadmap. The 2020 Climate & Energy Package legislation outlines three critical goals for the European Union. Those goals are: "20 percent cut in greenhouse gas emissions from 1990 levels, 20 percent EU energy from renewables, and 20 percent improvement in energy efficiency."[4] The European Union 2050 Low Carbon Economy roadmap outlines the following main ideas: "by 2050, the EU should cut greenhouse gas emissions to 80% below 1990 levels, milestones to achieve this are 40% emissions cuts by 2030 and 60% by 2040, all sectors must contribute, and the low-carbon transition is feasible and affordable."[5] These initiatives and many others like them are driving change in how companies operate. Companies turn to energy saving methods as a means to comply with legislation.

Gwynne Richards provides an example of the energy consumption of warehouses and areas for energy savings in its operation. Figures one and two, centers around a relatively average-sized warehouse of 15,000 square meters or approximately 161,000 square feet. Figure 1

Figure 2: Warehouse Energy Usage



Source: Richards, Gwynne. Warehouse Management: A Complete Guide to Improving Efficiency and Minimizing Costs in the Modern Warehouse.

Figure 1: Potential Warehouse Energy Savings

Key carbon reduction areas	Typical savings based on 10 fittings unless stated otherwise		
	£	CO_2 tonnes	Based upon
Turn lights off in warehouse when an area is unoccupied	£700	4.26	50% reduction in lighting
Turn lights off in warehouse when daylight is sufficient	£300	4.92	18% reduction in lighting
Replace 250W and 400W sodium or 400W metal halide lights	£550	3	

Source: Richards, Gwynne. Warehouse Management: A Complete Guide to Improving Efficiency and Minimizing Costs in the Modern Warehouse.

[4] "2020 climate & energy package." Climate Action - European Commission. February 16, 2017. Accessed January 06, 2018. https://ec.europa.eu/clima/policies/strategies/2020_en.
[5] "2050 Low-Carbon Economy." Climate Action - European Commission. February 16, 2017. Accessed January 06, 2018. https://ec.europa.eu/clima/policies/strategies/2050_en.

shows the percentage of energy usage that a warehouse consumes. From this pie chart, one notices that warehouse lighting, represented by 65%, and space heating at 12%, of the overall energy consumption of a warehouse, are the highest areas of energy consumption within a warehouse. Figure 2 represents three areas for reducing energy consumption and the associated reduction in CO_2 emission and energy saved. Some companies have implemented motion sensors in helping to reduce lighting efforts. The lights will automatically shut-off if no movement is detected. Numerous technologies exist to help make warehouses more energy efficient while incurring minimal or no cost to the company.

Other companies choose to make a substantial upfront investment in renewable energy resources to enjoy continual annual savings. Staples and Recreational Equipment Incorporated (REI) are prime examples of companies who made decisions centered around energy efficiency. Staples conducted an aggressive energy-saving program that concluded with a substantial reduction in carbon emission and significant energy cost savings. REI built a new distribution center from the ground up which generates on-site energy that is equal in volume to its annual energy consumption. This use of solar power results in the building requiring no additional electrical energy for its daily operations.

Bob Valair, Director of Energy and Environmental Management at Staples Incorporated, reported on Staples's showcase project, the Coppell Fulfillment Center.[6] This fulfillment center was built in 1990 and underwent an energy-conservation program lasting nine months, with an overall cost of $84,000.[7] The fulfillment center is 245,000 square feet, which makes it larger than

[6] Valair, Bob, Kirk Myers, and Alan Moran. "Better Buildings Webinar Seminars." U.S. Department of Energy. January 10, 2016. Accessed January 24, 2018. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/slides/Unlocking_Energy_Savings_in_Warehouses_and_Distribution-slides.pdf.
[7] "Showcase Project: Coppell Fulfillment Center." Better Buildings. Accessed January 24, 2018. https://betterbuildingssolutioncenter.energy.gov/showcase-projects/coppell-fulfillment-center.

four full-sized football fields. Its baseline energy-consumption in 2010, before the energy conservation effort, was 83 kBtu/sq. Ft.[8] The measure of energy as kBtu represents the British Thermal Unit of energy in increments of one thousand, denoted by the abbreviation of a kilo. After making changes to the areas of lighting, battery chargers, conveyors, HVAC, associates bathrooms, lawn irrigation, and energy-management systems, the fulfillment center reduced its energy usage to 61 kBtu/Sq. Ft.[9] These actions created a gain of 26% in energy efficiencies, which resulted in a 32% cost savings to the fulfillment center.[10] These gains in energy savings reoccur annually and continue to provide cost savings to the company. REI, like Staples, offers a prime example in developing an energy-efficient building from its conception.

REI is known for providing outdoor equipment. In a recent endeavor, it built a distribution center in Arizona, with a long-term focus on total cost of ownership. Sustainability was the primary focus. In the design of this distribution center, it implemented 2.2 megawatts of solar arrays that produce all the energy that the distribution center requires to operate.[11] The number of solar arrays is enough to produce the equivalent amount of power to feed 390 homes for one year.[12] Implementing this exhaustive number of solar panels will provide REI with 20 years of free electrical energy.[13]

Both Staples and REI made substantial initial monetary investments into curbing the energy consumption of their warehouses. This investment is not in vain because it will continually result in a lower operating cost for each subsequent year. These are clear examples of

[8] "Showcase Project: Coppell Fulfillment Center." Better Buildings. Accessed January 24, 2018. https://betterbuildingssolutioncenter.energy.gov/showcase-projects/coppell-fulfillment-center.
[9] Ibid
[10] Ibid
[11] Valair, Bob, Kirk Myers, and Alan Moran. "Better Buildings Webinar Seminars." U.S. Department of Energy. January 10, 2016. Accessed January 24, 2018. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/slides/Unlocking_Energy_Savings_in_Warehouses_and_Distribution-slides.pdf.
[12] Ibid
[13] Ibid

near-term investments that will continue to produce long-term gains in decreasing annual operating expenses. This annual operating cost could conceivably result in a lower price to consumers and more profit to corporations that run these warehouses. This level of energy conservation is the initial step in moving towards autonomous warehousing, but it is a more significant step forward in reducing costs overall. Costs drive consumer behavior and significantly influence the flow of materials in supply chain logistics. There are other applications of this technology as well.

This technology has applicability to the military in extending the deployability of information technology systems. Laptops are often employed to run software for inventory management in deployed environments. Utilizing solar power would decrease electrical energy requirements, traditionally provided by large generators, and increase the capability of the system to operate independently.

Robotics within a Warehouse

In looking at the energy efficiencies employed within a warehouse, one must evaluate the usage of a warehouse-management system and robotics. These areas directly relate to the internal operation of a warehouse, which would further aid in the independent operation of a warehouse. A well-developed warehouse-management system can serve as the information technology brain center of a warehouse. This brain center coupled with robotic technology has the potential to run and operate the internal functioning of a warehouse autonomously; supported by two real-world examples using the Defense Logistics Agency (DLA) and Cotswold. Cotswold provides a strong example of the value of a warehouse-management system when employed. DLA demonstrates their upcoming endeavor to integrate robotic technology into their logistical support efforts. Combining robotics and a warehouse-management system drive the larger picture of reducing costs, by replacing human labor with technology. Furthering the argument that an autonomous warehouse is a critical next step in gaining a competitive advantage in the global market of warehousing. This area of technology has applicable benefits to military warehousing in bridging the gap of a decreasing workforce

A warehouse-management system is a broad term used for the information technology systems that manages the overall operations of a warehouse. A warehouse-management system connects with outside resources, accounts for internal actions, and reports on information imperative to operations. In essence, a sound system combines internal processes with external resources and customers. Efficiencies gained by an excellent warehouse-management system include: “reduced lead times, reduced errors, minimization of unproductive labor, improved

space utilization, and improved equipment utilization."[14] All this information, reported in a real-time environment, leads to a more productive and efficient operation.

Another means of improving productivity and efficiency is through the use of robotics. Various forms of robotics include automated guided vehicles, automated storage, and retrieval systems, and augmented reality systems. The combination of these elements ensures a higher level of order accuracy and quicker order time. One type of automated guided vehicle is the laser-guided truck, which tracks its location throughout a warehouse by using reflective strips. According to Gwynne Richards, "by combining voice picking with laser-guided trucks, productivity increases can be up to 80 percent, with a typical ROI (return on investment) of two years."[15] Automated storage and retrieval system represent a complicated mechanical procedure of placing material back in location and retrieving content from location, typically done by some mechanical crane and conveyor belt combination. These systems are particularly useful in moving large and bulky items and preventing injuries to workers.

Augmented reality looks at making the worker more informed. DHL is working with technology giants such as Google to implement an augmented reality tool to aid in their picking program. The augmented reality would be able to overlay useful information on top of a live feed of what a worker is currently seeing.[16] These augmented-reality systems could show information such as where to find the item, which item to pick, and item quantity, and this system could be integrated with barcode scanners to verify the correct material. The key in all these robotic and technology innovations is that they must combine with the warehouse-management system. This

[14] Richards, Gwynne. Warehouse Management: A Complete Guide to Improving Efficiency and Minimizing Costs in the Modern Warehouse. Third Edition. Ed. New York, NY: Kogan Page, 2018. 139.
[15] Ibid. 294.
[16] "Germany: DHL Rolls out Global Augmented Reality Program." Mena Report, September 1, 2016. Accessed January 6, 2018. http://www.highbeam.com/doc/1G1-464522402.html?refid=easy_hf.

combination is critical so that accurate information is fed and received. This integration of technology into operations create efficiencies in productivity.

The warehousing giant, Amazon, has invested considerably in the area of warehouse robotics. In March of 2012, Amazon acquired a robotics company called Kiva for 775 million dollars.[17] Kiva engineered small robotic machines that would fit under a shelving unit, lift and proceed to move the entire shelving unit around the warehouse to wherever it was needed. The application of this technology was of importance in that material could now be transferred to the person packing and shipping the order. The same shelf can move to the receiving area upon the arrival of a delivery truck and workers could directly restock the shelf. The shelf could then navigate back to a location and wait for the next order. The implication of this strategy dramatically reduces the physical movement of humans, hence decreasing the wait time to build a customer's request. This strategy's downside is that it has a more significant upfront cost when first establishing the warehouse layout; however, this expense is recoupable over years of operations.

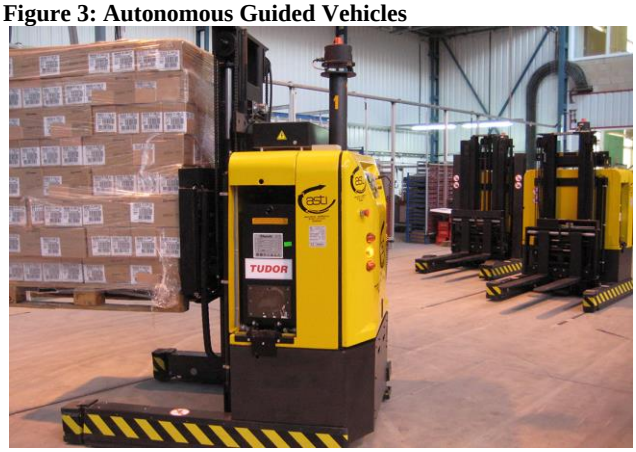
Applying these technologies to defense professionals, the Defense Logistics Agency (DLA) is investigating the application and use of robotics and their potential measured improvement. Cotswold implemented a warehouse-management system and quickly realized the vast amount of productivity gained from such a system. Listed below are examples from DLA and Cotswold in how robotics and a warehouse-management system affected their operations.

Strategic Distribution and Disposition Research and Development Program is a subsection within the Defense Logistics Agency. This program's mission is "researching advanced technologies that range from warehouse mobile tablets that provide real-time inventory

[17] Guizzo Posted 20 Mar 2012 | 3:21 GMT, Erico. "Amazon Acquires Kiva Systems for $775 Million." IEEE Spectrum: Technology, Engineering, and Science News. March 19, 2012. Accessed January 06, 2018. https://spectrum.ieee.org/automaton/robotics/industrial-robots/amazon-acquires-kiva-systems-for-775-million.

data to forklifts that drive themselves."[18] The agency admits that it has not always been at the cutting edge of technology and realizes there is a significant amount of neglected efficiencies. This ignorance of technology integration is consequently depriving the warfighter of the customer service he or she requires to accomplish his or her mission. The R&D program is currently evaluating the following technology areas for possible implementation: autonomous forklifts, autonomous guided vehicles (AGV), lightweight robotics mounted on an AGV, wearable technologies, Unmanned Aerial Vehicles, and technology system integration.[19] Figure three provides an example of the type of technologies DLA is evaluating. It is unknown at this time when full combination of these technologies will occur, but the agency realizes its need to utilize these technologies in optimizing its operations.

Figure 3: Autonomous Guided Vehicles



Source: Antczak, Alan. "Domo Arigato, Mr. Roboto The Future of Distribution at DLA." Loglines

Another area that DLA is refining is the metrics that drive its forecasting of future demand. Currently, DLA supports more than 2,430 weapon systems, processing 100,000 daily requisitions, and manages nearly 5.3 million items over nine supply chains.[20] These are impressive numbers to throw out, but the broader story is in the management of these items.

[18] Bell, John R. "Domo Arigato, Mr. Roboto The Future of Distribution at DLA." Loglines, 2016th ser., May-, no. June, 10-13. 10.
[19] Ibid. 11-13
[20] Erbe, Chris. "Process Problem Solvers." Loglines, 2016th ser., May-, no. June, 25-26. 25.

DLA is embarking on a new project called Peak/NextGen, which allows for better future demand planning. According to DLA, "the process moves the focus from forecasting to metrics and allows managers to make a single, integrated decision across those metrics on the minimum and maximum inventory level for every item."[21] This program implements a more exhaustive set of metrics to bear upon the problem of how much safety stock should be kept on-hand for the warfighter. The added benefits of the program are as follows: "an increase in material availability, less procurement workload, fewer unfilled orders, fewer canceled orders, and more efficient investment of capital."[22] This is an example of using performance metrics to increase the accuracy of items held as on-hand stock for the warfighter's use.

The next case study is an examination of the use of a warehouse-management system. Cotswold is an online retailer that sells wood furniture and a wide range of accessories.[23] Before implementing a warehouse-management system, the company used a paper-based ticket printout system. Paul Wilson of the Cotswold Company said "what we lacked in the process we made up for in people. We had no real-time stock visibility, and due to the amount of room for human error, inventory accuracy was not great, which meant we had to shut-down for annual stock-take."[24] For a company that wanted to grow in size, it limited by its manual processes and lack of accurate, real-time information. Cotswold implemented a cloud-based warehouse-management system that eliminated their paper-based process and moved to an all-digital computerized process. Paul Wilson notes that "we can now run goods in, replenishment and picks simultaneously. As a result of these effects and productivity improvements, headcount has remained proportionately stable despite a threefold increase in volumes over the last five years

[21] Erbe, Chris. "Process Problem Solvers." Loglines, 2016th ser., May-, no. June, 25-26. 25.
[22] Ibid
[23] Richards, Gwynne. Warehouse Management: A Complete Guide to Improving Efficiency and Minimizing Costs in the Modern Warehouse. Third Edition. Ed. New York, NY: Kogan Page, 2018. 247.
[24] Ibid

and we have reduced our overtime bill by 30 percent."[25] Knowledge is power and having information in a real-time and responsive manner is a crucial lever in managing warehouse operations. Cotswold demonstrates the advantage of operating a warehouse with real-time data.

The Defense Logistics Agency and Cotswold are two examples of companies that benefited from utilizing a warehouse-management system and robotics. The further refinement and integration of these two areas develop a strong possibility of creating an internally autonomous warehouse. Robotics could be used to conduct the physical actions of receiving, storing, and issuing material. A warehouse-management system could be used to coordinate the internal movements of these robots. This combined effort has the potential to create an internal autonomous warehouse, where humans would not be necessary. This next step toward autonomy further benefits the supply chain.

These benefits come in the form of higher accuracy of inventory and additional cost savings. Having accurate inventory aids in preventing warehouse downtime. Robotics provide cost savings in two primary means. The first being through their ability to continually operate, whereas humans require breaks. Also, if the robots can recharge based on the power generated onsite, this would further reduce the operating costs of utilizing robotics.

Military warehousing would benefit from the implementation of robotics. This technology could bridge the gap between dwindling workforce size, while increasing inventory accuracy. Creating a win-win situation in providing better support to the flight-line customer and increasing internal warehousing operations.

[25] Richards, Gwynne. *Warehouse Management: A Complete Guide to Improving Efficiency and Minimizing Costs in the Modern Warehouse*. Third Edition. Ed. New York, NY: Kogan Page, 2018. 248.

Artificial Intelligence applied to Warehousing

Artificial intelligence, once a concept only conceivable in movies, has now established a presence in our daily lives. Everyone can see the application of artificial intelligence in technologies such as Siri on the Apple iPhone or Alexa the in-home speaker made by Amazon. With the simple activation of a human voice, the artificial-intelligence system will search through the internet to find an answer to a user's question. This same technology applies to warehouse operations. These include such functions as machine learning, speech recognition, and cognitive robots. In summary of these concepts, a hypothetical example demonstrates what full implementation of artificial intelligence within a warehouse could equate too. This example is theoretical and exploratory since currently no complete example of a fully integrated and comprehensive artificial intelligence system in a warehouse environment exists. The extrapolated importance of artificial intelligence is the ability for computers to process a more considerable amount of information. This deeper level of analysis could provide information on such topics as inventory trend analysis, warehouse operations analysis, and areas for warehouse optimizations. Furthermore, the use of artificial intelligence can perform the duties typically allocated to a human to conduct data analysis. This results in an additional layer of cost reduction.

The essence of machine learning allows computers to take vast amounts of information and to analyze that information to find patterns of interest. A business report titled “The Evolution of Analytics," states, "To learn, machines need very granular and diverse data. In the past, the data we collected was often too coarse to train machine learning models, but that has changed.”[26] With the advances in utilizing robotics, a finite level of data and details is capturable. This allows machine learning to have the level of detail need to perform data

[26] Hall, Patrick, Wen Phan, and Katie Whitson. *The Evolution of Analytics: Opportunities and Challenges for Machine Learning in Business*. Report. SAS, O'Reilly. Sebastopol, CA: O'Reilly Media, 2016. 2.

analysis. The same report provides the following example of the volume of information necessary for machine-learning: "a self-driving car, for example, can collect nearly 1 GB of data every second-it needs that granularity to find patterns to make reliable decisions."[27] On the surface, this may seem like an extensive amount of information. This volume of information is necessary though as a computer is processing and evaluating a situation for the first time, or with a minimal amount of additional similar cases for comparison. Artificial intelligence requires a substantial amount of computing power to calculate the necessary algorithms. Computing power that has only recently been achievable. Large companies, such as Amazon, offer cloud computing services while other companies can rent computing time on more powerful computers to perform machine learning on their analytics. Brandon Barborka cited that

"Machine learning can also analyze and report consumer demand by interpreting data based on orders and returns. This reduces operating costs by cutting wasted replenishment and can improve customer service because its accuracy will show actual on-hand inventory. Cloud-based analytics provider FusionOps suggests that machine learning can improve demand forecast accuracy by more than 20 percent."[28] With the addition of new technology devices in the warehouse, the ability to capture a higher level of detail and accuracy of detail continues to rise. This will aid machine learning in analyzing data to find new levels of optimizations.

Artificial intelligence can facilitate further advancement through the utilization of voice recognition. The basic premise of this technology is that the user can speak commands and the system can understand the verbal input and process a corresponding action. Also, when provided further inputs such as location, the information that the artificial intelligence systems provide can

[27] Hall, Patrick, Wen Phan, and Katie Whitson. *The Evolution of Analytics: Opportunities and Challenges for Machine Learning in Business.* Report. SAS, O'Reilly. Sebastopol, CA: O'Reilly Media, 2016. 2.
[28] Barborka, Brandon. "Artificial Intelligence in Fulfilment Centers." Staff Management | SMX. December 21, 2017. Accessed January 07, 2018. https://www.staffmanagement.com/blog-integrating-artificial-intelligence-and-fulfillment-center/.

be refined to be more applicable. The use of this technology in warehouse operations is demonstrable in locating items. Using the picker to goods strategy, the worker puts a headset on and wears a handheld scanner. The worker can speak questions and cues to the system, and the system will provide information via the headset and the handheld scanner. So the worker can speak commands and thus free up the use of their hands for collecting material, while the system can audibly guide the worker in what they should be doing. In an article titled, “Integrating Artificial Intelligence into Your Fulfillment Center," states, "Voice-picking technology is not new to fulfillment operations, but recent AI improvements have enhanced its capabilities. Utilizing this technology has been shown to reduce picking errors by up to 90 percent."[29] This technology can also be integrated with virtual reality products to provide useful information to the picker in a graphical overlay through a set of glasses. The use of this technology integrates into the warehouse-management system, to push and pull real-time data.

Cognitive robotics is another area of advancement in artificial intelligence. Brandon Barborka states, "Robotics is becoming a part of fulfillment operations more quickly than originally expected. Nearly 40,000 robotics shipped to warehouses in 2016, but market intelligence firm Tactical predicts that amount will jump to 620,000 in four years."[30] This type of robotic technology exceeds the previous discussion of Kiva Robotics technology. Robotics span a wide range of warehouse operations, to include, unloading pallets, picking, sorting and preparing items for shipment. The uniqueness of this type of robot stems from the ability to operate mainly without the influence or assistance of human beings. This where the artificial intelligence comes into play in conjunction with an advanced warehouse-management system to

[29] Barborka, Brandon. "Artificial Intelligence in Fulfilment Centers." Staff Management | SMX. December 21, 2017. Accessed January 07, 2018. https://www.staffmanagement.com/blog-integrating-artificial-intelligence-and-fulfillment-center/.
[30] Ibid.

control what the robotics need to accomplish. Amazon, deploying 45,000 industrial robotics throughout its fulfillment centers, has capitalized tremendously on the productivity of robotics.[31] To demonstrate the productivity value of robotics, men's fashion etailer Bonobos partnered with a fulfillment center that utilized robotic technology. As a result, the company noticed an 800 percent increase in productivity, by locating and shipping orders faster via robotics.[32] It is not just the automation or robotics that are creating these optimizations. It is the integration of artificial intelligence, warehouse-management system, robotics, and automation joining together in harmony.

An important consideration to remember is that artificial intelligence is not just another extrapolation of automation or derivative of a warehouse-management system. The value in artificial intelligence systems is the ability to process a large volume of information then methodically analyzes that information to produce an output that is relevant to the end human user. This technology could examine years' worth of ordering and receive data, to find trends and patterns of behavior. Conceptually artificial intelligence would perform the supervisory tasks of the senior warehouse manager. The system could review daily operations and compare them to trends in historical activities, to provide reports and insights as to how well the warehouse is performing. An exceptionally advanced system would also provide recommendations for what needs to be improved or changed to optimize warehouse operations, such as seasonal demand and inventory reorder points. The value of artificial intelligence to humans, in a warehousing context, is the ability to provide recommendations and insight not typically derived due to the excessive amount of information and reduce costs by minimizing human labor hours.

[31] Barborka, Brandon. "Artificial Intelligence in Fulfilment Centers." Staff Management | SMX. December 21, 2017. Accessed January 07, 2018. https://www.staffmanagement.com/blog-integrating-artificial-intelligence-and-fulfillment-center/.
[32] Ibid.

Cutting Costs to Remain Competitive

Cost reduction has been demonstrated as feasible through the implementation of renewable energy resources, integrating robotics and automation inside the warehouse, and applying artificial intelligence to the supervisory actions of warehousing. These actions focus on reducing the two most substantial cost drivers in a warehouse, labor representing 40-50 percent and building operations as 25 percent. The effort to cut costs in these areas is to increase the competitiveness that a warehouse can offer on the global stage. A company by the name of DTZ Research, produced a logistics report in 2014.[33] The logistics report named, "Occupier perspective, Global Occupancy Cost" numerically displays the operating costs of warehouses globally. The outcome of this report, combined with information previously discussed in this paper demonstrates two main topics. The first being the minimal operating cost differentiation between warehouses in different regions, aiding to the competitiveness in cutting costs. Secondly, previously provided examples will be used to illustrate the importance of how reducing expenses can have a global impact.

Warehouses compete on narrow margins, providing the lowest cost for services rendered. The previously mentioned DTZ Research report illustrates the cost to operate a warehouse per square meters per year in the currency of United States dollars. Hyderabad, the cheapest warehouse, runs at approximately $75 a square meter, compared to London, who is the most expensive at $350 square meter, this creates a broad range. However, the more accurate picture is, excluding the high outliers, most warehouses operate below the $150 square meter cost. Realistically warehouse operation costs range between $75 to $150 square meter. Forming a tight spread of $75, being the difference between 150 and 75, as the range of competition. This range

[33] Kuljanin, Milena. "Occupier Perspective Global Occupancy Costs." Crushman Wakefield. October 22, 2014. Accessed January 1, 2018. http://www.cushmanwakefield.fi/userData/dtz/markkinakatsaukset/DTZ-Occupier-Perspective-Global-Occupancy-Costs-Logistics-2014.pdf.

demonstrates that cost-cutting is vital in warehouse operation to maintain competitiveness. To create this edge, the drive towards an autonomous warehouse is critical. As autonomous warehouses strike at the highest cost drives, being labor and building expenses.

In the same report, produced by DTZ research, New York listed as number 46 of 90 on the list, with an approximate cost of 95 dollars per square meters per year. For the state to move from mid-point on the index into the top ten of the list, New York would have to reduce its cost to below 60 dollars. That is a reduction of approximately 37% of their expenses. Recalling to the previous example of Staples' Coppell Fulfilment energy improvement project, after the implementation of a few energy saving methods, the fulfilment center enjoyed a 32% reduction in their energy costs. Mainly just by implementing one element of the three items discussed for autonomous warehouse operation, would provide enough leverage to bolster a region from the middle of the list to the top. Not that all situations are as clear-cut as this example, but it provides quantitative insight into the value gained from implementing the previously discussed topics leading to autonomous warehouse operation.

Staples' Coppell Fulfilment Center provides an example of the importance of reducing cost in warehouse operations. Cost reduction is not just a nicety for the customer or a financial benefit to the corporation. It is a necessity as a means of remaining competitive on the global stage. Minimizing warehouse costs demonstrates a competitive attitude towards other global markets illustrating the ability to operate in a streamlined and efficient manner.

Application to Military Warehousing

An application of renewable energy resources, robotics within warehousing, and artificial intelligence applies to military warehousing operations. This surface evaluation is intended to demonstrate where these technologies could be applicable in a sensible and intuitive nature. To narrow the focus, the term "military warehousing" will be directed towards the military occupational field of Marine Corps Aviation Supply, as viewed from the tactical level of operating within a Marine Aviation Logistics Squadron (MALS) and as an attachment to a single deployed squadron. Within this context it will be demonstrated that renewable energy resources can contribute to energy independence, robotics can assist in enabling a more forward deployable workforce, and artificial intelligence provides a deeper level of analysis into inventory management.

The unique applicability of renewable energy resources manifests its advantages in the context of deployed operations. The Marine Corps Operating Concept (MOC) directs how the Marine Corps is to operate moving toward 2025 and beyond. This document provides guidance regarding energy sources: "enhance energy storage, distribution, and throughput capabilities to support 21st-century maneuver warfare".[34] Previously, the military relied heavily upon petroleum-based fuels to provide the necessary energy for the operation of equipment. This is an area where renewable energy resources integrate to create an alternative energy source.

Marine Corps Systems Command has an Expeditionary Energy Office, that maintains a collection of Expeditionary Power Systems, six of which are based around renewable energy systems. Marine Corps Systems Command released an article stating, "All the HIMARS systems

[34] Marine Corps Combat Development Command. Quantico, VA. *Marine Corps Operating Concepts how an Expeditionary Force Operates in the 21st Century*. Washington D.C.: Headquarters Marine Corps, 2016

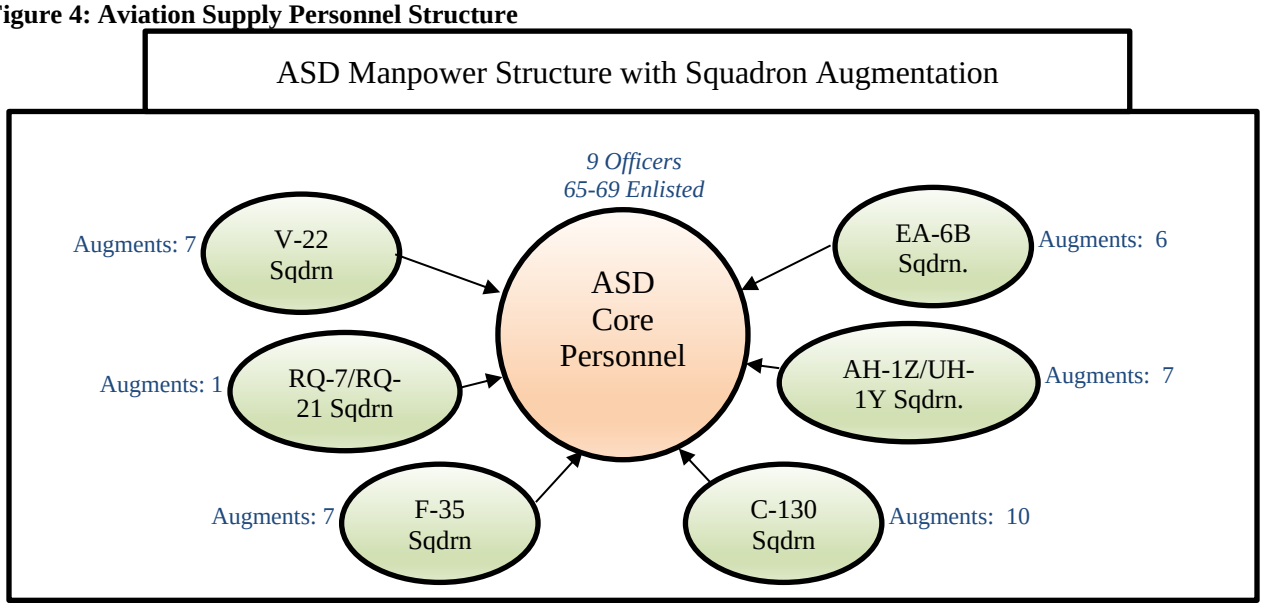
in Afghanistan are being powered by stationary GREENS.".[35] Ground Renewable Expeditionary Energy Network System is represented by the acronym GREENS. Utilizing renewable energy sources on the battlefield increases the expeditionary nature of the Marine Corps, while reducing the logistics footprint in continually providing resupply of petroleum fuels. It also decreases the noise signature of traditional generators. When conducting aviation supply warehousing in an expeditionary environment, the Expeditionary Pack-Up Kit (EPUK) is utilized. Which amounts to a suitcase that includes a computer, satellite, and various other accessory devices. The EPUK system is designed to manage the inventory within an aviation supply pack-up and communicate part-order requests to the parent MALS or the wholesale supply system. Combining this system with an expeditionary power system, further extends the ability to operate independently. Enabling the system to operate completely independent of any resources, aids to a higher level of expeditionary operations and self-contained deployment.

Robotics and technology can streamline current manual processes and fill the gap of personnel fluctuations. The Aviation Supply Department (ASD) operates with a base pool of personnel but is augmented with manning from the flying squadrons. Figure 4, provides a visual depiction of the additional augments supplied by the type of squadron supported. During CONUS based operations, these augments from the Squadron work at the Aviation Supply Department in support of providing aviation logistics to their squadron and others on the flight line. However, when a squadron deploys their augments go with them to offer aviation logistics support to their squadron. The effects of this action, causes workforce fluctuations, within ASD. Implementing robotics and technology would decrease the workforce requirements to operate a warehouse. Therefore, enabling ASD to work efficiency with just their base pool of personnel.

[35] Hedelt, Carden. "MCSC Helps Marines Go Green." Marine Corps Systems Command, December 20, 2012. Accessed March 31, 2018. http://www.marcorsyscom.marines.mil/News/News-Article-Display/Article/509517/mcsc-helps-marines-go-green/.

Ultimately allowing more Marines to be deployable with their squadrons, by implementing current technology practices and robotics.

Figure 4: Aviation Supply Personnel Structure



Source: Marine Corps Total Force Structure Management System, Fiscal Year 2018 Data

Implementations of two technologies would directly assist in this manner. The first step is implementing a warehouse-management system that supports a wireless network of handheld scanners. The second technology that would contribute dramatically is the utilization of robotics in moving shelving units, similar to Amazon's implementation of the Kiva robots. Handheld scanners operating from a wireless system would enable Marines to receive, issue, and stow gear more quickly by not relying on a paper-based ticket method and manually making entries into a computer system. There currently exists a technology for Marines to use handheld scanners; however, it is often fraught with problems, such as crashing and losing data, which then requires manual verification via paper documents. This causes a drastic increase in manpower processing time to receive, stow, and issue material. Additionally, these scanners are not wireless. A completely wireless system would allow transactions to be processed immediately and seamlessly entered into the system, upon being scanned.

The second advancement, of Amazon-like shelf robots, would assist in moving material around the warehouse and prevent the loss of time and effort in Marines finding and locating an item. The current process requires a Marine to have a piece of paper with a location on it, then search for the part. This creates an unnecessary loss of time in moving around the warehouse. A robot could be bringing the shelf with the correct material in it to the processing desk to issue stock or the robot could be carrying the shelving unit to the receiving dock for stowing items upon being received. Either combination of these actions, aids to requiring less workforce and results in less wasted time in locating an aviation asset.

Another means of increasing the accuracy of inventory management is through the implementation of artificial intelligence. Current inventory-management processes utilize a hybrid of a legacy system and buffer-size management. The legacy system is called “level sets” and works off of the premise of averaging the demand for an item over a specified time period. This methodology results in an average for a particular part. The newer process utilizes buffer sizing, which looks for the highest amount of demand for an item within a specified time period that typically corresponds to the time it takes to replenish that item. This system provides a maximum quantity for an item to ensure that supply is plentiful to meet squadron demand.

The benefit of implementing machine learning or other artificial intelligence systems into inventory management is that it could account for a more comprehensive historical period of inventory demand. Instead of focusing on just a fixed period, it could provide the necessary analysis to understand the broader cycle of that item and how that item might change and fluctuate throughout the year. As a notional example, artificial intelligence might notice that tires see a higher demand usage during the summer where deployments and training exercises are more common. Therefore, artificial intelligence could provide the recommendation that storing

four tires during the fall and winter timeframe is enough; whereas summer timeframe requires ten tires. The level-set system would normalize this data by averaging all the information. The newer system, of buffer sizing, might recommend storing ten tires since that is the highest demand point, leading to an excess of material to store and manage. Increasing manpower requirements to manage the excess material. This is a notional example of how artificial intelligence could do a more in-depth analysis of inventory demand to produce results of greater significance.

The key throughout this section is that technology has the capabilities to increase military warehousing operational efficiency. These are not naive products or ideas, but instead, are readily available technology items for off the shelf usage. There are numerous other possible applications for these technologies and many others. This is intended to provide insight and a window into the opportunities available utilizing ordinary commercial, off-the-shelf technology products. There would be numerous nuances in flushing out the details and integration of these items, but the intent here is to demonstrate the application of renewable energy resources, robots, and artificial intelligence to military warehousing.

Conclusion

The essence of warehousing remains the same business as it always has, the continual process of receiving, storing, and retrieving items for follow-on shipment. This is not a dead or archaic activity that has no room for improvement. As demonstrated with the examples presented in this paper, warehousing is an active and evolving entity that continues to optimize its processes. Optimizations that further lead to its ability to operate autonomously.

Warehousing can evolve into an autonomous activity. Using renewable and energy efficient operations to generate power requirements. Combined with the advances in robotics and warehouse-management systems, that can control internal warehouse operations. Artificial Intelligence could conduct the overall process of warehouse oversight. Through the combination of these three elements, it is conceivable that warehouses of the future would be autonomously operated self-storage sites. Cost savings will be beneficial to the consumer and the warehousing company, but more importantly; it provides that critical edge in global competition. Warehouse automation is the means to the path of reduced operating costs that leads to being globally competitive.

In addition to the commercial application, military warehousing can benefit from these technologies as well. Benefits demonstrated in the following areas: advancing the energy independence of EPUK aiding to a more energy independent system, utilizing robotics to fill the gap of reduced workforce availability, and implementing artificial intelligence to gain a greater comprehensive understanding of inventory management. These technologies provide a critical advantage in improving future warehousing operations.

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