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Analysis of Unmanned Systems in Military Logistics

December 2016

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ABSTRACT

The purpose of this thesis is to analyze the current and potential applications of unmanned systems in military logistics. In seeking to evaluate uses of unmanned systems, initially, we aimed to define current and proposed unmanned applications in civilian sector logistics and current military logistics challenges. Then, justifying uses of unmanned systems in the commercial sector and military, we analyzed the potential advantages and risks of these systems by using archival analysis and case studies. Finally, we addressed recommendations on the current and future uses of unmanned systems in military logistics.

Unmanned technology is an area open to development. There has been extensive use of unmanned vehicles in military operations such as reconnaissance, surveillance, and armed attacks. Changing economic conditions and advances in technology indicate that there may also be opportunities to employ unmanned systems to support logistic operations.

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ABOUT THE AURHOR

Yigit Ergene is an infantry officer from Turkish Army. He studied systems engineering in Turkish Military Academy and proceeded to work as a platoon and company commander in several units within Turkey (2007-2015) and EUFOR Multinational Battalion in Bosnia and Herzegovina during Operation Althea (August 2010-February 2011). He graduated from Naval Postgraduate School's Materiel and Logistics Support Management Curriculum (MBA 827) in December 2016. In his free time, he likes hiking and reading about unmanned systems. Yigit is married, with one kid and knows English.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACTD	Advanced Concept Technology Demonstration
AFO	Aircraft Flight Operations
AOM	Aircraft Operations Maintenance
BCA	Business Case Analysis
C2	Command and Control
C3	Command, Control, and Communications
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
CaMEL	Carry-All Mechanized Equipment Landrover
CASCOM	U.S. Army Combined Arms Support Command
CCD	Charge Coupled Device
CJCS	Chairman of the Joint Chief of Staff
CNAF	Commander Naval Air Forces
COTS	Commercial Off-the-Shelf
CSS	Combat Service Support
CUAS	Cargo Unmanned Aircraft System
DARPA	Defense Advanced Research Project Agency
DMZ	Demilitarized Zone
DOD	Department of Defense
DPDHL	Deutsche Post DHL Group
FAA	Federal Aviation Administration
FOB	Forward Operating Bases
FOV	Field of View
GPS	Global Positioning System
HADR	Humanitarian Disaster Response
IED	Improvised Explosive Device
IT	Information Technology
JCIDS	Joint Capabilities Integration Development System
JROC	Joint Requirements and Oversight Council
JPADS	Joint Precision Airdrop Systems
JUON	Joint Urgent Operational Needs
LEMV	Long Endurance Multi-Intelligence Vehicle
LIDAR	Light Detection and Ranging

LOS	Line of Communication
LS3	Four-Legged Squad Support System
MAE	Medium Altitude Endurance
MDARS	Mobile Detection and Assessment and Response System
MOB	Mobile Operating Base
MTVR	Medium Tactical Vehicle Replacement
NATO	North Atlantic Treaty Organization
OEF	Operation Enduring Freedom
O&S	Operation and Support
POW	Prisoner of War
PPBE	Planning, Programming, Budgeting, and Execution
REF	Rapid Equipping Force
RFI	Request for Information
RMA	Revolutions in Military Affairs
RPG	Rocket Propelled Grenade
R&D	Research and Development
SOF	Special Operations Forces
SUV	Sport Utility Vehicle
TRANSCOM	U.S. Transportation Command
TTP	Tactics, Technics, and Procedures
UAS	Unmanned Aerial Systems
UAV	Unmanned Aerial Vehicles
UGS	Unmanned Ground Systems
UGV	Unmanned Ground Vehicles
USD	Under Secretary of Defense
USMC	United States Marine Corps
USS	Unmanned Surface Systems
UUS	Unmanned Underwater Systems
USV	Unmanned Surface Vehicles
UUV	Unmanned Underwater Vehicles
UWO	Unconventional Warfare Operations

I.   INTRODUCTION

> Interaction therefore will be most frequent between strategy and matters of supply, and nothing is more common than to find considerations of supply affecting the strategic lines of a campaign and a war. (Clausewitz, 2007, p. 75)

Along with the dynamic character of science, technology is constantly changing and improving. Transformational improvements in science and technology are reflected in war. Throughout the history of humankind, the weapons used by militaries have evolved from swords and spears to firearms—made possible by the invention of gunpowder and capable of much greater destruction. However, no resource is infinite—there are limits to supplies of weapons, ammunition, and personnel. Military commanders have come to understand that victory is closely related to having sufficient units, soldiers, weapons, and supplies at the right time and place—logistics, in other words, has become a critical part of military operations. Historically, superior logistical capabilities have given a competitive advantage to militaries.

Around the turn of the 20th century, science reached a point at which humans could control machines from far distances (Singer, 2009). By this time, Thomas Edison and Nikola Tesla had significantly improved radio-control devices and wireless communication, which established a basis for unmanned systems (Singer, 2009). During the First World War, one of the first logistics applications of unmanned systems was implemented. Its name was the "electric dog." It was a three-wheeled vehicle designed to carry supplies to the trenches by following the lights of a lantern (Singer, 2009). Without any doubt, it was born from the necessity of transporting essential logistical assets in a deadly environment created by the trench warfare concept. In the years since then, both logistics and unmanned applications have become increasingly important to militaries.

The purpose of this research is to analyze both existing and potential uses of unmanned systems in logistics, focusing on the advantages and risks for military organizations and operations. Considering the historical and potential benefits of

unmanned technology in both civilian and military sectors, using this technology in military logistics would prove valuable in reducing costs, taking more risks with fewer casualties, increasing capacity, and speeding up delivery processes. Unmanned technology is an area open to development. This thesis intends to incorporate the studies and applications of current and potential technologies on the use of unmanned systems for logistical purposes. In addition to the strategic importance of unmanned systems for militaries, research and development for unmanned systems in the civilian sector has led to an incredible level of competition between huge industrial firms. During the writing of this thesis, ongoing research had to be updated several times to catch up with new emerging technologies, new regulations, and ethical discussions on unmanned systems. Because of the timeliness of this topic, the continuous need for updates was a limitation for this thesis.

This research aims to address the following questions:

1.   Primary Research Question

- What are the current and potential uses of unmanned systems for military logistics?

2.   Secondary Research Questions

- What are the current and potential applications of unmanned systems in civilian sector logistics?
- How would the use of unmanned vehicles impact the acquisition cost of products compared to other delivery methods?
- What are the advantages and risks of using unmanned systems in military logistics?

The term *unmanned systems* identifies a broad topic composed of several applications, including unmanned industrial applications, unmanned aerial systems (UASs), unmanned ground systems (UGSs), unmanned surface systems (USSs), unmanned underwater systems (UUSs), unmanned space applications and autonomous cyber applications. The scope of this thesis is limited to unmanned industrial applications, UASs, UGSs, USSs, and UUSs for logistical applications.

II. BACKGROUND AND LITERATURE REVIEW

This chapter presents relevant background information about military logistics; there are significant studies and several cases about unmanned technology and unmanned logistics applications in the civilian sector. The main purpose of this chapter is to define common problems in military logistics and possible civilian unmanned logistics applications that can also be used to fill potential gaps in military logistics.

A. BACKGROUND

> If the tools of warfare are no longer tanks and artillery, but rather computer viruses and micro-robots, then we can no longer say that nations are the only armed groups or that soldiers are the only ones in possession of the tools of war. (Toffler & Toffler, 1993, p. 45)

To define the potential uses of current and potential applications of unmanned systems in military logistics, existing literature was collected and compiled under the following categories: unmanned systems and technology, current and proposed applications of unmanned systems in civilian sector logistics, and military logistics. To contribute to the conversation on the potential uses of unmanned systems in military logistics, it is important to understand the general framework of future military logistics and the relationship between the civilian and military sectors.

In his thesis, McCoy (2002) highlighted *Joint Military Vision 2020* as an important framework for the military in its preparations for future operations. It is easy to predict that future operations will be increasingly risky thanks to the hybrid nature of military theaters all around the world. Operations will be held in difficult terrains and will involve many new concepts like irregular warfare. According to McCoy (2002),

> The overall goal of *Joint Military Vision 2020* transformation is the creation of a force dominant across the full spectrum of military operations. The *Joint Military Vision 2020* strategy will develop a new level of joint interoperability, including a force that accepts, expects, and encourages cross-service interdependence and operational integration. *Joint Military Vision 2020* also expects new dimensions in

robotics to dramatically increase the capability of the 2020 joint task force over what is available today. (p. 2)

McCoy (2002) also mentioned the term *focused logistics*, which is an important concept in *Joint Military Vision 2020*, and focuses on the necessity of delivering logistics goods on time to the related units, especially in risky terrains.

Piggee (2002) emphasized the importance of incorporating both military and civilian technologies into more efficient and capable ones. Mainly, the private sector focuses on achieving the most effective and profitable outcomes with the least cost. This goal is also an important target for military logistics professionals (Piggee, 2002).

History has shown that some disruptive technologies have been driven by civilian scientists. On the other hand, during other time periods, military inventions have driven innovations in human history. This research is mainly focused on a comparative analysis of both civilian and military technological advances—as well as the implications and effects that each has on the other—to discover best practices in the fulfillment of military efficiency goals.

B.   MILITARY LOGISTICS

1. Overview

In his study, Kress (2016) defined logistics as

a discipline that encompasses the resources that are needed to keep the means of the military process (operation) going in order to achieve its desired outputs (objectives). Logistics includes planning, managing, treating, and controlling these resources. (p. 7)

Kress (2016) came up with three logistics options:

- Obtain: Troops obtain the necessary supplies for military operations from the operational area.

- Carry: Troops carry their supplies with themselves to the campaign.

- Ship: Necessary supplies can be sent to the troops from a rear facility.

Obtaining and carrying choices were the main logistics options up until the middle of the 19th century in the absence of significant mass transportation options

(Kress, 2016). With the Industrial Revolution, the shipping option started to gain importance, particularly with the use of trains in military logistics (Kress, 2016). After the Industrial Revolution, the Logistics Revolution occurred in the 20th century with the help of different factors that affected military logistics (Kress, 2016).

According to Kress (2016), specifically, the emergence of ammunition and fuel as a necessity for troops in military campaigns has paved the way to the Logistics Revolution. He explained the relationship as follows: Mankind invented automatic machine-guns and other kinds of weapons, so they needed to carry more and different kinds of ammunition. As the ammunition technology has evolved with new weapon technologies, troops could not carry this ammunition with them, and the need for shipping supplies from rear depots occurred. Another factor Kress (2016) mentioned was the emergence of mechanized weapon systems. This has paved the way for the usage of fuel in the battlefield. Fuel has become a critical logistic element as well as ammunition, both of which must be shipped from rear (Kress, 2016). In addition, the need for technical expertise and support has become a necessity with technical improvements on military logistics (Kress, 2016).

Kress (2016) emphasized the importance of having a secure and uninterrupted line of communication (LOC) between the troops of the front and logistics facilities at the rear to implement an effective shipping option. Flowing information between troops and rear bases is also important, because of the uncertainties and fog of war (Kress, 2016). In addition to securing LOCs and effective information flows, another necessity is the presence of secure routes for carrying huge amounts of resources from the rear facilities. Blocks or lack of coordination on the routes of logistical convoys might have a slowing effect on military operations. The absence of logistical support might create problems such as lack of supplies and maintenance (Kress, 2016). Obviously, more technical weapon systems necessitate more maintenance and logistics support than others (Kress, 2016).

Although sending supplies from rear bases seems the most advantageous option, modern logistics necessitates a proper mix of all three options (Kress, 2016).

Obtaining logistics needs from the host nation's resources might prove more effective at times. As an example, during the Gulf War, Saudi Arabia provided resources to coalition forces (Kress, 2016). Carrying supplies has also been an option, especially when troops need to conduct military operations continuously. During Operation Desert Shield, troops sustained their needs during the first stages of the operation (Kress, 2016). Finally, sending supplies has been a sine qua non in maintaining a continuous military operation (Kress, 2016). A logistics planner should consider all options and come up with a plan of well-chosen options.

2. Levels of Logistics and Functions of Each Level

Like any hierarchical organization, it is appropriate to have three levels in military logistics organizations (Kress, 2016). As discussed earlier, there is a strategic level making the big investment decisions in commercial companies or military organizations. According to these strategic investments and operational decisions made by high and mid-level managers, smaller units conduct their specific smaller (tactical) tasks. Operational level (executers) bridges the gap between strategic and tactical levels. The presence of three levels of logistics can also be criticized. While it can be true that recent advances in information technology have revolutionized logistics and also blurred the traditional distinction between three levels, it is also a fact that there are still distinct differences between these levels worth considering separately (Kress, 2016). In parallel with three levels of war, logistics also has been divided into three categories: strategic, operational, and tactical logistics (Kress, 2016).

a. Strategic Logistics

High-level defense-related decisions having long-term effects are made by strategic-level commands (Kress, 2016). These decisions include "research and development (R&D) investments, procurement and replenishment policies, and decision issues related to the physical infrastructure" (Kress, 2016, p. 17). According to Kress (2016), within the context of strategic logistics, typical problems of logistic infrastructure have two stages:

1. Deciding the best proportion of assets within a logistics infrastructure.

2. Distributing the limited budget between different logistics infrastructures.

Obviously, economic issues have serious impacts on military logistics. Economic constraints affect both the force structure and logistic constraints (Kress, 2016). Figure 1 represents the dilemma between building the force and logistics constraints in strategic level (Kress, 2016).
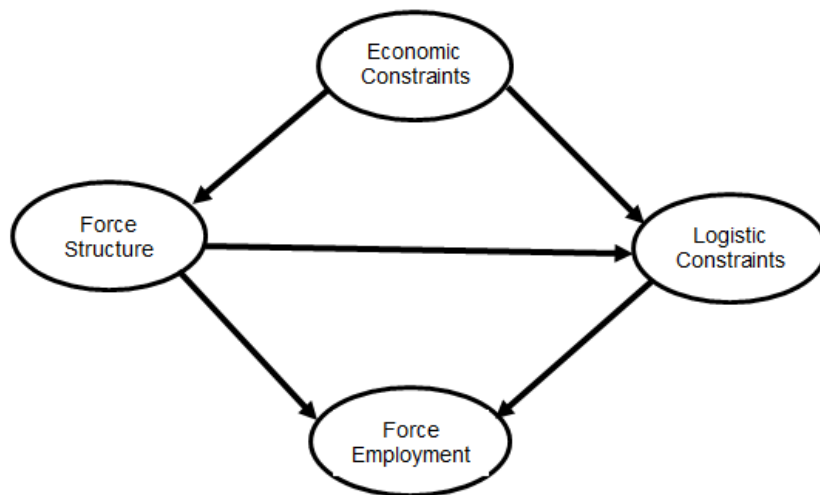
Figure 1. Economic and Logistic Constraints. Source: Kress (2016).

b. Operational Logistics

It is the utilization of logistics assets that are collected as a result of the strategic level of logistics such as resources, organizations, and processes, as an input for tactical needs (Kress, 2016).

According to Kress (2016), operational logistics includes six major functions:

1. Force accumulation: Mobilizing and locating the forces especially before the campaign is crucial in operational-level. Force accumulation includes routing, scheduling, and prioritization.

   - Routing: During the force accumulation process, it is important to select appropriate routing and "maintain a flow of military assets on the external line of communications (LOCs) that connect the source nodes at the strategic logistics level with the intermediate nodes at the operational level" (Kress, 2016, p. 43).

- **Prioritizing:** It is assigning the order of units that will be sent to the operational theater. "The main factor in determining this order is operational. It is derived from the military posture, the objectives of the campaign, and the operational plans" (Kress, 2016, p. 43).

- **Scheduling:** Depending on the priority, it is also necessary to schedule the dispatch of transportation assets including ships, aircrafts, trains, or vehicles considering operational plans.

2. Deployment of resources: It involves defining "logistic nodes such as ports of debarkation, supply points, ammunition dumps, maintenance areas, transfer points, combat service support (CSS) units and facilities, and selecting the corresponding LOCs—roads, railways, air routes, and sea-lanes" (Kress, 2016, pp. 45-46).

3. Logistic forecasting: In addition to the logistic planning before the operations, it is also possible that force size and structure might change in parallel with the operational plans. To be able to respond these shifts promptly, conducting effective logistic forecasting is a crucial factor. Logistic forecasting is also an ongoing process that facilitates moving to a new stage of operations efficiently and on time.

4. Management and control of the logistic flow: To be able to manage the logistic movement of material/services and distribute them efficiently, it is crucial to conduct an effective and well-coordinated logistic supply chain. It is also important to optimize limited transportation resources and their capacities.

5. Medical treatment and evacuation: They are directly related to human life. Also, time is so crucial for medical help at the battlefield. Because of that, despite its relatively small scale, medical treatment and evacuation are considered as an operational logistic mission.

6. Prioritization: Commanders set prioritization with logisticians during the planning phase of operations. It affects the amount and order of material deployed in operational terrain. It also affects the distribution and allocation of these resources (Kress, 2016).

c. Tactical Logistics

According to Kress (2016), "tactical logistics comprises basic and practical activities that facilitate the "production" of military outcomes" (p. 23). Tactical logistics is sustaining the units at a tactical level with necessary supplies such as weapons, ammunition, fuel, rations, and providing services like maintenance and

medical aid. These supplies and services can easily be measured by specific metrics, because of their prescriptive and technical features (Kress, 2016).

The main logistics activities at the tactical level are replenishing ammunition, refueling, maintenance, supplying personal needs (including rations), immediate medical aid and medical evacuation, treating "prisoners of war" (POWs) and civilians, some construction and engineering services (Kress, 2016). After defining three levels of logistics, it would be useful to define common logistics challenges and needs. It would also facilitate this research's efforts on finding unmanned solutions to these logistics problems.

3. Military Logistics Challenges

In her article, Harps (2005) emphasized that although military and civilian logistics usually have common difficulties such as tracking, moving, inventory holding, and visibility, these two sectors diverge from each other when it comes to their goals. She mentioned that while business logistics consider profitability in their logistics operations, military logistics consider survival and ability to perform in every condition. In her article, she also included remarks by Rear Admiral Marc L. Purcell, director of strategy, plans, policy, and programs for the U.S. Transportation Command (TRANSCOM). According to him, another big difference between business and military logistics is that military conducts logistics operations in hostile areas and supports troops on the move. Obviously, carrying out military logistics operations in terrains that are exposed to the enemy would cause security challenges and bigger uncertainties that can disrupt operational effectiveness. In parallel with these opinions, Kang (2016) also defined challenges of military logistics in two main areas: uncertainty and security. Sharing all these opinions, we considered Kang's (2016) view on the classification of military challenges.

a. Uncertainty

In his book, Kress (2016) points out that while strategic logistic decisions focus on *efficiency*, the tactical level of logistic decisions mainly focuses on *effectiveness*. Within the scope of effectiveness, tactical logistic decisions are based

on minimizing the quantity gap of desired logistic assets and time gap of when actually troops have those assets (Kress, 2016).

These shortcomings bring the term "uncertainty" into play. Perhaps the biggest challenge for logistics has been uncertainty since earlier times because uncertainty increases risk. Clausewitz (2007) mentioned "fog of war" in the same meaning with uncertainty in his reference book *On War*. He emphasized that uncertainty is part of the nature of war (Clausewitz, 2007). According to Clausewitz (2007), "war is the realm of uncertainty; three quarters of the factors on which action in war is based are wrapped in a fog of greater or lesser uncertainty" (p. 46). In considering the logistic network of operations, it would be easy to predict that uncertainty has an overall effect on all levels of logistics. Kress (2016) mentioned the level of uncertainty increases from the strategic level of logistics to tactical level of logistics. This is mostly because while strategic logistics can be characterized by standardization and uniformity, tactical logistics is more variable due to the unpredictable nature of battlefield (Kress, 2016).

Civilian logistic managers also have the same problem, except with a different name: *visibility*. The efficiency of commercial supply chains is tied to the visibility of the supply chain. Finally, more uncertainty necessitates holding more inventory, and more inventory holding causes more money spending (Kang, 2016).

Kang (2016) classified the main reasons for uncertainty into three categories: fluctuations in supply/demand, natural disasters, and terrorist attacks.

b. Security

As discussed before, security would be an important issue for military logistics operations, because they are being conducted in hostile terrains, which are open to enemy disruption. Another security threat for military logistics is the irregular warfare and emerging terrorist groups. So, even if military logistics facilities, convoys, or supply chain elements are considered to be in safe areas, including the homeland, they can still be attacked. Kang (2016) classified security-related challenges under

physical (airport/seaport, transportation network) and information security/assurance headings.

Within the scope of this thesis, the Analysis chapter discusses these military logistics challenges and seeks efficient unmanned solutions considering both military and business applications.

C.   UNMANNED SYSTEMS AND TECHNOLOGY

Because unmanned systems and their technology are the focus of this research, it is important to begin the literature review section with a definition of unmanned systems. During this research, we found that researchers have used different terms for what we call "unmanned systems." These terms include unmanned aerial vehicles (UAVs), unmanned ground vehicles (UGVs), unmanned sea vehicles (USVs), autonomous systems, robots, and drones.

The *Oxford Dictionary* provided a variety of definitions for the terms mentioned here. *Unmanned* means not having or needing a crew or staff ("Unmanned," n.d.). *Autonomous* means acting independently or having the freedom to do so ("Autonomous," n.d.). *Robot* means a machine capable of carrying out a complex series of actions automatically, especially one programmable by a computer ("Robot," n.d.). A *drone* means remote-controlled pilotless aircraft or missile ("Drone," n.d.).

To identify the differences between these terms and use them in the correct context, we searched existing literature and tried to find some explanations and comparisons about these terms. In his reference book for unmanned aerial vehicles, Springer (2013) clarified some of these terms by providing comparisons among them. He explained that if a vehicle does not carry an operating human being, then it can be called *unmanned*. Therefore, unmanned aerial vehicles, unmanned ground vehicles, and unmanned sea vehicles are rooted in the same terminology. According to Springer (2013), various definitions of *robot* have this in common: that at least some level of decision-making activity must occur for an object to be defined as a robot. Drones, on the other hand, do not make independent decisions. They fulfill

programmed tasks with or without human control (Springer, 2013). Springer defined both drones and robots as *robotic*. Robotic systems may have different levels of autonomous performing ability. Recent unmanned systems practices and applications have not been fully designed to be autonomous yet. At least a small human interaction exists in them (Springer, 2013).

Rogers and Hill (2014) used the term *drones* for UAVs. They also used the term *robota,* which means "self labour, and drudgery" (p. 120). To improve economic and mission efficiency, scientists and officials have tried to increase the level of drones' autonomy (Rogers & Hill, 2014).

The National Research Council (2005) explained that if an unmanned system has some level of autonomy built in, it can be called *autonomous*. Then, they decided to use autonomous vehicles for all the unmanned systems that do not have a human onboard. According to the National Research Council (2005),

> in defining "autonomous vehicles" for purposes of this study, the Committee on Autonomous Vehicles in Support of Naval Operations elected to include all vehicles that do not have a human onboard. This definition is broad enough to include weapons systems such as torpedoes, mobile mines, and ballistic and cruise missiles—although these systems are not discussed in this report. Space vehicles are also not discussed, although the applications of space such as enhanced command, control, and communications (C3) are discussed for their role in enabling autonomous vehicles. (National Research Council, 2005, p. 1)

Within the scope of this study, the term *unmanned systems* is used as a general term for all UAVs, UGVs, and USVs, while the term *robotic systems* is used to identify any kind of system in which decision-making abilities are a part of the system's computing capabilities.

D.   CURRENT AND PROPOSED APPLICATIONS OF UNMANNED SYSTEMS IN CIVILIAN SECTOR LOGISTICS

Up until recently, militaries all around the world have been the leader in unmanned and robotic technology. Governments have supported comprehensive research and have generously funded projects for military purposes to gain a competitive advantage over other countries. As a result of these efforts, unmanned

technology has undergone major developments within the defense sector, leading to the invention of many kinds of unmanned systems—with and without weapons.

The civilian sector has also seen a dramatic rise in unmanned and robotic technologies in logistics over the last few years. A critical question comes to mind: Why have robotic technologies become a rising trend for commercial firms? In his report, Bonkenburg (2016) explained this trend by pointing out two factors: rising demand for logistics workers and labor availability to fulfill this need. These two important factors are closely related to each other (Bonkenburg, 2016). In a standard supply chain system, products, which are produced or combined together in the factories, are packed and sent to the warehouses and then to the retailers. Customers purchase goods from the nearest retailers. On the other hand, with the emerging e-commerce system, products have been sent from warehouses or distribution centers directly to customers (in some cases, from factories directly to the customers). In either method, workers pick and sort the items in the warehouse to fulfill each order coming from the customers on time. Then workers find each item and prepare it for shipment. This significantly increases the need for more workers in warehouses or in distribution centers. Bonkenburg (2016) highlighted that, thanks to increasing e-commerce trends, more logistics workers are needed for preparing parcel shipments. He also emphasized the decreasing population levels in Western countries.

Atwater and Jones (2004) described another approach focusing on labor shortages. According to these researchers, the industrial world will suffer a systemic labor shortage. The three primary reasons they gave for the systemic labor shortages were that there will be increased needs for productivity, significant demographic changes, and changes in labor force participation trends (Atwater & Jones, 2004). In their research, Atwater and Jones (2004) analyzed these three reasons for systemic changes and drew significant conclusions. First of all, they expect a dramatic increase in the United States' demographic structure, especially "in the number of Americans over the age of 65" (Atwater & Jones, 2004, para. 6); this shift leads them to conclude that numbers of consumers will grow faster than producers (Atwater & Jones, 2004). They also stated that expected participation

rates for men and women will be equal, and productivity needs will rise dramatically in the upcoming years.

These lines of thought and industrial trends in the logistics world lead some commercial companies to seek a way to prevent inefficiencies resulting from labor losses. Therefore, these commercial companies have started to substitute workers with robotic systems to decrease their costs.

We also found it useful to mention the Google Self-Driving Car Project as an example of significant advances in unmanned systems here. In 1939, "a vision of automated highways" (Google, 2016, para. 2) were presented to the audience at the New York World's Fair. "Then in the mid-2000s, the Defense Advanced Research Project Agency (DARPA) organized the Grand Challenges" (Google, 2016, para. 2). It was a chance for teams to compete in self-driving car technology (Google, 2016). "In 2009, Google initiated the self-driving car project" (Google, 2016, para. 2) and recently they have been testing this technology in California; Texas; Washington, DC; and Arizona with both "Lexus Sport Utility Vehicles (SUVS) and new prototype vehicles" (Google, 2016, para. 3–4). This project also had pushing effect on the car industry and other leading companies such as Tesla.

In this thesis, common uses and possible trends of current civilian unmanned applications are grouped into two sub-categories: industrial robots at warehouses/distribution centers and deliveries with unmanned systems.

1. Industrial Robots at Warehouses / Distribution Centers

According to Dineen (2015), robotic industrial solutions are gaining pace "throughout Asia, Europe, and the United States" (para. 11). As an example of industrial robot usage, Dineen (2015) highlighted the Rethink Robotics Company and the Kiva Systems. Rethink Robotics Company has been providing cost-saving industrial solutions to U.S. factories (Dineen, 2015). On the other hand, Amazon's acquisition of Kiva Systems has been a remarkable effect on the robotics industry.

a. Kiva Systems and Amazon Warehouses

Kiva Systems—a Massachusetts company founded in 2003—has introduced "robotic solutions to warehouses for picking, packing and shipping products" (Dineen, 2015, para. 2). Since the company's establishment, it has had dramatic effects on warehouse automation solutions. In 2009, according to Inc. 500, Kiva Systems was the sixth fastest growing company in the United States, and in 2012, it was the 23rd most innovative company, according to Fast Company rankings (Dineen, 2015).

Amazon, one of the top e-commerce companies in the world, bought Kiva Systems Company for $775 million in 2012 (Dineen, 2015). Although Amazon's robotic warehouses have been considered the most well-known success story by the industry, some other companies, including Walgreens, Staples, Gap, and Crate & Barrel, had already been using Kiva robots when Amazon acquired them (Dineen, 2015). After the acquisition of Kiva Systems, Amazon stopped the sale of Kiva Systems to other warehouse operators and retailers (Bhasin & Clark, 2016). Kiva Systems had 25 existing customers by the time Amazon bought the company, and as of 2019, Amazon will not provide service support for those companies (Borison, 2016). After the existing contracts ended, other firms had to find other alternatives to catch up with the growing customer demands (Bhasin & Clark, 2016). Borison (2016) mentioned that there are other firms trying to fill the gap in warehouse automation technologies, including Locus Robotics, Home Delivery Services, Toyota Motor, "Kuka, Knapp Logistics Automation, AutoStore, Swisslog, Dematic, Fetch Robotics, and GreyOrange" (Borison, 2016, para. 30).

Amazon established a robotic system in its warehouses with the Kiva robots, which are basically programmed robots that move on a designated path in the warehouse and find their direction with the help of barcodes (Dineen, 2015). They find and carry racks loaded with merchandise to a single workstation and point out the required merchandise to the responsible worker. This operation of Kiva robots has helped Amazon significantly improve its fulfillment speed and capacity and decrease employment costs, as well (Dineen, 2015). Amazon established a new

division called *Amazon Robotics* and started operating Kiva robotics technology under this division (Borison, 2016). Amazon had 15,000 robots at the end of 2014 in its 10 fulfilment centers, and this number rose to 30,000 recently in 13 fulfillment centers (Borison, 2016).

Amazon's big investment has been paying off, dropping its operating expenses by 20% at its fulfillment centers (Lamm, 2016). An analysis by Deutsche Bank determined that adding this new robotic technology to a new warehouse saves approximately $22 million in fulfillment expenses. By that estimate, about 100 Amazon distribution centers would save approximately $2.5 million by instituting robotic technology (Bhasin & Clark, 2016). In addition, consulting firm MWPVL International calculated that Amazon saved 21.3 cents per unit shipped (or 48% of costs) by eliminated the hours wasted in walking around warehouses to pick up products (Borison, 2016).

Moreover, this improved robotic process has dropped Amazon's cycle-time from over an hour to 15 minutes and has increased inventory space by 50%, because robots can navigate in narrower aisles in warehouses. Most importantly, these improvements have enabled Amazon's two-day shipping advantage for its Amazon Prime members (Lamm, 2016). Another benefit of Kiva robots is the ability to adjust warehouse lights and climate controls where Kiva robots operate (Madrigal, 2009). Normally, warehouse operators must have bright enough lights and comfortable climate conditions for human workers, but these are not necessary for Kiva robots (Madrigal, 2009). Hence, that leads to an approximately 50% energy cost savings where Kiva robots operate (Madrigal, 2009).

According to Dineen (2015), some companies like Fanuc America intend to manufacture smarter and faster robots that can spot the merchandise, pick it up, and package it. Dineen (2015) further explained that Fanuc America was the sponsor of the *Amazon Picking Challenge*, in which teams from different universities competed with their robots in order to pick items from the shelves to test their robots' speed and ability.

b. Walmart Warehouses

Abrams (2016) also highlighted Walmart's efforts to test flying drones in order to handle the inventory level in its warehouses. According to Abrams, if these experiments prove to be effective, Walmart will implement this system of drones to its big distribution centers in six to nine months. Abrams (2016) also stated that Walmart officials mentioned generally that drones might be used in some other processes within Walmart in the short term.

2. Unmanned Systems Delivery

Huge commercial companies like Amazon, Google, and Deutsche Post DHL Group (DPDHL) are researching unmanned systems delivery technology. Research and news about unmanned system delivery have put the use of drone delivery in the spotlight, creating an increasing interest in this kind of futuristic technology. Recent applications of unmanned systems in civilian sector logistics focus on UAVs.

The first UAV applications with a military purpose were clearly intended to create a force multiplier for their operators and home country. According to DPDHL's trend report, *Unmanned Aerial Vehicle in Logistics* (DHL, 2014), most people have negative feelings toward the term "drone" because of past perceptions and because of the most recent, improved, and lethal uses of drones for military purposes. *Unmanned Aerial Vehicle in Logistics* (DHL, 2014) pointed out important factors about civilian uses of UAVs over the next 10 years. This report used Larry Downes' famous theory to explain future trends, explaining that technological changes generally occur before the social and political changes—with social changes occurring slowly and political changes taking even more time.

The report mentioned that it is likely to take some time before drone delivery becomes a disruptive innovation, because there is a significant speed difference between changes in drone technology and other domains that are subjected to social, business, and political shifts (see Figure 2).
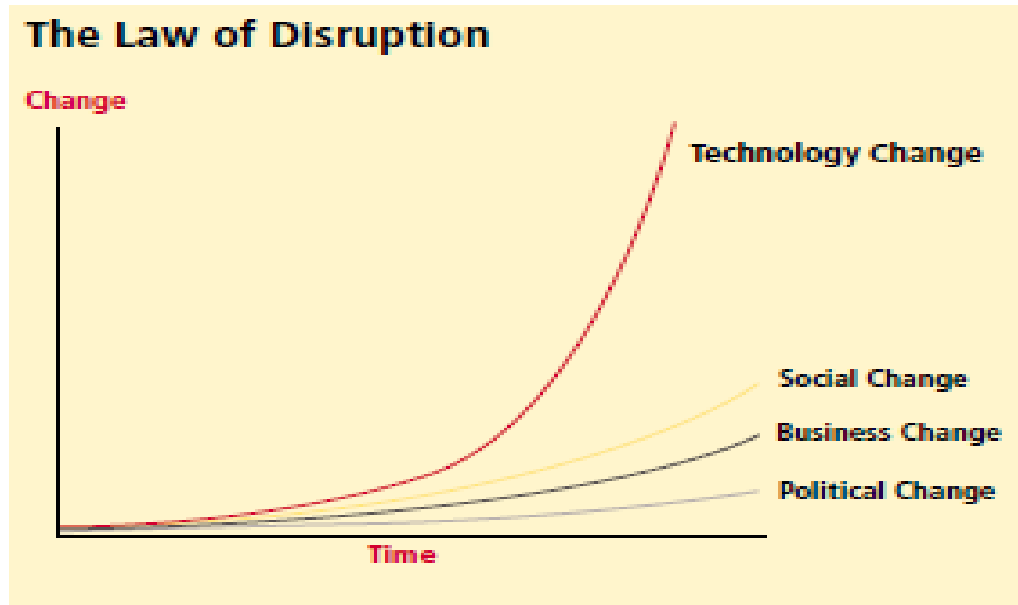
Figure 2. Larry Downes' Law of Disruption. Source: DHL (2014).

In the same trend report, military UAVs were classified into different types according to their capabilities and task purposes, like ranges and endurances. The report explained the broad range of possible applications that were being used in different kinds of civilian industry practices. These applications include the following: "energy/infrastructure, agriculture and forestry, site and layout planning; construction sector, environmental protection, emergency response and police, film and photography, development aid" (DHL, 2014, p. 2). In addition, the trend report mentioned interesting implications of the uses of UAVs in logistics with an increase in e-commerce, as mentioned previously in this thesis. Other than urban or rural delivery, a customer might send a notification to the UAV hub to request a specific place for delivery, and a UAV might carry the delivery to that exact place (DHL, 2014). Another implication is the use of UAVs on top of delivery trucks. When an employee within a truck places a delivery in a specific place that the UAV can identify, the UAV scans the barcode and leaves with the parcel to find the specific address. This address may be off the main route being followed by the truck, and after leaving the package, the UAV returns and places itself on top of the moving delivery truck again to get ready for another delivery (DHL, 2014).

Amazon, the world's largest online retailer, has been one of the leading companies making investments in drone delivery. Pogue (2016) interviewed Paul Misener, Amazon's vice president for public policy. Pogue revealed many important details about Amazon's Prime Air project and insights into UAV delivery. According to Pogue (2016), different kinds of circumstances—like weather conditions (for example, wet, hot, dusty) and building types that customers live in—necessitate different kinds of drones. Another problem that Amazon has to face is the regulations of the Federal Aviation Administration (FAA) and other regulators around the world. According to Pogue (2016), Amazon has proposed to use a certain part of the airspace between 200 and 400 feet. Amazon and the FAA are still negotiating over the regulations of using commercial UAVs, and it is likely that this technology will be used in other countries before the United States, depending on the length of negotiations with the FAA (Pogue, 2016).

Along with Amazon, other commercial companies have been working on drone delivery. Madrigal's (2014) article revealed that Google has also been researching drone delivery systems (Project Wing). It is possible that Google will face the same kind of regulation issues, but with one difference: Madrigal (2014) posited that Google would have a deeper influence over the drone delivery issue, considering its success in dealing with regulators on its driverless car project. Bermingham's (2014) article showed that FedEx has also been researching drone delivery technology since 2014.

According to Prigg (2014), research is ongoing on the uses of UAVs for emergencies. Prigg stated that ambulance drones can track emergency mobile calls and move towards the place where help is needed. This kind of ambulance drone can carry defibrillators to people having cardiac arrest. They can also watch and talk with people who use the defibrillator in order to help deliver first aid.

In his article, Toor (2016) reported that a Silicon Valley startup company, Zipline International, has started medicine and blood deliveries with UAVs in Rwanda. Rwanda has a poor population and high infant mortality, and the Rwandan government has invested in the healthcare system to decrease unhealthy conditions

and to combat the spread of dangerous illnesses such as HIV, tuberculosis, malaria, and others. Zipline International has begun UAV operations in partnership with the Rwandan government.

Another current application was Uber's unmanned truck and its first delivery test was proved successful (Davies, 2016). Uber bought Otto Company, a San Francisco startup, for $680 million last year (Davies, 2016). According to Davies (2016), Otto's system established at the truck was level-four autonomy, which means it can handle the driving experience totally by itself. However, Uber started using this technology only on highways for now. Davies (2016) highlighted that "the trucking industry hauls 70% of the nation's freight—about 10.5 billion tons annually—and simply doesn't have enough drivers. The American Trucking Association pegs the shortfall at 48,000 drivers, and says it could hit 175,000 by 2024" (Davies, 2016, para. 11). In addition, with the help of autonomous trucks, roads would be safer, more efficient, and cleaner with lower level of emission rates (Davies, 2016).

E.   CONCLUSION

By the end of our literature review, we found that there have been considerable improvements in the use of unmanned systems in logistics within the civilian sector. Current civilian improvements for unmanned systems rely on aerial delivery and warehouse / factory logistics. Competition among giant logistics companies might drive the research into further advanced applications.

Dynamic improvements have been made in unmanned systems technology. The strong competition among companies in the civilian sector has driven these developments, and military applications of these same technologies are likely to be affected by the fast pace of change; thus, the military will likely need to reevaluate the technology to stay up to date. In this thesis, our main intention is to contribute to the conversation on uses of unmanned systems in military logistics by analyzing some current cases that have been implemented by civilian companies and military institutions.

III. METHODOLOGY

With their complexity and high costs, unmanned systems necessitate detailed planning and evaluation before implementation, especially in military applications. Unlike commercial applications, the military requires additional durability, adaptability, and reliability in dangerous tasks. Systems should be durable enough to be sustainable during harsh terrains. They should be adaptable to other military technologies and weapons. Additionally, they should be reliable so they can support military operations continuously.

The purpose of this research is to analyze both existing and potential uses of unmanned systems in both commercial and military logistics focusing on the advantages and risks for military organizations and operations. In seeking to evaluate and analyze uses of unmanned systems, we aimed to address the following primary research question: What are the current and potential uses of unmanned systems for military logistics? To answer this primary research question, we addressed the following three secondary research questions:

- What are the current and potential applications of unmanned systems in civilian sector logistics?

- How would the use of unmanned vehicles impact the acquisition cost of products compared to other delivery methods?

- What are the advantages and risks of using unmanned systems in military logistics?

Considering these research questions, we adopted a technology benefit analysis supported with archival analysis and multiple case studies embedded in our thesis to define the potential uses of unmanned systems for military logistics.

A. TECHNOLOGY BENEFIT ANALYSIS

Jones (2006) described the technology benefit analysis as a method of defining supportability when applying or acquiring a new technology:

> A technology benefit analysis looks for opportunities to apply state-of-art capabilities for support. This analysis looks at new and emerging technologies for application to the new system. Supportability

engineering searches for how new technologies are being applied to other acquisition programs. It also looks to the future. There is a continual improvement and evaluation of technologies. These may be in areas of reliability, maintainability, testability, transportation, support equipment, computer-based training, innovative materials, alternative methods of production, different power sources, or anything else. (p. 6.14)

No exact method has been developed to conduct a technology benefit analysis (Jones, 2006). In our thesis, we implemented the following methodology to find reliable and efficient results for a technology benefit analysis.

First of all, we define the recent logistics problem areas of modern militaries. After defining logistics problem areas and needs in the literature review, we collected relevant data about the current and proposed applications of unmanned systems in civilian sector logistics. The Analysis chapter discussed the impact of using unmanned systems on the acquisition cost of products and their potential benefits and risks. In addition, we conduct research on the current and proposed applications of unmanned systems in military logistics. We classify these systems' logistics usages according to their platforms such as UAVs, UGVs, and USVs/Unmanned Underwater Vehicles (UUVs). By doing that, we examine existing and emerging unmanned technologies and evaluate the effects of these applications on the future of military logistics. Then, we analyze and process data and define positive and negative impacts of unmanned systems to military logistics in the Analysis chapter. In the Conclusion chapter, we recommend the most likely future uses of unmanned systems in military logistics.

B.   CASE STUDY METHOD

According to Yin (2009), defining the research questions is probably the most important phase of the thesis. When research questions focus on "what" questions, Yin (2009) suggested this approach: If the "what" question has an exploratory character such as "What can be learned from a study of a startup business?" (p. 9), then any of the research methods—including "an exploratory survey, an exploratory experiment, or an exploratory case study" (p. 9)—can be used (Yin, 2009). On the other hand, if the "what" question is more of a "how many, how much" type of

question such as "What have been the ways that communities have assimilated new immigrants?" then a survey or archival analysis would be a more favorable approach (Yin, 2009). In contrast, questions having an exploratory character like "how and why" questions are more suitable for case studies, experiments, or histories.

As explained previously, this thesis involves the following "what" question as the basis of its primary research: "What are the current and potential uses of unmanned systems for military logistics?" Considering Yin's (2009) ideas, this question can be seen as having a "how much, how many" character at first glance. However, while evaluating the potential uses of unmanned systems specifically in the context of logistics, we used a step-by-step method to seek answers to the secondary research questions within the scope of the literature review.

During the first step of this thesis, we sought to find relevant data within the scope of the following two secondary questions: "What are the current and proposed applications of unmanned systems in civilian sector logistics?" and "How would the use of unmanned vehicles impact the acquisition cost of products compared to other delivery methods?" Gathering relevant data to answer these questions required a detailed archival analysis and multiple case studies. The rationale for using multiple case studies together with archival analysis was to understand the investment decisions of specific commercial companies and military organizations.

The data compiled to answer these two questions established a basis for the following secondary research question: "What are the advantages and risks of using unmanned systems in military logistics?" This thesis analyzes the systems that justify future investment.

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IV. ANALYSIS

In the first section of this chapter, we suggest answers for the current and proposed applications of unmanned systems in military logistics. Then, in the second section, we evaluate unmanned systems' impacts on the acquisition processes and cost evaluations. In the third and fourth sections respectively, we evaluate the potential benefits and risks of unmanned systems when used in military logistics.

A. CURRENT AND PROPOSED APPLICATIONS OF UNMANNED SYSTEMS IN MILITARY LOGISTICS

The *Unmanned Systems Integrated Roadmap* (DOD, 2013) has played an important role in identifying trends about "vision and strategy for the continued development, production, test, training, operation, and sustainment of unmanned systems" (p. 5) between 2013 and 2038. It highlighted that, although the greatest technological improvements in unmanned systems have been on UAVs in the operational theater, the use of unmanned systems for of all kinds of military purposes has increased at an exponential rate for the last 10 years. The report listed the following as the primary areas in which unmanned systems have proven effective: reducing the heavy risk and workload for military personnel, improving situational awareness and task performances, and reducing costs related to military logistics operations. According to the roadmap, there are three kinds of missions that are preferred for unmanned systems: dangerous, dirty, and dull. The roadmap further explained that unmanned systems have the potential of fulfilling dangerous and dirty (chemical, nuclear, biological) tasks without putting military personnel in a risky position; in addition, dull tasks involving long-time surveillance can be a desirable choice for unmanned systems.

According to existing literature, there are two primary uses for unmanned systems in current military logistics applications. One of them is making deliveries to combat units or military bases with unmanned systems. The other use for unmanned systems (especially UAVs) for military logistics is ensuring security against threats that target military logistics assets like convoys, depots, and critical facilities. There

are also other proposed applications that are still in the research and development phase.

1. Warehouses and Other Logistic Capabilities

Beyond security and unmanned delivery, Plinsky, Glass, and Yates (2012) mentioned another implication in their research. In accordance with the *Unmanned Systems Integrated Roadmap* (DOD, 2013), the Army has been applying logistics operations like material handling, robotics base packaging, and warehousing with both manned workers and unmanned systems. Plinsky et al. (2012) also described other logistics operations that can be handled by unmanned systems, such as routine maintenance, munitions handling, and combat engineering. According to Plinsky et al. (2012), it is important to use unmanned systems in these kinds of applications, because they increase the level of safety and efficiency of the operations. Other studies have been going on under the umbrella of The Agile Robotics Project, which includes semi-autonomous commercial forklifts and autonomous material-handling capabilities (Plinsky et al., 2012).

2. Security Tasks for Logistic Convoys and Facilities

In their research, Peters et al. (2011) focused on security-related applications for military logistics. Peters et al.'s (2011) research defined the difference between UAVs and UASs. UAVs are described as unmanned aircrafts, and UASs are described as aircrafts with a complete system, including ground stations for their operation, launch-recovery systems, and maintenance elements. In their research, Peters et al. (2011) defined 10 logistics applications and classified them according to their feasibility and cost-effectiveness. These logistics applications are convoy over-watch; river navigability; surveillance of critical assets like depots, pipelines, electrical lines, and important routes; support to domestic disaster responses; pre-deployment theater reconnaissance; finding airdropped cargo; and retrograde of critical items (Peters et al., 2011).

Peters et al. (2011) evaluated these 10 possible military logistics applications considering six factors. These factors are cost; terrain; enemy tactics, techniques,

and procedures (TTPs); "values of damage or loss that could be avoided through reconnaissance and surveillance" (Peters et al., 2011, pp. 14–15); weather; and bandwidth. In the cost factor, they discussed that as systems with the same abilities become cheaper, there is an economically favorable outcome for UAS uses. In the terrain factor, they discussed the specific characteristics of terrain. According to them, if the military operations take place in complex and preclusive terrains and if long distances prevent other uses, then UAVs are more attractive. As for the enemy tactics, techniques, and procedures (TTPs) factor, Peters et al. (2011) explained that when confronting an enemy who refuses to gather in groups and who makes use of hit-and-run tactics typical of terrorists, then it is not favorable to use UASs. Another factor they mentioned is that when using UASs can greatly decrease the risk of damage and loss, it is favorable to use UASs. The last two factors they highlighted were weather and bandwidth. It is favorable to use UASs in suitable "weather conditions that do not challenge flight parameters—such as high wind velocity, shear, and very cold temperatures—or sensor-operating parameters" (Peters et al., 2011, p. 15)—such as clouds, rain, and lightning. Regarding bandwidth, Peters et al. (2011) discussed another important term that is likely to affect future operational theaters, as well as the logistics needs of military units. According to Peters et al. (2011),

> If the Under Secretary of Defense for Intelligence (USD (I)) Lieutenant General John Koziol's *2024 vision* of extremely high band width networked Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) eventuates and the Army can operate in Afghanistan and future theatres supported by a much richer, denser C4ISR network, then ownership of UAS for any specific tasks will be less critical because the network will quickly provide information from all of them in a theater. (p. 14)

In their research, Peters et al. (2011) focused on the surveillance and reconnaissance capabilities of UASs and their effects on the security and survivability of logistics convoys, which is an important aspect in the combat arena.

Green (2011) focused on convoy security with UGVs (autonomous vehicles) in his research report. According to him, convoys with autonomous capability are necessary for the military because of the rapidly changing, unstable, and

unexpected combat theater. In his study, Green (2011) also mentioned that in order to continue conducting operations in a dangerous and foggy environment, gaining an autonomous capability is crucial. He highlighted that although fully autonomous vehicles are possibly farther off into the future, an important step would be to have at least some part of a convoy composed of UGVs that follow a manned leader vehicle. It is particularly important to keep soldiers away from danger and keep conducting military actions without reducing the tempo. Green (2011) also asserted that an autonomous convoy capability might be an effective force multiplier and might increase the commander's operational initiative and flexibility. In addition, an autonomous convoy might advance in the field at a higher speed and with a closer formation, ensuring rapid movement of the convoy (Green, 2011). For a manned convoy, moving closer together increases the risk of casualty from an improvised explosive device (IED) attack. But for the unmanned convoy, that might be an affordable risk when a commander considers speed over security concerns.

Although it is not specific to logistic facilities, Blain (2010) provided information about a South Korean military manufacturer DoDAMM and its product, an autonomous robot gun turret, Super aEgis 2 (see Figure 3). It was specifically invented for protecting the border, demilitarized zone (DMZ), between North and South Korea (Blain, 2010). According to Blain (2010),

> The Super aEgis 2 is an automated gun tower that can find and lock on to a human-sized target in pitch darkness at a distance of up to 1.36 miles (2.2 kilometers). It uses a 35x zoom charge coupled device (CCD) camera with "enhancement feature" for bad weather, in conjunction with a dual field of view (FOV), autofocus Infra-Red sensor, to pick out targets (para. 6).

We included this autonomous weapon in our research because of its potential for use in military logistic facilities.

Figure 3. DoDAMM's Super aEgis 2: South Korea's Autonomous Robot Gun
Turret. Source: Blain (2010).

According to Shachtman (2008), the U.S. Army also tested robotic patrol sentries called "Mobile Detection and Assessment and Response System (MDARS)" (para.1) from 2004 to 2008 at Hawthorne Army Depot in Nevada (see Figure 4). Then in 2008, the U.S. Army decided to order 24 more MDARS for $40 million.

In his article, Shachtman (2008) also pointed out that

the diesel-powered robots, in development since 1989, operate "at speeds up to 20 miles per hour and can run for 16 hours without refueling," according to its manufacturer, General Dynamics. "Using radio frequency identification tags, MDARS keeps track of inventory, as well as gates, locks and other barriers." (para. 2)

Figure 4. Robot Sentries for Base Patrol. Source: Shachtman (2008).

3. Unmanned Systems Delivery

Joint Vision 2020, a report that guides the continuous transformation of the U.S. Armed Forces, explained the concept of *focused logistics* (National Defense University, 2000). According to *Joint Vision 2020*,

> Focused logistics will provide military capability by ensuring delivery of the right equipment, supplies, and personnel in the right quantities, to the right place, at the right time to support operational objectives. It will result from revolutionary improvements in information systems, innovation in organizational structures, reengineered processes, and advances in transportation technologies. This transformation has already begun with changes scheduled for the near term facilitating the ultimate realization of the full potential of focused logistics. (p. 69)

Joint Vision 2020 pointed out the importance of advances in transportation regarding military logistics and also made the case that following the best private practices is an important factor for military leaders.

Chestnut (2012) also focused on the importance of the distribution capability of the military. Use of unmanned systems has decreased the risks to human life and also decreased the potential costs of military. Chestnut (2012) studied UAVs, UGVs, and USVs and their use in the delivery of logistics supplies.

a. Unmanned Aerial Systems for Logistics and K-MAX Cargo Unmanned Aircraft System (CUAS) Case

Although not a common way of delivering goods, UAVs have been the focus of both studies and applications for logistics delivery. Plinsky et al. (2012) explained that using UAVs for logistics delivery would be a viable alternative to the classic means of logistic distribution. They also mention that

> LIA has been actively involved in assessing the requirement for a cargo unmanned aircraft system (Cargo UAS). The U.S. Army Combined Arms Support Command (CASCOM) and the Army G-4 study, *The Future Modular Force Resupply Mission for Unmanned Aircraft Systems*, assessed the technical and operational feasibility of a Cargo UAS. (Plinsky et al., 2012, p. 42)

McCoy (2002) discussed UAVs in his study regarding their uses for logistics operations, comparing them with other means of logistics deliveries. He also concluded that using UAVs in operational theaters would decrease the risk of human life and logistic footprints significantly.

In her study, Chestnut (2012) went back to 1783 and reported historical facts about aerial balloons that shed light onto the invention of unmanned aerial technology. She supposed that uses of unmanned aerial systems would make it faster to deliver critical goods like ammunition, food, medical supplies, and so forth. She also mentioned that not many applications currently use unmanned systems for logistics. According to Chestnut (2012), the U.S. military has a growing interest in using unmanned systems in military logistics; for example, the Marine Corps has been testing an unmanned helicopter that can carry 6,000 pounds of supplies in Afghanistan. She also highlighted that in 2012, the Army published a request for information (RFI) for unmanned aerial systems that could serve as a cargo vehicle. The U.S. Army is focusing on Cargo UAS-related concepts for the next eight to 10 years, and among these concepts, the ability to carry between 5,000 and 8,000 pounds of supplies was a remarkable one.

(1)   K-MAX Cargo Unmanned Aircraft System (CUAS)

The unmanned helicopter Chestnut (2012) mentioned was K-MAX. K-MAX is a partnership of Martin Corporation and Kaman Aerospace Corporation (Lockheed Martin, 2016). It can be used as both the autonomous and remote-controlled models (see Figure 5).

K-MAX features Kaman's proven high-altitude, heavy-lift K-1200 airframe and Lockheed Martin's mission management and control systems, enabling autonomous flight in remote environments over large distances.

Figure 5. Unmanned Cargo Resupply. Source: Lockheed Martin (2016).

In his study, Haddick (2016) explained that the U.S. Marine Corps started using unmanned systems for delivery in military special operations concept (see Figure 6).

> Beginning in 2011, the U.S. Marine Corps started using the K-MAX unmanned autonomous cargo helicopter to deliver supplies and equipment to distributed combat outposts in Afghanistan. K-MAX can carry 6,000 pounds of cargo at sea level and 4,000 at 15,000 feet density altitude. 37 K-MAX unmanned helicopters flew 1,730 resupply sorties for the Marine Corps in Afghanistan, delivering four million pounds of cargo. (Haddick, 2016, p. 21)

Troops are familiarizing themselves with the downward thrust of a K-MAX unmanned aerial vehicle during initial testing in Helmand province, Afghanistan. U.S. Marine Corps photo by Corporal Lisa Tourtelot.

Figure 6. U.S. Marines with Combat Logistics Battalion 5 Return from K-MAX. Source: Haddick (2016).

According to Haddick (2016), the military official should continue developing unmanned systems like K-MAX that can carry supplies in unconventional warfare operations (UWO). On the other hand, autonomous cargo helicopters have still problems like reliability, affordability, and stealth problems for use in UWO concept (Haddick, 2016).

K-MAX was also used in Afghanistan during Operation Enduring Freedom (OEF) by the U.S. Marine Corps (Peterson & Staley, 2011). It has a capability of carrying 3,000 pounds of supply one at a time and four times 750 pounds of supply in multiple drop operations (E. N. Pratson, personal communication, June 12, 2011) as cited in (Peterson & Staley, 2011). The payload capacity of K-MAX also depends on the altitude at which it operates (see Figure 7).
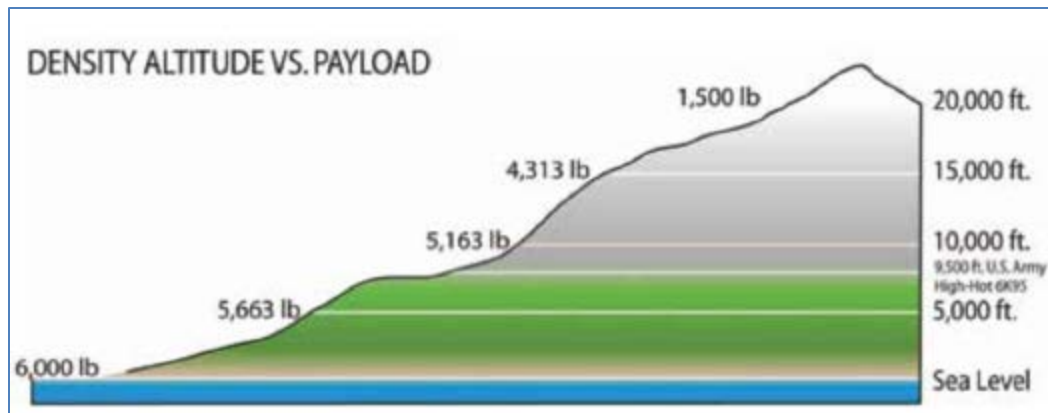
Figure 7. K-MAX Payload Capacity. Source: Lockheed Martin (2010), as cited in Denevan (2014).

(2)   A160T Hummingbird CUAS

A160T Hummingbird CUAS had a small ground station, which is less than 20 pounds, and it could drop deliveries with a precision of less than three meters (E. N. Pratson, personal communication, June 12, 2011) as cited in Peterson and Staley (2011).

As shown in Figure 8,

> both K-MAX and A160T have successfully demonstrated the ability to accomplish the following: deliver 2,500 pounds of cargo in a six-hour period to a location 75 nautical miles away, hover with 750-pound loads at 12,000 feet, operate beyond line of sight with GPS en route navigation, deliver cargo with the accuracy of 10 meters with terminal controller, terminal control capability to shift location 1,000 meters, and maintain a cruise flight of 15,000 feet. (Peterson & Staley, 2011, p. 17)
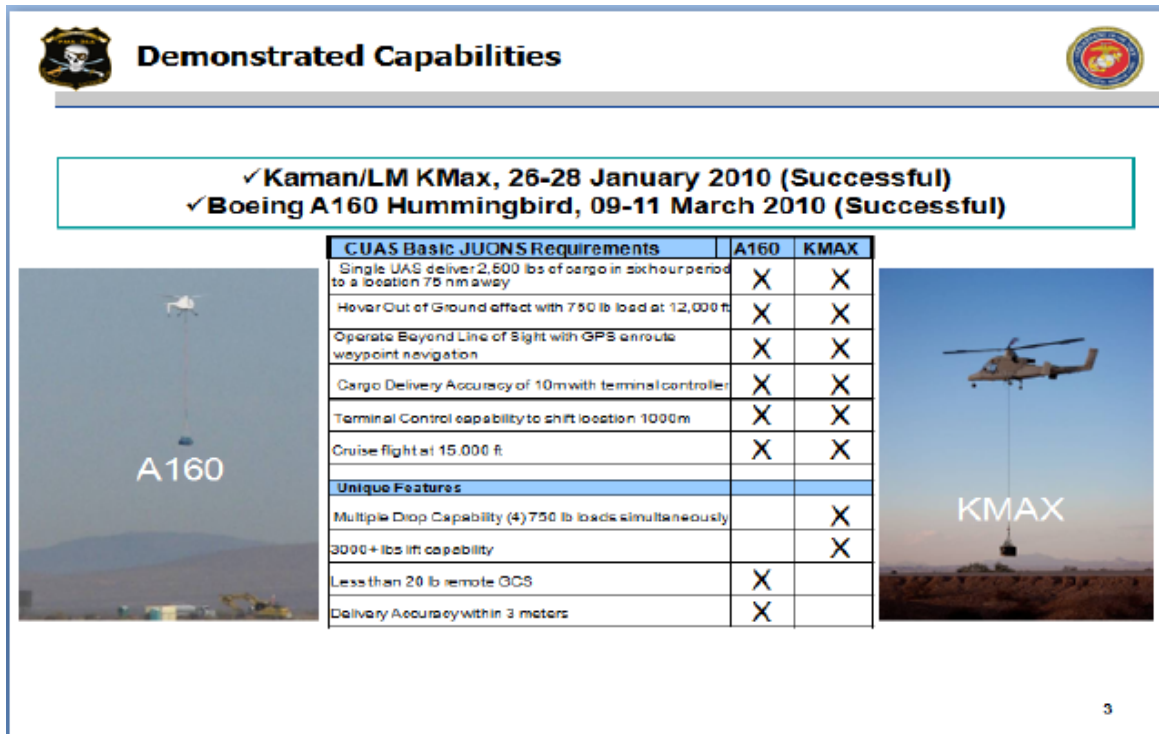
Figure 8. UAS Demonstrated Capabilities. Source: E. N. Pratson, personal communication, June 12, 2011, as cited in Peterson & Staley, (2011).

(3)   Delivery with Micro Aerial Vehicles

Another method for delivering supplies is the micro aerial vehicles. Haddick (2016) mentioned that with their small size, micro UAVs can carry supplies in a clandestine environment successfully. According to him, new recreational micro UAVs can be quickly improved and used with a GPS-enabled auto-pilot system with a small cost. Micro UAVs could be vulnerable to small arms, but this can be prevented with night operations (Haddick, 2016). Haddick (2016) explained their uses:

> The micro-UAV concept could be employed on a small scale to deliver high-value items such as medical supplies, vaccines, cash, and water purification equipment. On a larger scale, the concept could deliver routine supply classes to combat outposts, patrols, and remote guerrilla and SOF operator sites. Although preparing 200 micro UAVs for a night mission would be a tedious task and would risk creating an unfavorable signature in the host country, spreading the load among that many delivery vehicles would mitigate the risks when delivery aircraft are lost to malfunction or enemy action. (p. 28)

Although recent micro UAVs can hardly fulfill military cargo delivery, improvements in UAV components like batteries, motors, and electronics will prove successful in using these systems for cargo delivery missions in access-denied areas.

b. Unmanned Ground Systems for Logistics

Chestnut (2012) gathered valuable information about the unmanned ground systems that organizations like the Defense Advanced Research Projects Agency (DARPA) and the Marine Corps are exploring.

- According to Chestnut (2012), the Marine Corps Warfighting Laboratory has started testing Unmanned Medium Tactical Vehicle Replacement (MTVR) Truck to prevent Marines' exposure to danger for resupply convoys.

- Another unmanned system that the Marine Corps has started testing is the Ground Unmanned Vehicle Support Surrogate. Their plan is to use this vehicle for carrying supply items for dismounted personnel (Chestnut, 2012).

- DARPA has been doing research on a four-legged Squad Support System (LS3). LS3 has the mobility to stand, lie, and move with the soldiers, and it can walk 20 miles in 24 hours without refueling. There are also other types of unmanned systems with different characteristics, like R-Gator, Carry-all Mechanized Equipment Landrover (CaMEL), and Porter. The U.S. military has been conducting research and development on them (Chestnut, 2012).

According to Marshall (2016), U.S. Army started testing four semi-autonomous trucks in real Michigan traffic. He stated that trucks also had their drivers inside for monitoring the drive. These beta-trucks were using Light Detection and Ranging (LIDAR) system with cameras and short-range radios (Marshall, 2016). According to Army engineers, "fully autonomous convoys would be ready to serve in conflict zones in 10 to 15 years" (Marshall, 2016, para. 5). It is obvious that this technology would significantly decrease the potential for casualties from IED threats for ground logistics convoys (Marshall, 2016).

c. Unmanned Maritime Systems for Logistics

Although UUVs and USVs are mainly intended to be used for reconnaissance, surveillance, warfare, and other missions, the *Navy's Master Plan* defined some important tasks for them regarding logistics support of units (Chestnut, 2012). In her study, Chestnut (2012) stated that *U.S. Navy's Unmanned Surface Vehicle Master Plan* defined USVs' role as providing logistical support to Special Operations Forces (SOF).

Haddick (2016) explained that SOF logisticians should use small UUVs to deliver supplies to friendly forces (see Figure 9). He also mentions that these vehicles can begin operating in international waters, and they can go to the operational area by themselves. After leaving the necessary supplies to friendly forces, they can go back to their starting point.

Unmanned Undersea Vehicle (UUV), Keyport Undersea Warfare Center, and Penn State University lower SUBDEVRON 5 Det. UUV's first UUV LTV-38 into the water to conduct its first in-water training. Source: U.S. Navy photo by Breanna Zinter.

Figure 9. Members of Submarine Development Squadron Detachment 5 (SUBDEVRON Det.) Source: Haddick (2016), p. 29.

A. IMPACTS OF UNMANNED SYSTEMS TO THE ACQUISITION COSTS OF PRODUCTS COMPARED TO OTHER DELIVERY METHODS

Logistics delivery with all kinds of unmanned systems is on the verge of significant improvements. However, we decided to consider only unmanned aerial delivery methods to evaluate the potential impacts on the acquisition costs of products compared to other delivery methods. In our decision, we took the growing potential of aerial delivery applications in civilian-sector logistics including Amazon, Ali Baba, and DHL and the existing research on military aerial delivery applications in previous operations like OEF into account.

1. Previous Studies on the Cost Evaluations of Unmanned Aerial Delivery Methods

During our research, we found two significant studies that helped us to define cost drivers and cost differences between Cargo UAVs and standard cargo delivery methods.

a. Economical Evaluation of Cargo UAVs in Support of Forward Deployed Logistics in OEF

As discussed earlier in the chapter, Cargo UAVs have already been tested by the U.S. Marine Corps during OEF. Peterson and Staley (2011) conducted a business case analysis (BCA) in their MBA professional report: *Business Case Analysis of Cargo Unmanned Aircraft System (UAS) Capability in Support of Forward Deployed Logistics in Operation Enduring Freedom (OEF)*. In their study, they aimed to find out the potential cost savings when Cargo UAVs (K-MAX and A160T) are used in the OEF. Within the scope of their research, they compared procuring, operating, and sustaining costs of Lockheed Martin K-MAX or Boeing A160T Hummingbird Cargo UAVs with standard cargo delivery methods. When comparing Cargo UAVs' capabilities with the traditional ground and air logistics delivery methods, they mainly focused on the IED threats for ground convoys and the potential delays in supply chains caused by harsh weather conditions, fuel replenishment, maintenance necessities, and flight crew rest as the basis of their research on the BCA of Cargo UAVs' capabilities.

In their study, Peterson and Staley (2011) conducted an analysis comparing Cargo UAVs, "Boeing's A160T Hummingbird and Lockheed Martin's K-MAX" (p. 29), with four standard methods of logistics delivery methods, "medium-security ground convoy, high-security ground convoy, CH-53E, and KC-130J with joint precision airdrop systems (JPADS)" (p. 29). They used five different scenarios while comparing costs by using linear programming. In these five scenarios, Peterson and Staley (2011) simulated "an infantry battalion operating in Afghanistan with five forward operating bases (FOBs)" (p. 31). They assumed both Cargo UAVs and traditional methods may be started from mobile operating base (MOB) Camp Bastion. Peterson and Staley (2011) used the distance (in miles) from MOB to each FOBs for the cost evaluations.

Within the scope of their analysis, they defined these four known cost drivers:

(1)   Platform Procurement/Replacement Costs

These costs stem from the attrition rate for replacing assets destroyed by enemy. Table 1 provides the relevant information for these costs.

Table 1.   Summary of Replacement Costs. Source: Peterson & Staley (2011).

Platform	Procurement Costs/Replacement Costs	Data Source
CH-53E	$26,100,000	Global Security, 2011a
KC-130J	$52,000,000	Global Security, 2011b
MTVR	$230,000	Deagel, 2011
HMMWV	$143,632	Army-Guide, 2011
A160T	$12,020,928	E. N. Pratson, personal communication, June 12, 2011
K-MAX	$11,105,912	E. N. Pratson, personal communication, June 12, 2011
GCS FOB (Lockheed Martin)	$410,715	E. N. Pratson, personal communication, June 12, 2011
GCS FOB (Boeing)	$300,881	E. N. Pratson, personal communication, June 12, 2011
GCS MOB (Lockheed Martin)	$1,000,000	E. N. Pratson, personal communication, June 12, 2011
GCS MOB (Boeing)	$1,637,000	E. N. Pratson, personal communication, June 12, 2011
JPADS	$12,000	E. N. Pratson, personal communication, June 12, 2011

(2)   Platform Operating and Support Costs

Peterson and Staley (2011) used "dollars per mile for ground convoys and dollars per flight hour for air platforms" (p. 36). Peterson and Staley (2011) calculated the "platform operating and support costs" (p. 36) with these formulas:

- The calculations for ground convoy costs include fuel/mile + manpower/mile + maintenance/mile + personnel risk exposure/mile + platform risk exposure/mile.

- The calculations for CH-53E are fuel/hour + manpower/hour + maintenance/hour + personnel risk exposure/hour + platform risk exposure/hour.

- The calculations for KC-130J are fuel/hour + manpower/hour + maintenance/hour + personnel risk exposure/hour + platform (KC-130J) risk exposure/hour + platform (JPADS) risk exposure/hour. The calculations for JPADS costs include 0.05 × $12,000 (replacement costs). This cost is based on the assumption that 95% of the JPADS will be recovered by global positioning system (GPS) and associated sensitive equipment for each evolution, whereas the canopy will not always be recovered in a reusable manner.

- The calculations for both variants of CUAS costs included fuel/hour + maintenance/hour + GCS manpower/hour + risk exposure platform/hour (Peterson & Staley, 2011, p. 36). (see Table 2).

Table 2. Summary of Platform Operating and Support Costs. Source: Peterson & Staley (2011).

Platform	Fuel Costs	Manpower Costs	Maintenance Costs	Personnel Risk Exposure	Platform Risk Exposure	Total ($)	Data Source
MTVR (per mile)	$4.11	$18.38	$6.20	$1,393.20	$26.00	$1,447.89	U.S. Army Logistics Innovation Agency, 2011
HMMWV (per mile)	$1.86	$18.38	$6.20	$1,393.20	$16.00	$1,435.64	U.S. Army Logistics Innovation Agency, 2011
CH-53E (per flight hour)	$1,031.73	$5,794.83	$18,460.08	$619.20	$673.00	$26,578.84	VAMOSC, 2011
KC-130J (per flight hour)	$2,708.04	$4,179.47	$4,707.88	$619.20	$1,342.00	$13,556.59	VAMOSC, 2011
JPADS	N/A	N/A	N/A	N/A	$600.00	$600.00	S. R. Parker, personal communication, August 1, 2011
A160T (per flight hour)	$20,720			N/A	$1,298.00	$22,018.00	Defense Acquisition Management Information Retrieval, 2011
K-MAX (per flight hour)	$20,720			N/A	$1,199.00	$21,919.00	Defense Acquisition Management Information Retrieval, 2011

(3) Personnel Risk Exposure

In their study, Peterson and Staley (2011) defined the cost of life for one Marine soldier as $6 million. Then, they found out the loss rate of ground personnel from 2008 joint IED defense office (General Dynamics, 2010) as cited in (Peterson & Staley, 2011).

Peterson and Staley (2011) calculated the personnel risk exposure costs with the following formulas:

- Ground convoys are attacked every 808 miles and there would be one killed in action (KIA) out of every 16 attacks;

- Assumption of a one-year deployment resulting in 122 ground convoys (365/3=122);

- 122 convoys multiplied by the total miles traveled for one complete replenishment of all five FOBs equaled 575.2 miles;

- 122 convoys * 575.2 miles resulted in 70,175 total miles per year;

- The total miles per year divided by miles per attack resulted in 87 attacks (70175/808 = 87 attacks);

- The 87 total attacks per year divided by every 16 attacks resulted in one KIA per 5.43 attacks (87/16 = 5.43);

- Total miles traveled divided by attacks resulted in a KIA rate of 0.0000774 (5.43/70,175 = 0.0000774); and

- The attack rate multiplied by the $6,000,000 cost of human life, resulted in a $1,393.20 per mile per truck cost (Peterson & Staley, 2011, p. 38).

Table 3 provides a summary of personnel risk exposure costs.

Table 3.   Summary of Personnel Risk Exposure Costs. Source: Peterson & Staley (2011).

Personnel	Loss of Personnel Due to Enemy or Mishap (Rate)	Number of Personnel Exposed	Value of Human Life	Total ($)	Source of Data
CH-53E (per flight hour)	0.0000258	4	$6,000,000	$619.20	Naval safety center, 2011
KC-130J (per flight hour)	0.0000258	4	$6,000,000	$619.20	Naval safety center, 2011
MTVR (per mile)	0.0000774	3	$6,000,000	1,393.20	General Dynamic, 2010
HMMWV (per mile)	0.0000774	3	$6,000,000	1,393.20	General Dynamic, 2010

(4)   Platform Risk Exposure

To find platform risk exposure, Peterson and Staley (2011) defined losses that stemmed from each method of resupply. Then, they multiplied rate of losing resupply because of enemy or mishap with replacement costs of platforms.

For this calculation, "the loss rate of ground personnel was determined by using the 2008 joint IED defense office JIEDDO as stated in the General Dynamics AR-5 study, 2010" (Peterson & Staley, 2011, p. 41).

Peterson and Staley (2011) also used General Dynamics's 2010 study when calculating the following costs:

- On average, ground convoys are attacked every 808 miles;

- There would be one ground convoy prevented from completing its resupply mission for every 11 attacks;

- With the assumption of a one-year deployment resulting in 122 ground convoys (365/3 = 122) multiplied by the total miles traveled for one total replenishment of all five FOBs equaling 575.2 miles resulting in 70,175 total miles per year;

- The total miles per year divided by miles per attack (70175/808 = 87 attacks) resulted in 87 attacks;

- Of the 87 total attacks per year divided by every 11 attacks resulting in one resupply mission being prevented (87/11 = 7.91) resulted in a rate of 7.91 attacks;

- The rate of attacks resulting in resupply mission being prevented was then divided by total miles (7.91/70,175 = 0.000113) resulting in a rate of 0.000113;

- This attack rate is then multiplied by the procurement cost of ground vehicles and provides a per mile cost for each ground platform;

- Loss rates for manned fixed and rotary wing aircraft were taken from the Naval Safety Center and are the same calculation as previously stated for the risk exposure of personnel; and

- Unmanned loss rates were taken from the average loss rates of the MQ-9 Reaper (Air Force safety center, 2008). They were calculated by dividing the total Class A Mishaps by the total flight hours (Peterson & Staley, 2011, p. 41). (see Table 4).

Table 4.   Summary of Platform Risk Exposure Costs. Source: Peterson & Staley (2011).

Platforms	Loss of Asset Due to Enemy or Mishap (Rate)	Replacement Cost of Asset	Total ($)	Source of Data
CH-53E (per flight hour)	0.0000258	$26,100,000	$673	Naval safety center, 2011
KC-130J (per flight hour)	0.0000258	$52,000,000	$1,342	Naval safety center, 2011
MTVR (per mile)	0.000113	$230,000	$26	General Dynamic, 2010
HMMWV(per mile)	0.000113	$143,632	$16	General Dynamic, 2010
A160T (per flight hour)	0.000108	$12,020,928	$1,298	Air Force safety center, 2010
K-MAX (per flight hour)	0.000108	$11,105,912	$1,199	Air Force safety center, 2010
JPADS (per flight hour)	0.05	$12,000	$600	S.R. Parker, personal communication, August 1, 2011

According to the findings of this study, if human life is considered to have a value below $2 million, then it would be more economical to use ground convoy than to use K-MAX in logistics delivery. However, most U.S. government agencies, including the "Department of Transportation and the Federal Aviation Administration" (Silney, Little, & Remer, 2010) as cited in (Peterson & Staley, 2011, p. 38), value human life higher than $2 million, depending on several factors including "life insurance, survivor benefits, loss of earnings, lost human capital, and welfare lost to society" (Peterson & Staley, 2011, p. 38). In addition, using ground convoys would increase the risk of losing more soldier lives (Peterson & Staley, 2011). The study also found that "when the human life valued $0, then three ground convoys, seven CH-53E sorties, four KC-130J sorties and four K-MAX sorties are used" (Peterson & Staley, 2011, p. 55). Based on the study, K-MAX is an efficient alternative way of replenishment in comparison with the traditional methods. According to the research, K-MAX can be used especially in class-I deliveries by decreasing transportation costs and eliminating all ground convoys.

On the other hand, A160T Hummingbirds have "potential to provide responsive and time-sensitive support for special operations" (Peterson & Staley,

2011, p. 59). In addition, because of their less payload capacity than K-MAX models, they significantly increase transportation costs (Peterson & Staley, 2011).

b. Cost-Based Analysis of UAVs in the Logistical Support Role

In his thesis: *Cost-Based Analysis of Unmanned Aerial Vehicles/ Unmanned Aerial Systems in Filling the Role of Logistical Support,* Denevan (2014) conducted a cost-based analysis with different models of UAVs and traditional aircrafts with a larger scope than Peterson and Staley's (2011) study. Denevan (2014) defined various kinds of UAVs and traditional logistical resupply resources that were being used in the U.S. Department of Defense (DOD). He used KC-130J, MV-22, and CH-53E as the traditional resupply resources and MQ-4C Triton, MQ-8B Fire Scout, MQ-8C Fire Scout, MQ-9 Reaper, K-MAX, and RQ-4 Global Hawk as UAV models for his cost-based comparison.

Table 5 shows capabilities of different aircrafts that Denevan (2014) used in his study.

Table 5.   Nomenclature of Aircraft Used in This Study.
Source: Denevan (2014).

AIRCRAFT NOMENCLATURE							
MQ-4C Triton							
Length (ft)	Weight lbs	Airspeed (mph)	Range (miles)	Service Ceiling (ft)	Endurance (hrs)	Payload (lbs)	Contractor
48	32250 lbs.	381	11450	56000	24	6600	Northrop Grumman
MQ-8B Fire Scout							
Length (ft)	Weight lbs	Airspeed (mph)	Range (miles)	Service Ceiling (ft)	Endurance (hrs)	Payload (lbs)	Contractor
31	3150	132	537	20000	4.5	300	Northrop Grumman
MQ-8C Fire Scout							
Length (ft)	Weight lbs	Airspeed (mph)	Range (miles)	Service Ceiling (ft)	Endurance (hrs)	Payload (lbs)	Contractor
35	6000	161	1863	17000	10	700	Northrop Grumman
MQ-9 Reaper							
Length (ft)	Weight lbs	Airspeed (mph)	Range (miles)	Service Ceiling (ft)	Endurance (hrs)	Payload (lbs)	Contractor
36	4900	230	1151	50000	24	3750	General Atomics
K-MAX							
Length (ft)	Weight lbs	Airspeed (mph)	Range (miles)	Service Ceiling (ft)	Endurance (hrs)	Payload (lbs)	Contractor
	6866 lbs	92	246		12 +	6000	Lockheed Martin
RQ-4 Global Hawk							
Length (ft)	Weight lbs	Airspeed (mph)	Range (miles)	Service Ceiling (ft)	Endurance (hrs)	Payload (lbs)	Contractor
48	25250	357	14155	60000 ft.	32 +	3000	Northrop Grumman
Unmanned Combat Air System (UCAS) Aircraft Carrier Demonstration (UCAS-D)							
Length (ft)	Weight lbs	Airspeed (mph)	Range (miles)	Service Ceiling (ft)	Endurance (hrs)	Payload (lbs)	Contractor
38	44000	> 660	2416.638	40000		4500	Northrop Grumman
KC-130J Super Hercules							
Length (ft)	Weight lbs	Airspeed (mph)	Range (miles)	Service Ceiling (ft)	Endurance (hrs)	Payload (lbs)	Contractor
98	175000	311	4083	28000 ft.	N/A	44000 lbs.	Lockheed Martin
CH-53 Super Stallion							
Length (ft)	Weight lbs	Airspeed (mph)	Range (miles)	Service Ceiling (ft)	Endurance (hrs)	Payload (lbs)	Contractor
99	73500	173	621	10000 ft.	N/A	30000 lbs.	Sikorsky Aircraft
MV-22 Osprey							
Length (ft)	Weight lbs	Airspeed (mph)	Range (miles)	Service Ceiling (ft)	Endurance (hrs)	Payload (lbs)	Contractor
63	52600	322	990	25000 ft.	N/A	20000 lbs.	Bell-Boeing

To calculate relevant costs of aircrafts, Denevan (2014) used "flight operations budget, known as Operational Plan 20 (OP-20)" (p. 35), and personnel risk exposure costs. He ignored life-cycle costs, because many of the aircrafts that he used were emerging technologies.

Denevan (2014) explained his cost drivers as follows:

(1)   The Flight Operations Budget (The OP-20 and the Flight Hour Program)

In his study, Denevan (2014) explained the OP-20 as a planning document that had several particular funding options. When it comes to "the Operation and Support (O&S) level of acquisition" (Denevan, 2014, p. 35), he considered Glenn and Otten's (1995) MBA Professional Report, *Commander Naval Air Forces (CNAF) Flight Hour Program: Budgeting and Execution Response to the Implementation of the Fleet Response Plan and OP-20 Pricing Model Changes.* In their report, Glenn and Otten (1995) broke O&S funding into two sections, "Aircraft Flight Operations (AFO) and Aircraft Operations Maintenance (AOM)" (Denevan, 2014, p. 35).

- Aircraft Flight Operation Costs: AFO funding consists of two codes: 7B (fuel, petroleum, oil, lubricants) and 7F (flight equipment such as flight suits, boots, and other equipment.) (Glenn & Otten, 1995) as cited in (Denevan, 2014).

- Aircraft Operations Maintenance Costs: AOM funding consists of 9S (repairable material), 7L (consumable material), FW (contract costs), and F0 (other costs) (Glenn & Otten, 1995) as cited in (Denevan, 2014).

(2)   Personnel Risk Exposure Costs

In his study, Denevan (2014) used the same rate and value of $6 million for the loss of a life as in Peterson and Staley's (2011) study and adjusted the cost to the FY14$ value.

Considering these two cost drivers (the flight operations budget and personnel risk exposure costs), Denevan (2014) calculated "Costs per flight hour = total procurement costs of each aircraft divided by projected hours to be flown" (p. 42). Table 6 provides information on Denevan's (2014) calculation of costs per flight hour for each aircraft vehicle.

Table 6.   Cost per Flight Hour for Each Vehicle Used in This Study. Source: Denevan (2014).

Costs per Flight Hour					
TMS	7B Fuel	9S FA/DLR	7L AFM	Loss of Life Calculations	Total Cost Per FH
KC-130J	$2,971.54	$477.87	$470.17	$738.80	$4,658.39
MV-22	$1,844.23	$4,326.04	$2,225.61	$738.80	$9,134.68
CH53E	$1,551.80	$7,321.43	$2,269.19	$738.80	$11,881.22
K-MAX (1)	N/A	N/A	N/A	$0.00	$3,000.00
K-MAX (2)	N/A	N/A	N/A	$0.00	$9,000.00
RQ-4 Global Hawk	N/A	N/A	N/A	$0.00	$24,123.00
MQ-9 Reaper	N/A	N/A	N/A	$0.00	$2,617.00
MQ-8B Fire Scout	$90.96	$1,651.91	$823.62	$0.00	$2,566.49
MQ-8C Fire Scout	$116.95	$1,770.94	$882.96	$0.00	$2,770.85
MQ-4C Triton	N/A	N/A	N/A	$0.00	$6,319.81

After finding costs per flight hour, Denevan (2014) conducted cost-based analysis for the following known distances: 25, 50, 100, 250, 500, 1,000, 2,500, 5,000, 10,000, and 15,000 miles. In our study, we provide Denevan's (2014) 25 and 15,000 miles of cost-based analysis to understand the effects of cost drivers better. Table 7 and Table 8 provide Denevan's (2014) cost-based analysis for 25 and 15,000 miles accordingly.

Table 7.   Cost-Based Analysis for Known Distance of 25 Miles. Source: Denevan (2014).

25 Miles					
TMS	Total Costs Per Hour	Flying Time (hrs)	Max payload capacity (lbs)	Max Range (miles)	Cost (FY14$)
MQ-9 Reaper	$2,617.00	0.11	1151	3750	$284.26
KC-130J	$4,658.39	0.08	44000	4083	$374.82
MQ-4C Triton	$6,319.81	0.07	6600	11450	$414.79
MQ-8C Fire Scout	$2,770.85	0.16	1863	700	$429.96
MQ-8B Fire Scout	$2,566.49	0.19	537	300	$484.83
MV-22	$9,134.68	0.08	20000	990	$708.73
K-MAX (1)	$3,000.00	0.27	246	6000	$814.66
RQ-4 Global Hawk	$24,123.00	0.07	3000	14155	$1,690.51
CH53E	$11,881.22	0.14	621	30000	$1,720.75
K-MAX (2)	$9,000.00	0.27	246	6000	$2,443.99

Table 8.   Cost-Based Analysis for Known Distance of 15,000 Miles.
Source: Denevan (2014).

15000 Miles					
TMS	Total Costs Per Hour	Flying Time (hrs)	Max payload capacity (lbs)	Max Range (miles)	Cost (FY14$)
MQ-9 Reaper	$2,617.00	65.17	1151	3750	$170,558.23
KC-130J	$4,658.39	48.28	44000	4083	$224,890.40
MQ-4C Triton	$6,319.81	39.38	6600	11450	$248,871.32
MQ-8C Fire Scout	$2,770.85	93.10	1863	700	$257,978.68
MQ-8B Fire Scout	$2,566.49	113.34	537	300	$290,897.97
MV-22	$9,134.68	46.55	20000	990	$425,240.25
K-MAX (1)	$3,000.00	162.93	246	6000	$488,798.90
RQ-4 Global Hawk	$24,123.00	42.05	3000	14155	$1,014,305.02
CH53E	$11,881.22	86.90	621	30000	$1,032,449.41
K-MAX (2)	$9,000.00	162.93	246	6000	$1,466,396.70

Denevan (2014) shared his findings based on his cost-based analysis. According to him, with its high payload capacity compared to other UAVs, K-MAXs would lower costs, provided that their speed would be increased by their manufacturers. K-MAX provided significant cost savings when compared to the MV-22 and the CH-53E types of traditional aircrafts (Denevan, 2014). Among the traditional aircrafts, KC-130J was the cheapest and the most ideal one for large payloads.

2. Unmanned Systems' Effects on Acquisition Processes

Military technologies have always been important for countries. Countries have to equip their armies with necessary technologies. Weapons and vehicles are among the most important military assets necessitating technological advance. There are different kinds of sensors, radars, communication devices, armor technologies, and computer software embedded in these military assets' more recent versions. With their complex technology, unmanned systems also have most of these advanced technologies inside. After their introduction to the warfare theater, they have changed the game significantly with their superior capabilities.

In addition to cost efficiencies mentioned earlier, unmanned systems have significant effects on the acquisition system and its processes. Thirtle, Johnson, and Birkler (1997) mentioned some of these effects in their RAND report, *The Predator Advanced Concept Technology Demonstration (ACTD): A Case Study for Transition Planning to the Formal Acquisition Process.* According to them, the ACTD concept

was introduced in 1993, because the senior DOD officials were sharing the same opinion that traditional acquisition processes had not been efficient enough in meeting warfighters' technological demands. Thirtle et al. (1997) explained ACTD:

> An ACTD is a joint exercise: It is developed and implemented by both the operational user and the materiel development communities. Acceptance or rejection of an ACTD is based on the warfighter's evaluation of the military utility of the system as well as on other factors, such as affordability and supportability. (p. 14)

So "given these criteria, not all ACTDs are expected to be successful or to make the transition to the formal acquisition process" (Thirtle et al., 1997, p. 14). After the ACTD process started, an existing project, "the Medium Altitude Endurance (MAE) Unmanned Aerial Vehicle (UAV), or Predator, a new system within the old UAV family was selected" (Thirtle et al., 1997, p. 14) to be a model for this new process. According to Thirtle et al. (1997), the main goal for the ACTD process was the successful implementation of ACTD or transitioning of it to the usual acquisition process, and the Predator was among the first projects that achieved this. Specifically in ACTD process,

> operational users not only participate in the management and execution of program decisions, they also provide the final decision on whether an ACTD should be transitioned to the formal acquisition process. If warfighters believe that ACTD has military value, then "military utility" is declared and the ACTD is transitioned, provided that ample funding exists. (Thirtle et al., 1997, p. 15)

Jones (2014) also pointed out the effects of various unmanned system projects on acquisition processes in his thesis report, *An Analysis of the Defense Acquisition Strategy for Unmanned Systems.* He addressed unmanned systems as revolutionary assets for war with their effects on warfare like decreasing time and increasing capabilities for military operations, and also protecting human lives. In addition to these effects, he also mentioned that unmanned systems have necessitated "new contractual arrangements that focus more on outcomes, not parts and services" (Jones, 2014, p. 51). Jones (2014) explained the Joint Capabilities Integration Development System (JCIDS) process:

The Joint Capabilities Integration Development System (JCIDS) process was implemented in 2003 to assist the Joint Requirements and Oversight Council (JROC) and the Chairman of the Joint Chiefs of Staff (CJCS) in "identifying, assessing, validating, and prioritizing joint military capability requirements" (Chairman of the Joint Chiefs of Staff [CJCS], 2012, p. 1). (Jones, 2014, p. 52)

According to Jones (2014), the JCIDS process gives the combatant commander the opportunity of detecting capability gaps of their units in comparison with enemies. However, he also emphasized that the JCIDS process is cumbersome and time consuming. In addition, "JCIDS process has been the lack of synchronization with the Planning, Programming, Budgeting, and Execution (PPBE) system designed to fund service programs" (Jones, 2014, p. 52). JCIDS cannot prioritize its programs the same as individual services do (Jones, 2014).

Jones (2014) pointed out another discussion point for JCIDS system. "The JCIDS process identifies the 'lead users' as the regional and functional combatant commanders" (Jones, 2014, p. 52). Jones (2014) emphasized that main reason for this is to gain enough feedback about the product in the early phases of its development to shape it according to its targeted capabilities. He also added that the JCIDS process is problematic because of its length. Combatant commanders and operational necessities frequently change during the long JCIDS process (Jones, 2014). This, obviously, causes a significant drop in reliability of the acquisition process. Another issue with JCIDS process is that most of the combatant commanders are not the end users of the products that are in the acquisition process (Jones, 2014).

On the other hand, unmanned systems have positively affected the slow-moving JCIDS process (Jones, 2014). With the successfully articulated demands coming from the front lines, better feedback has started to be sent from these lead users, and better responses have started to be given from more capable and dynamic unmanned systems industry (Jones, 2014). Jones (2014) also explained the Joint Urgent Operational Needs (JUON) program. According to Jones (2014), "the JUON process has a staffing goal of 15 days after the JUON submission, with a complete development and fielding time frame of not more than 24 months (CJCS,

2012)" (p. 53). He also provided a remarkable example of the JUON program, the procurement of K-MAX Cargo Unmanned Aerial System (CUAS). In his article, Putrich (2010) explained that the U.S. Marine Corps provided a $75 million contract award for this procurement between Lockheed Martin (with Kaman) and Boeing for development of two different CUASs, K-MAX and A160T respectively. As a result, the U.S. Marine Corps chose and procured two K-MAX CUASs and started using them for cargo delivery in Afghanistan (Hoffman, 2013). Jones (2014) pointed out this procurement in such a short time as unprecedented. In addition, the abovementioned private companies proved this remarkable success thanks to their continuous research and development (R&D) and marketing efforts (Jones, 2014).

Another effect of unmanned systems to the acquisition process is related to the use of performance-based logistics (Jones, 2014). According to Jones (2014), within the concept of performance-based logistics, the DOD does not pay for "individual transactions for things like spare parts, repairs, or hours of technical support" (Vitasek, Geary, & Quick, 2006, p. 1). However, it pays for "weapons system performance over the entire life cycle of the systems," (Vitasek et al., 2006, p. 1). Jones (2014) also added that "by shifting performance responsibility to the contractor, the DOD can reduce total ownership cost and benefit from contractor measures to improve efficiencies" (p. 54). Owings (2010) also provided an example from RQ-7B Shadow Tactical UASs' acquisition process. According to Owings (2010), the DOD required specific metrics for contractors and let them decide how to fulfill them. With the fulfillment of these contracted metrics, innovational design of assets are also possible to be implemented (Jones, 2014). Jones (2014) also mentioned that

> Tadjdeh (2013) pointed to the Army's Rapid Equipping Force (REF) as a model for shortening the lead user feedback loop. The REF was responsible for the procurement of AeroVironment's Puma UAV, which has now become a program of record. The REF communicates directly between the lead user and AeroVironment for upgrades demand by the warfighter. (p. 54)

On the other hand, there have also been negative examples of unmanned systems' acquisition processes like in the Long Endurance Multi-Intelligence Vehicle (LEMV) case (Jones, 2014). Lockheed Martin and Northrop Grumman were the only two competing contractors (Jones, 2014). However, Lockheed Martin opted out from the acquisition process because of the 18-months development schedule (Jones, 2014). With Northrop Grumman as the only contractor, Army Intelligence officials tried seeking funds directly from Congress skipping the usual acquisition process (Axe, 2013). Jones (2014) pointed out the results as not desirable. The LEMV project saw cost and schedule overruns, as well as developmental inefficiencies regarding its weight (Jones, 2014). In addition, the LEMV project met with budget cuts, and it was eventually canceled (Jones, 2014).

B. POSITIVE IMPACTS OF USING UNMANNED SYSTEMS IN MILITARY LOGISTICS

In this part of our "Analysis" chapter, we evaluate the current and proposed applications in both military and civilian sectors, and defined positive impacts of unmanned systems in military logistics. In the "Background and Literature Review" chapter of our thesis, we studied military logistics and defined military logistics challenges. These challenges were grouped under two main problematic areas, as in Kang's (2016) lecture notes: uncertainty and security issues. In this part, we initially grouped positive impacts of unmanned systems under the two mentioned problematic areas. After defining possible solutions for these two problems, we focused on other positive impacts.

1. Impacts of Unmanned Systems to Uncertainty Issue

Ivanov and Sokolov (2010) defined uncertainty as drifting from the expected results in either positive or negative ways. Li and Schulze (2011) provided valuable information about uncertainty that can be applied to military logistics in their research paper, *Uncertainty in Logistics Network Design: A Review*. According to them, uncertainty is among the biggest problems in a supply chain because it is possible to encounter this issue in all levels of a supply chain. They explained this process in three steps: At the beginning of supply chain, a supplier can be late, at the middle of

a supply chain a normal working procedure can stop working, and at the end customer demand always changes. Li and Schulze (2011) also pointed out the performance measures of logistics network model. According to them, quantitative performance measures are mainly related to costs, profits, and customer-related metrics. On the other hand, there are qualitative performance measures: customer satisfaction, flexibility, visibility, and trust. If we apply this explanation of Li and Schulze (2011) to the military supply chain, we can find out the same results with different terminology.

In the strategic level of logistics, logistic necessities of combat units should be forecasted before military operations. According to the results of these forecasts, military logistics officials decide necessary amounts of logistic assets like personnel, weapons, vehicles, equipment, fuel, food, and ammunition. In addition to the materiel needs, service needs such as medical treatment and evacuation are also planned by military officials. Considering these items and services, military officials decide necessary R&D planning or acquisition processes in peace time. At this level, production and acquisition processes are mainly impacted by the time and cost uncertainties. For some logistic assets, militaries might consider using their own capabilities and facilities. On the other hand, for logistic assets that require higher technology, officials might consider strategic purchasing. Then contracts are made with suppliers. Acquisition processes begin.

As we discussed in previous chapters, civilian firms with high profit margins have started investing in automation systems. Militaries also can overcome uncertainty issues at the beginning and middle of their supply chain regarding suppliers and production by investing more in automation systems in military warehouses and production facilities. These automation capabilities in factories/warehouses can have the same cost-efficiency and time-savings effects on Li and Schulze's (2011) quantitative performance measures as they do in civilian sector logistics. In addition, increasing automation in military warehouses/factories can also help decreasing working personnel in these facilities. These personnel can be assigned to other value-added missions. This can be explained as the flexibility effect on Li and Schulze's (2011) qualitative performance measures.

Peltz, Halliday, Robbins, and Girardini (2005) also discussed the issue of uncertainty in their RAND report, *Sustainment of Army in Operation Iraqi Freedom.* They pointed out that having quality information in all logistics processes would have significant effects on the operational decision-making process. According to them, poor logistics information and visibility would have an incremental effect on uncertainty. In addition, while every single item count is crucial on the tactical level, information about readiness on the operational and strategic levels must rely on information that was obtained in the tactical level and that is available in an automated system (Peltz et al., 2005). The authors added that "the more automated that detailed supply accounting becomes, the more current high-level logistics situational awareness will be" (p. 70). The visibility issue might also affect inventory levels and safety stock calculations accordingly. With the help of unmanned industrial systems, inventory levels might significantly drop. Jesion (2002) also mentioned that autonomous systems might have a direct effect on decreasing unit/personnel sizes and their sustainability levels. He also added that "embedded sensors have the capability to radically improve ammunition and spares management in the same way that commercial 'checkout counters' automatically re-order stock for items that are being purchased or drawn on" (p. 10).

As discussed earlier in this chapter, unmanned systems like K-MAX, A160T Hummingbird types of Cargo UAS, proposed Cargo UGVs, and USVs can also significantly decrease lead-time and uncertainty accordingly by interfering less risk and carrying on missions in less time. For medical emergencies and urgent ammunition requirements in small sizes, small UAVs can be used as an alternative delivery method especially when units are under fire like recent commercial applications, which are mentioned in our literature review chapter.

2. Impacts of Unmanned Systems to Security Issue

Another important aspect of military logistic operations is the security issue. Security is the part that mainly diversifies military logistic applications from the commercial ones. Although civilian logistics has concerns about the security of their

facilities like warehouses and factories, in military logistics the spectrum is dramatically broader.

We mentioned Blain's (2010) and Shachtman's (2008) articles earlier in this chapter that autonomous sentries have already been tested and used by different country's militaries including United States and South Korea. These autonomous weapons applications are important examples of where sentry technology can be used. According to Singer (2009), "unmanned sentries can guard entrances, automatically patrol perimeters, check IDs, and even use facial recognition software to know who should or shouldn't be allowed into the area" (p. 39). In addition, Cares and Dickmann (2016) emphasized unmanned sentry technology in their book, *Operations Research for Unmanned Systems*. According to them, unmanned sentries can be a cheaper option than using humans when considering military base security tasks. With their superior surveillance and sensor capabilities, detection of intruders can be easier for autonomous sentries. Logistics facilities can be protected with autonomous sentries better than with humans.

In addition to the sentry concept for logistic facilities, unmanned systems can also be used in convoy operations. Peters et al. (2011) also highlighted that surveillance and reconnaissance missions for logistic convoys, which are done with UAVs, are among the recent successful applications. Considering the proposed military and civilian applications referring to Green's (2011) research, we can also say that unmanned UGVs would be used as logistic vehicles in the near future. The same technology can also be applied to UUVs and USVs.

Another concept DHL (2015) mentioned was the small UAVs placed on top of delivery trucks. Particularly in military convoy operations, this small UAVs can automatically patrol critical points on the road for potential IEDs. It can also be helpful when detecting potential attackers who are hidden and waiting for the convoy to trigger the implanted IEDs.

3. Other Positive Impacts of Unmanned Systems

With the evolving nature of warfare, speed has become a crucial element in every aspect of warfare. Proving the role of autonomy on speed, the Defense Science Board also highlighted in its *Summer Study on Autonomy* that "employment of logistics autonomy can also be proactively used against an adversary. For example, speeding logistics helps get inside an adversary's decision cycle" (DOD, 2016, p. 69). From the operational logistics perspective, troops having higher maneuver capability have defined the difference between victory and defeat. Also carrying effective weapons, vehicles, equipment and soldiers quickly to a critical geographical place is a feature most military commanders want. Certainly, speeding any process regarding logistics will make a difference, and unmanned systems are the key to it.

As we mentioned earlier, using unmanned systems in the military would cause significant cost and time efficiencies. However, in many cases, positive impacts of unmanned systems can be intertwined to each other. Specifically, time and cost efficiencies have an exponential effect on the other aspects of the defense industry. An example of this can be the relationship between impacts on acquisition processes and time efficiencies. It is clear that when acquisition processes get less complex, warfighters will be able to use newer technology without losing time. Higher technology in the field has usually meant more lives saved. In addition, Peterson and Staley's (2011) and Denevan's (2014) research on the cost efficiencies showed that there could be significant cost savings when Cargo UAVs were used. Another impact of unmanned systems is the change they do in operational planning. Without carrying a life, dangerous supply missions can be implemented vigorously by military leaders using unmanned systems. Even under fire, more than the necessary amount of critical supplies can be sent with more than one unmanned system (depending on the value of supplies); losing an unmanned system with its supply payload cannot be compared to a potential loss of any human lives. When significant cost efficiencies and exposing less risk are combined, inventory levels will also be decreased accordingly. This again will lead to significant cost savings.

Unmanned systems, specifically UAVs, have also taken part in Humanitarian and Disaster Response (HADR) operations. Recent applications include mostly surveillance tasks.

Another advantage for using unmanned systems in military logistics was eliminating human weaknesses. Militaries have started using these robotic technologies in dull, dirty, and dangerous jobs to decrease loss of human lives and improve the quality of certain military tasks. Because robots were not getting tired, hungry, or sad, they could implement the same tasks and maybe more of them with fewer and fewer errors.

C.   NEGATIVE IMPACTS AND RISKS OF USING UNMANNED SYSTEMS IN MILITARY LOGISTICS

In this part of our Analysis chapter, we addressed potential negative impacts and risks that unmanned systems might be exposed to. Without any doubt, unmanned systems have dramatically affected military logistic capabilities and acquisition processes in a positive way. However, these superior capabilities and advantages listed earlier in our study have come with a cost. As a general term, unmanned systems have high procurement costs for each system because they need intensive R&D studies and expenses. In addition, they are exposed to different kinds of risks such as cyber threats and safety issues. In our study, we evaluated negative impacts and risks of unmanned systems mainly from a general point of view because most vulnerabilities of unmanned systems would also be valid for military logistics applications.

1.   Cyber Attacks

Today with the help of technological improvements, nations have become more and more dependent on information technology (Owens, Dam, & Lin, 2009). As nations understand the exponential pay-off their technological investments can make, governmental entities and private companies all around the world have tried to catch up with the Information Age's requirements. However, these technological improvements have come with vulnerabilities that can be exploited because any device connected to the Internet is a possible target for adversaries. Owens et al.

(2009) defined the cyberattack concept in their report *Technology, Policy, Law, and Ethics Regarding U.S. Acquisition and Use of Cyberattack Capabilities.* According to Owens et al. (2009), "cyberattack refers to deliberate actions to alter, disrupt, deceive, degrade, or destroy computer systems or networks or the information and/or programs resident in or transiting these systems or networks" (p. 1). There are different kinds of cyberattacks that can target computer systems and networks (Owens et al., 2009).

According to Defense Science Board Task Force Report (DOD, 2012), cyberattacks can vary from "denial of service to taking over command and control (C2) of the actual platforms" (p. 75). The Defense Science Board Task Force report also highlighted an important point that

> at best, current UxV requirements deal with traditional information assurance aspects and not defense against offensive cyberattacks. This threat is compounded by the affordability pressures to use commercial off-the-shelf (COTS) and open source products in ground stations, and the increasing desire to network platforms and ground station locations. The dependence on commercial information technology hardware (processors, etc.) also exposes the UxV to the cyber vulnerabilities of the global supply chain. (DOD, 2012, p. 75)

Russon (2015) shared valuable information about cyberattacks in her article, "Wondering How to Hack a Military Drone? It's All on Google." In her article, she highlighted the risk of "GPS spoofing attacks" (para. 2). According to Russon (2015), "In 2011, a CIA stealth drone—or unmanned aerial vehicle (UAV)—was captured by Iranians, who hijacked its GPS coordinates and safely brought it down so that they could learn to reverse-engineer the technology for themselves" (para. 2). She also pointed out that this event took place approximately one month later than a paper called "*On the Requirements for Successful GPS Spoofing Attacks* was published by Nils Ole Tippenhauer and other academics from ETH Zurich and the University of California" (Russon, 2015, para. 3). The paper was explaining how to hack a military drone in detail, and soon afterward hackers used that information for hacking a drone (Russon, 2015). She also shared warning remarks from Kathleen Fisher who was the previous program manager of DARPA: "Cyberattacks on your PC—they can steal information and they can steal money, but they don't cause physical damage,

whereas cyberattacks in a UAV or a car can cause physical damage and we really don't want to open that can of worms" (para. 12).

Jesion (2002) specifically addressed unmanned military logistic applications. In his research, he highlighted that complex unmanned logistic applications "might be vulnerable to disruption, spoofing, and interception" (Jesion, 2002, p. 15). If that happens, automated systems might provide unreliable or erroneous information regarding "demands for resupply, medical services, transportation, etc." (Jesion, 2002, p. 15).

2. Safety Issues / Limitations

Although they are unmanned, unmanned systems are also open to vulnerabilities regarding safety issues like accidents and malfunctions that might cause casualties. Singer (2009) told the story of the first person in history to be killed by a robot in his book, *Wired for War*:

> January 25, 1979, was to be a special day for Robert Williams, a worker at Ford Motor Company's Flat Rock casting plant in Michigan. The twenty-five-year-old man's son was celebrating his second birthday. Unfortunately, it was also the same day that the robot operating an automated parts retrieval system near William's workstation went on the fritz. In reaching out for a part, the robot's arm swung up unexpectedly and smashed into the man's head. (p. 195)

Statistics also show the seriousness of safety issue. According to one survey, "American factories where robots are present found that 4% have had major robotic accidents" (Singer, 2009, p. 195). Singer (2009) also mentioned that in other industrialized countries, such as Japan and Britain, the same kinds of accidents have happened. He also added that as the unmanned technology advances, it becomes more complex and more vulnerable to accidents because it is quite possible for programmers to make a tiny mistake among thousands of lines of computer code. The history of unmanned systems is full of accidents and malfunctions, particularly a 1960 incident, which was among the most dangerous ones (Singer, 2009). According to Singer (2009),

The Ballistic Missile Early Warning System was a detection system based in Greenland that was to warn if the Soviets launched their nuclear missiles. On October 5, 1960, the system "detected" a launch "with a certainty of 99.9%." North Atlantic Treaty Organization (NATO) went on alert and prepared its retaliation. But with just minutes to spare, the military figured out that the Soviets had not attacked; instead of flames from intercontinental ballistic missiles flying at the United States, the computer had detected the rising moon. It is fortunate for all humankind that this incident happened in October 1960, not two years later, which would have placed the computer's mistake right in the middle of the Cuban Missile Crisis, when fingers were more of a hair trigger. (p. 197)

When the incidents in Singer (2009)'s book considered, it is obvious that accident and malfunction statistics might increase, depending on the level of autonomy in unmanned systems. In addition, if the authorities cannot take necessary precautions, unmanned systems will likely cause more casualties in the future. As discussed before in this section, nations are inclined to invest in advanced technologies like unmanned systems because of their strategic benefits. Particularly for UAVs, there is also a race between high-profit private companies. Militaries all around the world also use UAVs. Although airspaces can be regulated by relevant institutions by implementing specific corridors for different aerial vehicles, proliferating the number of UAVs increases the risk of possible accidents in the sky. Singer (2009) gave Baghdad as an example regarding the risks of unmanned systems because Baghdad has the most crowded airspace. "In one instance, an unmanned Raven drone plowed into a manned helicopter" (Singer, 2009, p. 202). In the absence of necessary regulations, the high number of UAVs might cause unwanted accidents with casualties.

In his study, Peterson and Staley (2011) highlighted the susceptibility of Cargo UAVs to potential air-defense attacks: "Specifically, it may prove to be susceptible to small arms fire and rocket propelled grenade (RPG) attacks. This may result in high attrition rates, which could prove to be a major factor in the overall program cost" (p. 59). As a result, air-defense attacks might affect the required number of Cargo UAVs for aerial delivery missions (Peterson & Staley, 2011).

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V. CONCLUSION AND RECOMMENDATIONS

Singer (2009) shared important information about Revolutions in Military Affairs (RMA) in Chapter 10 of his book, *Wired for War*, "The Big Cebrowski and the Real RMA: Thinking about Revolutionary Technologies." To address RMAs, Singer (2009) pointed out that most people predict a linear approach, when it comes to the expectations about the possible changes regarding "business, technology, and war" (p. 181). "Every so often, however, a change comes along that wipes the table clean. It rewrites the rules, changes the players, and alters the organizations, strategies and tactics" (Singer, 2009, p. 181). He also said that "the parallel in business world is 'disruptive technologies' that fundamentally transform an industry, even to the point of ending it" (Singer, 2009, p. 181). When these fundamental changes occurred in military, Singer (2009) identified these improvements as RMAs.

RMAs are basically the "introduction of a new technology or organization, which in turn creates a whole new model of fighting and winning wars" (Singer, 2009, p. 181). According to Singer (2009), these RMAs would have "first, second and third order effects" (p. 181) on the society. He also mentioned that it is hard to understand what these effects might be when the technology is new. Singer (2009) provided new weapons as an example regarding the RMAs that were introduced. "A new weapon is introduced that makes obsolete all the previous best weapons, such as what armored, steam-powered warships did to wooden, wind-powered warships" (Singer, 2009, p. 181).

According to Vice Admiral Arthur Cebrowski, the 21st century revolution was *Network-Centric Warfare* (Singer, 2009). Singer (2009) explained this concept:

> Central to the network-centric concept was, as the name suggests, the power of the network. That is, a network linked together would be quicker, smarter, and more lethal than the sum of its individual parts and would quickly overwhelm whatever foe lay in its path. This "information advantage," argued Cebrowski, would be huge. The sharing of information across the system, as well as the ability to crack into the enemy's systems, would create "near-perfect" intelligence. The side that was networked would not only know exactly where its own soldiers were, so that they could be deployed to perfect efficiency, but

it would also know where the enemy was, even better than the enemy troops' own leaders (p. 184).

On the other hand, Singer (2009) asserted that the real revolution of the 21st century was not the Network-Centric Warfare. It was the robotic revolution because it would affect warfare more dramatically than well-maintained information technology (IT) networks in Network-Centric Warfare concept (Singer, 2009). Science and technology are in incremental nature.

In parallel with Singer (2009), we also considered that robotic (unmanned) technology as the 21st century's real military revolution. However, it is also important to take into account that robotic technologies have already been nurtured by earlier technological improvements including the IT networks. In addition, recent concepts and improvements related to unmanned systems such as swarming and the increasing level of autonomy necessitate strong and well-maintained IT networks. In this chapter, we provide information about our findings regarding the unmanned applications in military logistics.

A.   CONCLUSION

Within the scope of military logistics, we sought answer to our primary research question: What are the current and potential uses of unmanned systems for military logistics? To answer this question, we also provided three secondary research questions that would help us to answer our primary research question in a step by step approach.

In the literature review chapter of our thesis, we evaluated military logistics as a whole and found the main problematic areas in military logistics. We found that there were two main challenges of military logistics. These challenges were uncertainty and security. In addition, we also studied current and potential applications in civilian sector logistics.

Then, we answered our first secondary research question about unmanned applications in civilian sector logistics. According to our studies, the most advanced recent applications were industrial robotics at warehouses and distribution centers. Specifically, the case of Amazon Warehouses in this section showed us the

economic race between private companies and the importance of cost efficiencies regarding inventory for them. Another important finding was the technological advances in UAV delivery in the civilian sector. Profitable private U.S. companies such as Amazon, Google, and Walmart have already invested significantly in UAV delivery technology; however, the potential applications were waiting for FAA approval. We also found out that the commercial UAV delivery concept has not been limited to commercial goods; some commercial companies were delivering blood and medical supplies.

In the first section of our Analysis chapter, we studied the current and potential applications of unmanned systems in military logistics. According to our findings, most common unmanned applications already in use are convoy over-watch missions with UAVs. It is also important to point out here that we also considered a parallel opinion with Peters et al.'s (2011) RAND report considering logistic convoy over-watch missions as logistics tasks for UAVs. In our K-MAX Cargo Unmanned Aircraft System case, we found out that the UAV delivery concept for military purposes was limited to the U.S. Marine Corps' usage of K-MAX Cargo UAVs in OEF in Afghanistan. K-MAX's high payload capacity and the high risk of IED threats for ground convoys made this first operational attempt possible and afterwards it turned out successfully. For the UUVs and USVs, there were not current significant applications regarding military logistics. However, there have been UGV projects in the evaluation phase for logistic purposes as mentioned in our literature review. For the UUVs and USVs, various projects have been in the evaluation phase, but neither of them were related to logistics purposes. Logistic uses of UUVs and USVs have already been in conceptual phases. On the other hand, especially for UGVs, there have been current commercial applications that are in test period such as Google's driverless cars and Otto's driverless trucks. These applications might have a pushing effect on the military technologies regarding driverless logistic convoys.

In the second section of our Analysis chapter, we evaluated the impacts of unmanned systems to the acquisition costs of products compared to other delivery methods. According to our research, there have been substantial cost reductions

with specific Cargo UAVs (K-MAX). Peterson and Staley's (2011) and Denevan's (2014) studies on the cost evaluations of Cargo UAVs were significantly valuable for our research. In addition, our research showed that unmanned systems have proven their positive impact on the slow moving acquisition system. Thirtle et al.'s (1997) RAND report, *The Predator ACTD. A Case Study for Transition Planning to the Formal Acquisition Process*, and Jones's (2014) thesis report, *An Analysis of the Defense Acquisition Strategy of Unmanned Systems*, were important with their explanations regarding the impacts of unmanned systems to the acquisition processes.

In the third section of our Analysis chapter, we evaluated the positive impacts of unmanned systems to military logistics. In this section, we specifically addressed the positive impacts of these systems on the military logistics challenges (uncertainty and security) that were mentioned before in our literature review chapter. Then we addressed general positive impacts under the other positive impacts of unmanned systems section. Regarding the positive impacts, we found out that

- Unmanned systems have been decreasing personnel assigned to logistic facilities such as factories.

- They have been decreasing uncertainty and inventory levels and increasing visibility and flow of information in the military supply chain.

- They have been decreasing risks in logistic delivery tasks.

- Urgent deliveries including medical supplies, ammunition, and gasoline might be implemented even with small UAVs with limited payload capabilities.

- They have been providing significant time and cost efficiencies.

- They impacted acquisition processes in a positive way, making them more efficient.

In the fourth section of our Analysis chapter, we evaluated the negative impacts of unmanned systems to military logistics. We evaluated these effects under two headings: cyberattacks and safety issues/limitations. According to our research,

- Cyberattacks have been an important vulnerability for all computer-based physical applications including all unmanned systems.

- There have been reported accidents with casualties in both industrial unmanned applications and defensive applications with weapon systems.

- Rapidly increasing the number of unmanned systems (especially UAVs) might cause accidents.

- Cargo UAVs have been vulnerable to air-defense attacks.

B.   SUMMARY OF RECOMMENDATIONS

In this section of our Conclusion and Recommendations chapter, we address our recommendations regarding the use of unmanned systems in military logistics.

- Countries should continue investing in R&D activities for unmanned systems.

- Considering the high costs of inventory in both military and civilian logistics, R&D activities for unmanned systems should also be specified to military logistics applications, as well as other military applications.

- Military officials should continue following civilian logistics applications and improvements related to unmanned systems.

- Unmanned systems in civilian applications should be supported, and technology should be transferred between commercial and military entities.

- Universities and commercial entrepreneurs should be continuously supported by governmental entities.

- Government officials should regularly seek logistics leaders' opinions and feedback about current and proposed unmanned applications.

- Safety standards for unmanned systems should be reevaluated until the accident statistics significantly drop.

- End-user training programs should be considered and implemented continuously for system operators.

- Unmanned systems technology should be evaluated with emerging technological applications such as 3D printers and network systems.

- With the emerging concepts like swarming and human-machine interface studies, unmanned systems technology on military logistics should be reevaluated.

- Necessary precautions against cyberattacks should be taken vigorously. Investments for more secure programming methods and autonomous cyber defensive technologies should be considered against cyberattacks.

- Unmanned systems should be designed with a single power-off system linked to the operator with a diverse network system in case the control of the unmanned system was taken over with a cyberattack.

- An electronic technology portal should be founded for safety standards. Incidents and experiences regarding safety should be used and shared between NATO member and/or partner countries.

- Humanitarian Assistance and Disaster Response (HADR) efforts of different countries should be combined in the scope of a common plan and exercises should be implemented.

- Unmanned systems should be used in ammunition factories and storage facilities to decrease accidents.

- With the advancing technology, existing military tactics and techniques should be reevaluated, such as delivery of an urgent supply (medical, ammunition, etc.) to a soldier under fire with small UAVs or equipping logistic convoys with small reconnaissance UAVs.

C.   AREAS FOR FURTHER RESEARCH

As we mentioned before in our Introduction chapter that our research was limited to unmanned industrial applications, UASs, UGSs, USVs, and UUVs for military logistic applications. However, there have been important advances in the unmanned cyber systems and unmanned space systems.

In our research, we did not provide current logistics applications for both USVs and UUVs. However, quickly advancing unmanned technology might create USV and UUV applications and increase for military logistics purposes. Then new research should be conducted to evaluate these technologies.

In addition, because of the timeliness of the topic, both commercial and military applications for unmanned systems might be updated in the light of emerging technological advances.

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