Closing the Gap Between Information and Payment Flows in a Digital Transformation

by

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SUBMITTED TO THE PROGRAM IN SUPPLY CHAIN MANAGEMENT
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ENGINEERING IN SUPPLY CHAIN MANAGEMENT
AT THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

May 2020

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ABSTRACT

Companies spend significant resources on digital transformation projects that do not always meet expectations. This thesis contends that these projects fail or fall short because organizations do not consider the three fundamental flows of a supply chain; materiel, information, and payment. To address the issue, this thesis develops a lens to identify mismatches between materiel, information, and payment flows, and applies this lens to putaways and the post goods receipt process in the US Army's supply chain. The thesis identifies an increased risk of loss for putaways confirmed before physical movement could take place, and confirmations that occurred after seven days. The thesis recommends measuring putaway time as a key performance indicator and establishing a two duty-day key performance standard, which would hypothetically lead to a reduced rate of loss. With respect to the post goods receipt process, it was found that a failure to confirm goods receipt led to the creation of millions of dollars in phantom inventory and late payments. This thesis recommends allowing customers to pay for materiel even if intermediate digitized information flows were not confirmed. It also recommends monitoring materiel available to be received so that leaders can spot and address errors. By considering the three fundamental flows of a supply chain, digital transformation practitioners can achieve better results.

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ACKNOWLEDGMENTS

The author would like to thank Dr. Chris Caplice, who challenged me to think beyond my previous Army assignments and to communicate my ideas more clearly.

Thank you to MG Rodney Fogg, SES John Hall and the Combined Arms Support Command for sponsoring my research. In addition, I would like to thank CPT Robert (Kenny) Miller, CW4 Sulaiman Bah and Mr. Romulo (Jay) Santos for their help.

Thank you to Mr. Patrick Scott, SCM Class of 2017, for telling me about this amazing program and encouraging my application.

Thank you to BG John Kline, LTC Ryan Forshee, LTC Patrick Lyons, CW5(ret) Wade McIntyre and CW3 Sonia Sanders for supporting my first study of the Army's digital transformation when I was a member of the 3rd Combat Aviation Brigade, 3rd Infantry Division.

Thank you to the Soldiers, non-commissioned officers and officers of the 62nd Quartermaster Company whom I had the pleasure of leading from July 2017 to October 2018. A special thank you to CW3(ret) Danny Cadena, CW2 Shemir Fountain, CW2 Dana Brown, SFC Sandra Golden, SSG Kiera Kaplan, SSG Michael Vandenberg, and SGT Deandra Beggs who aided with my research.

Thank you to LTC Jason Book, LTC Jesus (Jesse) Pena, CW5 Patrick Opfor, CW5 Cheryl Bartly, CW4 Chad Ellison, CW3 George Powell, CW3 Cary Gordon, Dr. Ken Girardini, Mr. James Blalock, Mr. Frank Portz, Mr. Robert Tackett, and Mr. Mike Wilson who provided me with expert insights.

The author acknowledges special help and assistance from Mr. Danny Keaster and CW5 Melanie Harris, who answered countless questions about the Army's digital transformation and warehouse operations.

Special thanks to Mrs. Pamela Siska, Mrs. Ann Pentz, Dr. Nima Kazemi and COL Erin Miller, who listened as my thesis developed and provided invaluable mentorship.

The author would like to thank his daughter, Adaline, whose smile and joyful outlook brightened every day.

The author would like to thank his wife, Megan, who has offered unwavering support and made countless sacrifices to enable my journey at MIT.

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1 INTRODUCTION

This thesis examines the US Army's digital transformation from 14 legacy tactical or field logistical systems into one consolidated system known as the Global Combat System Support – Army (GCSS-Army)(Coker & Hallinan, 2006). The study reveals that the digital transformation did not meet expectations due to a failure to consider the three fundamental flows of a supply chain: materiel, information, and payment. While no one would argue that digital supply chains should be replaced with pen and paper methods of old, there is a need to improve their accuracy. The results of this thesis are relevant to all industries undergoing a digital transformation of their supply chain as they adapt to new technologies or make changes to their business model. It provides a framework that can be utilized by any company to ensure a smoother successful digital transformation journey.

Indeed, a review of literature on digital transformation and interviews with supply chain professionals indicates that the Army is not the first to experience digital transformation growing pains. For example, an administrator at a Big Tex Trailer distributor stated that their new cloud-based inventory management system experiences the same problems as the Army (R. Carpenter, personal communication, March 19, 2020). However, most literature on digital transformation focuses on businesses selling to external customers, whereas this thesis focuses on intra-agency sales. Intra-agency sales are relevant to most large companies that engage in sales across national borders, departments or divisions, or where tracking to ensure tax compliance is essential. The intersection of intra-company sales and digital transformation has not been well researched; this thesis will add to the academic literature.

1.1 Army digital transformation background

Senior Army leaders committed to transforming 14 separate sustainment information systems into a single SAP based Enterprise Resource Planning solution in 2002 (Coker & Hallinan, 2006). Early press releases stated that the GCSS-Army would provide accurate information which would enable a more responsive and efficient supply chain (Coker & Hallinan, 2006). An emphasis was placed on accurate information because the legacy systems were not financially compliant due to data discrepancies between functional areas such as maintenance, warehousing, and durable property inventory (GCSS-Army Program Manager, 2019).

In 2010, Congress explicitly stated that the Department of Defense would "achieve an unqualified audit opinion" by September 30, 2017(National Defense Authorization Act for Fiscal Year 2010, 2009, sec. 1003). In addition, the law established a secondary goal of improving the accuracy and reliability of management information for military and general equipment, inventory, supplies, and validating its accuracy through existence and completeness audits(National Defense Authorization Act for Fiscal Year 2010, 2009).

1.2 Army SSA background

The US Army distributes repair parts, construction materiel, and general supplies through its network of Supply Support Activities (SSAs)[1]. This network consists of installation/depot SSAs, analogous to distribution centers, and tactical SSAs, analogous to warehouses and customer package pickup points (Figure 1). While the bulk of materiel flows forward from

[1] The word 'activity' in Supply Support Activity (SSA) denotes "an organizational unit for performing a specific function" which is a less common usage of the word activity (Merriam-Webster, 2019). In everyday use, the abbreviation SSA also refers to the facility where distribution operations take place.

installation/depot SSAs to the tactical level, a reverse logistics pipeline exists for major assemblies, such as engines or helicopter blades that can be economically repaired by specialized mechanics.

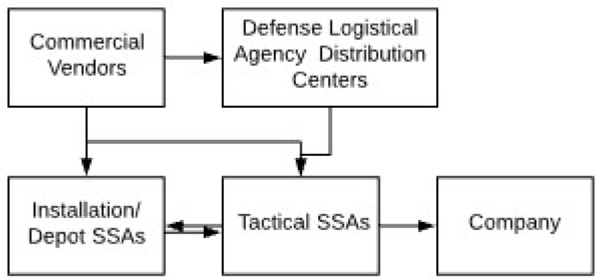

Figure 1. Army supply network

Tactical SSAs are dedicated to a brigade combat team, the Army's basic deployable unit. Their customers consist of 20-30 smaller units, called companies, organized under the brigade combat team's headquarters. Tactical SSAs must be prepared to rapidly relocate and operate in austere environments and during large-scale ground combat operations (ATP 4-42.2. Supply Support Activity Operations, 2014). Their effectiveness is vital to sustaining the Army's readiness and ability to project combat power.

1.3 Motivation

The motivation for this thesis stems from the author's time in command of the 62nd Quartermaster Company from July 2017 to October 2018. As the 62nd Quartermaster Company commander, the author was responsible for the training and readiness of 133 Soldiers and the equipment that operated the U.S Army's largest tactical SSA.

During the tenure of this command, the benefit of an assigned subject matter expert in SSA operations, accountable for the 62nd SSA's inventory and responsible for training the Soldiers in SSA operations, was realized. This expert emphasized that the digital steps in GCSS-

Army must match the flow of materiel. His insistence on synchronizing the flows of information and materiel was different from the dominant Army approach to supply chain, in which the only priority was that a customer received the ordered materiel.

Another challenge the author experienced during command originated from the Army's digital transformation and the mismatch between the new software and outdated regulations that referenced legacy information systems. The outdated regulations were a source of confusion because the business rules of the ERP system did not match documentation requirements from headquarters. This thesis will propose a framework which will enable policy makers to identify applicable rules and regulations that must be updated simultaneously with any software transformation.

1.4 Thesis organization

The remainder of the thesis is organized as follows. Chapter 2 defines digital transformation, provides a framework for evaluating supply chain management and discusses academic and business literature on the three supply chain management flows. Chapter 3 details the methodology for this thesis. Chapter 4 provides the results, discussion and conclusion regarding the desynchronized flow of materiel and information flow for putaways. Chapter 5 provides the results, discussion and conclusion regarding the desynchronized flow of materiel and information flow for the post goods receipt step of the Army's requisition cycle. Chapter 6 recommends areas for future research and provides a conclusion.

2 LITERATURE REVIEW

Most organizations are experiencing, or will experience, a digital transformation of their supply chain as they adopt new technologies or make changes to their business model. However, digital transformations such as the Army's do not always meet expectations. The main reason is that organizations do not ensure the synchronized flow of materiel, information, and payment in their supply chain which leads to inaccurate inventories and failed audits.

This chapter first defines digital transformations, then provides a framework for evaluating supply chain management (SCM) and the antecedent concept of supply chain orientation (SCO). The final section examines existing literature on the three supply chain management flows.

2.1 Digital transformation

Digital transformation is considered a mega-trend that is also referred to in literature as big-data, machine learning, Industry 4.0, digital business model or eGovernment(Collin, 2015; Mergel et al., 2019). Ismail, Khater and Zaki (2017) identified six distinct perspectives covered in literature on digital transformation: (1) era, (2) social/ economic, (3) industry/ ecosystem, (4) network, (5), company/ institutional, and (6) individual. This thesis will focus on the network and institutional company domains given that the Army's supply chain receives materiel from outside vendors and issues it to internal customers.

The definition of digital transformation used in this thesis is "to leverage data and technology to accelerate and automate business operations, using insights from analytics to improve forecasts and enable rapid response to those forecasts where possible" (Saenz et al., 2019, p. 1). Digital transformation is best thought of as an aspirational notion because future requirements for an organization's information technology infrastructure cannot be predicted; thus, it will need continuous revisions (Mergel et al., 2019).

One common element in the digital transformation literature is the concept that analog information can be converted to digital information through a process known as digitization (Brennen & Kreiss, 2014). However, some experts have extended the basic definition of digitization to also cover newly required knowledge that that can be gained from converting analog signals to digital (Schallmo & Williams, 2018). An example of digitization is when FedEx requires a package recipient to sign for a package on an electronic pad instead of maintaining physical copies of signed receipts.

Another common element is the concept of digitalization; the idea that digital technologies and data can be used to generate revenue, improve businesses, and transform business process (Schallmo & Williams, 2018). While often thought of as replacing a physical medium, such as DVDs with a streaming service, digitalization can also describe automating processes. For example, electronic tolling technology such as EZ-Pass has replaced the necessity to stop and pay highway tolls in 17 states (E-ZPass, 2020).

This thesis will use the framework of digitization and digitalization to describe organizational supply chain management digital transformation efforts. Section 2.2 will discuss what key factors have been identified for digital transformation success in literature.

2.2 Keys to digital transformation success

The call for papers exploring digital transformation challenges by top quality journals such as *Information Systems Frontiers, Journal of Business Research, International Journal of*

Entrepreneurial Behavior & Research, Business Horizons, and *Academy of Management Discoveries* illustrates the need for additional research (Mahmood et al., 2019).

Much of the research specific to digital transformation comes from consulting firms working in collaboration with business schools. The resulting literature tends to focus on the factors that contribute to digital transformation success at the strategic level of companies.

2.2.1 Keys to digital transformation success – business model

Kane et al. (2019) surveyed 16,000 people across 157 countries and more than 28 industries to write a book on digital transformation. They found that companies need to build a culture that is adaptable to change before implementing new technology and business processes; focusing on the selection and implementation of digital technologies is not enough.

A McKinsey report found similar indicators for success; (1) laying out clear priorities, (2) investing in talent, (3) committing time and money, (4) embracing agility, (5) empowering people (Bughin et al., 2019).

70% of digital transformations fail and the consensus in digital transformation literature is that it is not due to technological problems (Saldanha & McDonald, 2019). Rather, the root cause of failure lies in the execution of digital transformation.

2.2.2 Keys to digital transformation success – supply chain

Kochar (2019) studied supply chain digital transformations and identified four steps for success: (1) develop a digital target, (2) evaluate current capabilities, (3) assess technology options and create a short list, and (4) prioritize potential projects and create a digital roadmap. His analysis defines a digital transformation success in terms of whether the project was completed rather than if the project achieved its stated results.

Infor, a global software company that provides ERP solutions, contends that a digital supply chain is successful when it integrates supplier and company data collection systems in order to provide end-to-end visibility (Infor, 2017). They propose a digital supply chain maturity model that establishes data driven predictions as the goal of a digital transformation. However, their model does not address the steps companies must take to ensure they collect accurate data.

Durbha (2019) provides another perspective on supply chain digital transformation pitfalls and recommends that companies remain focused on their core competencies and attempt the journey in small bites rather than sweeping ERP upgrades. In addition, he recommends that companies rethink processes rather than digitizing existing processing. Digitizing faulty processes risks creating errors at a faster rate.

Within the digital transformation literature studies at the company level focus on strategic issues. There are gaps when it comes to describing actions, behaviors and factors that lead to success at the operational level. From the human and computer interaction perspective, the literature does not address factors required to collect accurate information. Accurate information is vital for effective supply chain management operations and decision making. Section 2.3 will discuss digital transformation literature as it relates to supply chain management flows and identify gaps in the literature.

2.3 Supply chain management and supply chain orientation

The term “supply chain management” has only been around only since 1982, so there is not complete consensus as to its meaning (Ellram & Cooper, 2014). Most definitions view supply chain management as a management philosophy, implementation of a management philosophy, or a set of management processes (Mentzer et al., 2001). Mentzer et al. (2001) explored the definitions in detail and proposed a comprehensive definition:

> "Supply chain management is defined as the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole" (2001, p. 18).

In addition to the definition, the authors proposed a conceptual model (illustrated in Figure 2) which illustrates six supply chain flows: products, services, information, financial resources, demand, and forecasts.

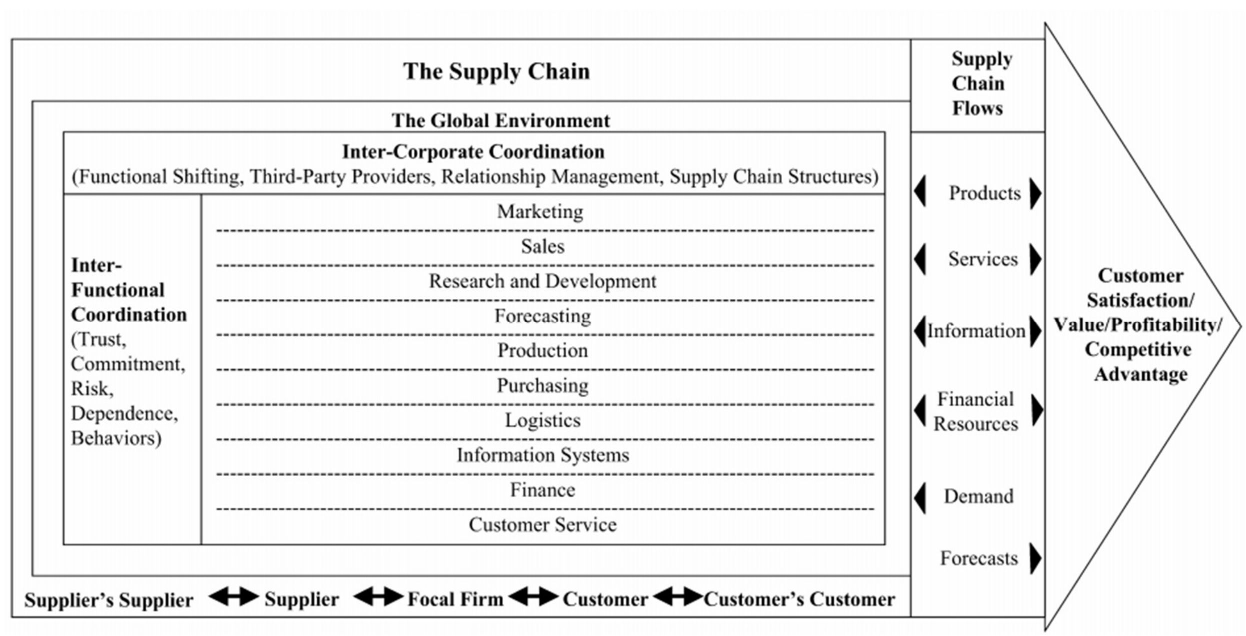

Figure 2. Supply chain management model (Mentzer et al., 2001, p. 19)

A key concept in many SCM definitions is the concept of 'flow' or interconnected movement between interorganizational partners (Esper et al., 2010). Premkumar (2000) proposed a simpler model that incorporates just three flows: goods and services, payments, and information between trading partners as displayed in Figure 3. The three-flow model with the word ‘materiel’ replacing ‘goods’ will be used in this thesis to evaluate digital transformations because it is a straightforward model that can easily be understood. Services, which are direct interactions between a supplier and customer, will be excluded from this thesis because none of the information systems digitally transformed by the Army recorded services.

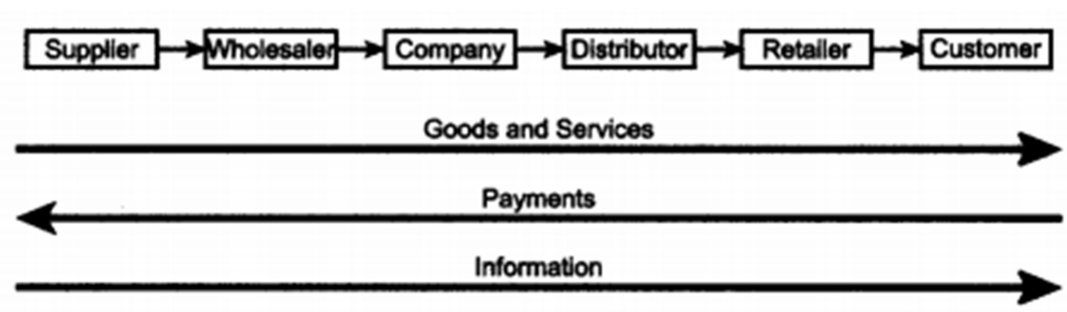

Figure 3. Supply chain management flow (Premkumar, 2000)

The antecedent concept to SCM known as Supply Chain Orientation (SCO) is relevant to this thesis because digital transformations involve the implementation of software that may or may not support legacy assumptions (Esper et al., 2010). Trent (2004) proposed an SCO framework that consists of four pillars: capable human resources, proper organizational design, real-time and shared information technology, and right measures and measurement systems. Although not cited as SCO, a 2019 study on digital transformations conducted by Deloitte Consulting LLP in collaboration with MIT Sloan Management Review found that companies must align their culture, people, structure and tasks in order to achieve powerful results (Hyatt, 2019).

Mergel et al. (2019) found that changes in mindset, competencies, and culture are necessary for digital transformation to occur among government agencies. The findings were echoed by Seth, Goyal and Kiran (2015) which identified top management support as the most important of 18 factors that lead to successful implementation of supply chain information systems.

The concept of three flows in a supply chain and the antecedent concept of SCO provide a useful lens through which to analyze digital transformations. Extending this SCO foundation to digital transformations is a novel approach that will extend the literature.

2.4 Digital transformation and SCM flows

Literature on the Cash Conversion Cycle (CCC) (Figure 4), a measure of working capital management efficiency, highlights the important relationship between inventory (materiel), sales outstanding (information regarding future sales collection), and payments.

Metric	Description	Calculation
Cash Conversion Cycle (CCC)	A metric describing how efficiently the firm can generate cash.	*CCC = DSO + DIO – DPO*
Days Sales Outstanding (DSO)	The number of days needed to collect on sales.	*DSO = Accounts Receivable/Daily Sales*
Days Inventory Outstanding (DIO)	How many days it takes to sell the available inventory.	*DIO = Inventory/Daily COGS*
Days Payable Outstanding (DPO)	The company's payment of its own bills.	*DPO = Accounts Payable/Daily COGS*

Figure 4. Cash conversion cycle (Rogers et al., 2016)

Companies that manage their working capital well minimize the amount of time to produce materiel, sell inventory, and collect payment which means more capital is available for the business to reinvest (Kelly & Stagliano, 2018). Therefore, suppliers want to ensure that buyers acknowledge receipt of finished goods and pay their invoice as soon as possible. Cagle (2019) conducted a study of firms that underwent a digital transformation in 2015 and found that the transformation had reduced their "CCC by 25% and 26%" within the first two years of implementation mainly due to higher productivity and not faster cash collection policies or inventory cycles. A limitation of Cagle's study was that the author did not identify factors that made the digital transformation successful.

The supplier to buyer relationship can also occur intra-firm either between divisions or across borders. This is a major concern for multinational companies, which must keep track of inventory flows and transfer-prices in order to pass tax audits (Fernandes et al., 2015). For a digital transformation to be successful, buyers must ensure that they have a mechanism to validate invoices or they will risk alienating suppliers or experience a non-compliant tax audit.

Literature on the topic of digital transformation tends to focus on technological aspects or narrow industries such as education, healthcare, retail, manufacturing or government but not flows (Parviainen, 2017). The remainder of this chapter will review literature that brings together two of the three SCM flows.

2.4.1 Materiel and information flows

Liu and Chua (2016) presented a theoretical framework for increased information sharing in the construction industry with the goal of reducing waste. The research team identified real-time information transparency and accuracy as key elements to eliminating waste. Koperberg also identified the importance of accurate inventory information in his study of the automotive supply chain (Koperberg, 2007).

Cannela et al. (2015) studied inventory record inaccuracy due to shrinkage error, (a permanent inventory loss) for a multi-echelon supply chain. They found that the benefits of sharing information between echelons were compromised to such a degree that upstream stages of the supply chain may not realize any of the theoretical benefit from information sharing. The authors recommended zero inventory inaccuracy policies, i.e. frequent physical counts, for downstream supply chain members which would increase holding costs for inventory on purchasers.

These studies clearly demonstrated that information transparency and inventory accuracy are essential to effective supply chains. None of them provided solutions to minimize inventory inaccuracies from occurring which is one of the goals of supply chain digital transformation.

2.4.2 Information and payment flows

Smith and Enos (2016) utilized a Lean Six Sigma methodology to study an Army aviation brigade that lost $1,201,620 in credit after multiple legacy information systems were digitally transformed to a single Enterprise Resource Planning solution. The team discovered that the root cause of the loss problem was a lack of knowledge among Soldiers regarding the new business rules implemented after an automated credit matching system was replaced with manual requirements (Smith & Enos, 2016). This paper demonstrated that digital transformations can fail if changes to the information and payment flows are not communicated to responsible personnel.

2.5 Addressing the gap in the literature

Digital transformation is the leveraging of data and technology to automate business processes. Implementing these business processes is notoriously difficult, and the consensus found in literature is that most implementations do not fail due to technological problems. Rather, they fail because of the organizational culture, lack of priorities, and failure to rethink processes.

This thesis examines the digital transformation of supply chain encompassing business processes related to the flow of materiel, information and payment. Some literature on supply chain digital transformation emphasizes a need to validate invoices, while other research highlights the importance of accurate inventory. Few writers have focused on the interdependence of the movement of material, transmission of related supply movement data, and the resulting impact upon the payment cycle.

This thesis will add an operational perspective to the existing literature on digital transformation success, which is heavily skewed towards the strategic perspective. Although early supply chain management literature defined information, materiel, and payment flows as critical, there is scarce literature on these flows at the transactional level. It is evident that there is a connection between the digital systems used to manage supply chains and the three supply chain flows, yet this connection remains unexplored. Applying a supply chain management lens to digital transformations within an existing operational environment will extend the existing research boundary.

3 METHODOLOGY

This chapter presents the framework used to study the Army's digital transformation through the lens of information, materiel, and payment flows and the supporting information gathering activities.

3.1 A matrix to identify desynchronized flows

The Army's requisition process was examined against a two-by-two matrix with materiel flow versus information and payment (Figure 5). Information and payments were combined in the matrix because payments are usually triggered by an information signal. The information and payment field was classified as sent or unsent, while the material was classified as having physically moved or not.

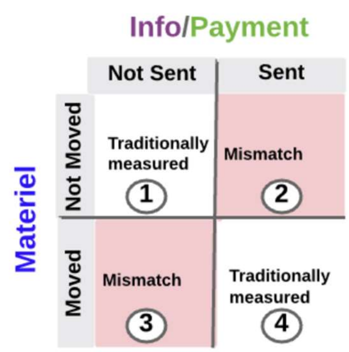

Figure 5. Highlighted areas showing mismatched flows.

Figure 5 illustrates the four quadrants of possible outcomes. Traditional measurement systems assume the materiel and information flow are in sync that is both moving or not moving (figure 5 quadrants 1 and 4). Mismatches occur when the information recorded in the data system does not match the physical inventory (Figure 5 quadrants 2 and 3). An example in a civilian context is when the US Postal Service sends a home delivery package notification when the package reaches the local post office rather than when the package reaches the recipient’s actual home (Figure 5 quadrant 2). Another mismatch exists when materiel has moved but a notification has not been sent. This is analogous to a postal worker failing to confirm delivery despite dropping off a package at a destination (Figure 5 quadrant 3).

3.2 Overall approach

The Department of the Army’s implementation order for GCSS-Army stated that it would “provide commanders… with near real-time logistics and financial data” and “enable auditability of financial operations as mandated by Congress (DA G-4, 2015).“ To test whether the fielding met expectations, the three-flow lens was applied to SSA inventory accuracy, which forms the basis of Chapter 4, and the goods receipt step of the Army’s requisition cycle, covered in Chapter 5.

4 APPLYING THE THREE-FLOW LENS TO PUTAWAYS

In this chapter, the three-flow lens is applied to putaways, i.e., the process of moving materiel from the receiving dock to a warehouse storage area. Real time and accurate inventory reports are critical for SSAs because a customer order is filled with inventory on hand so that the customer does not have to wait for a product to be shipped from a national level vendor. SSA stock levels are designed to support customer equipment in austere environments; inaccurate inventories will degrade the ability of customer units to repair their fleets because short picks will result in orders taking multiple days, instead of hours, to be filled. In order to measure the time it takes to move materiel into the storage area, a new to GCSS-Army key performance indicator, putaway time, was calculated. Results suggest that if putaways are confirmed extremely fast (less than 30 minutes) or slow (more than 7 days) the inventory is likely to have been lost.

4.1 Understanding putaways

SSA training materiel states that putaways are to be confirmed (information sent) after they have been physically moved to the assigned storage bin (CASCOM, 2019). SSA clerks can scan putaway transfer order barcodes at the point of the putaway using a handheld scanner and wireless tablet combination, or they can manually enter the putaway transfer order number at their workstation.

The putaway process begins once materiel is processed as received at the SSA dock and GCSS-Army determines that the materiel must be assigned to a storage bin. A properly completed putaway is moved to a storage bin and confirmed (information sent) by an SSA clerk (Figure 6 quadrant 4). Putaway confirmation has the effect of making the materiel available to fulfill an order.

A mismatch arises when either a putaway is confirmed but not moved to the storage bin (Figure 6 quadrant 2) resulting in inaccurate real time inventory data in GCSS-Army. If the materiel is moved to a storage bin but the putaway information is not sent (Figure 6 quadrant 3) then there will be a delay in the fulfillment of customer orders because GCSS-Army business rules stipulate that stock must be confirmed to a storage bin before it can be picked. The Figure 6 quadrant 3 (material moved, information not sent) mismatch also negatively impacts an SSA performance metric, which tracks the percentage of its authorized stock list on-hand.

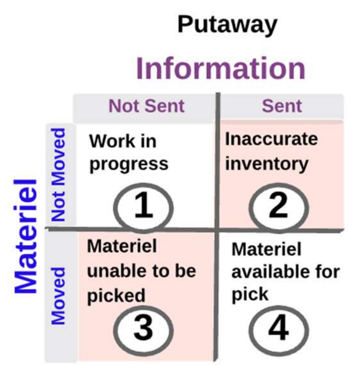

Figure 6. Three-flow lens applied to putaway

4.2 Measuring putaways and linking them to inventory results

Information flows for goods movement internal to the SSA are captured via digitized transfer orders, which direct materiel from a source storage bin to a destination storage bin. In addition to the source and destination bins, transfer orders specify the quantity moved, reason for movement, materiel condition code, creation time, and confirmation time. The creation and confirmation times should match the materiel movement; however, SSA clerks may confirm transfer orders asynchronously with materiel movement.

Putaways can be identified because their source storage bin corresponds to the inventory management material document (unique document number) for materiel that was delivered to the SSA and received in GCSS-Army. Figure 7 depicts the flow of materiel and the information flows at this step; they are represented by a solid line because they are assumed to occur synchronously. The destination storage bin is printed on a putaway ticket which directs the clerk where to putaway the materiel. An SSA clerk triggers an information flow to GCSS-Army whenever they confirm a putaway. Currently, it is not possible to verify whether the materiel was actually placed in the assigned bin, so this step is represented by a dashed line in Figure 7.

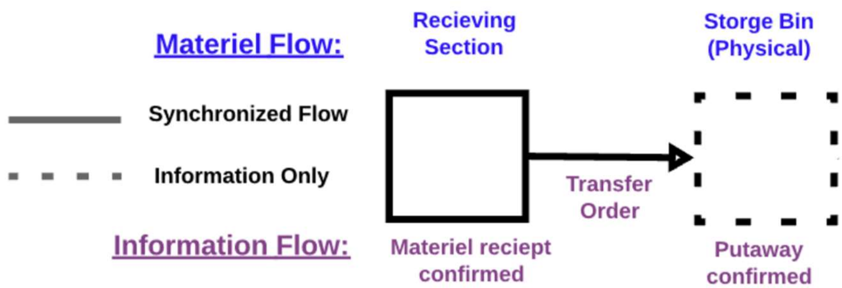

Figure 7. Typical putaway flow

The putaway time for a typical putaway is the putaway confirmation time minus the time materiel was received at the SSA.

If GCSS-Army does not have a putaway strategy assigned to a given materiel or there are no available bins, then a transfer order is generated to a 'virtual bin' (Figure 8). In those instances, GCSS-Army generates a transfer order from the receiving section to a 'virtual bin' (new materiel or overflow). Once an SSA clerk confirms that they have moved the material to a physical bin, the system will close the transfer order to the 'virtual bin' and create and simultaneously confirm a transfer to the physical bin. The transactions must be linked in order to determine the putaway time.

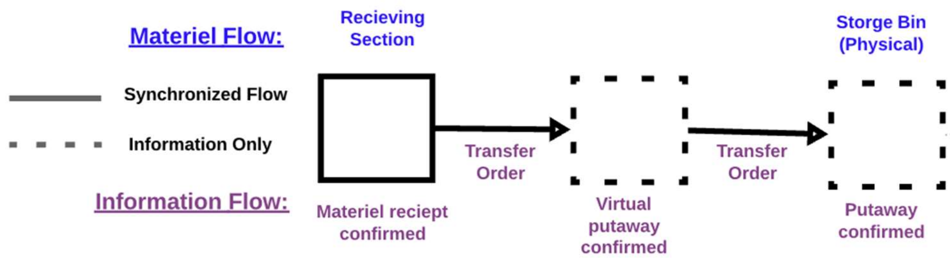

Figure 8. New or overflow materiel flow

SSA personnel can rearrange their inventory and assign it to a new storage bin using bin-to-bin transfers. The author was unable to link inventory that was transferred bin-to-bin to the original putaway time, so that data was excluded from the analysis.

After determining the final storage bin of a transfer order or series of transfer orders, the next step identified the nearest inventory date for each transfer order. The author analyzed 72,000 inventory records for the 1st Air Cavalry Brigade's SSA from its digital transformation to GCSS-Army on 19 August 2014 until 26 February 2020. The SSA was selected for further study because the author was aware that a significant number of losses had been identified during a change of accountable officer transition inventory conducted in 2018. Inventory results from the first year operating in GCSS-Army were excluded since the Army transferred inventory counts from the legacy information system and there was no corresponding putaway data available.

13,029 putaway transfer orders and associated inventory records were identified. The overall loss rate for the sample was 14.5% (1,891/13,029). Reasons that inventory records were not matched to putaways include the exclusion of first year inventory records, the inability to trace bin-to-bin transfers, and the fact that losses for materiel issued to customers was out of the project scope.

4.3 Hypothesis

SSAs are mandated by Army regulations to inventory all materiel in their storage section once a year and to conduct quarterly cycle counts of sensitive items, which are defined as materiel that could do damage if procured by an enemy, such as weapon parts(Supply Policy Below the National Level (AR 710-2), 2008). Unscheduled inventories also occur whenever a short pick must be reconciled, for example, stock that GCSS-Army is showing as on hand is not present when a clerk attempts to pick the materiel.

Discrepancies between information flows and physical inventory reality are reconciled during storage bin inventories. At that time, the impact of desynchronized information flows can be tested. Inventory is lost if the on-hand quantity counted during in an inventory is below or less than the count reported in GCSS-Army. The proportion of loss is defined as the number of inventory counts with a loss divided by the total number of inventory counts. The null hypothesis is that the proportion of loss over a given putaway cycle time is the same as the average proportion of loss for all cycle times. The alternative hypothesis states that the proportion of loss for a given time span is not the same as the average proportion of loss for all time span. The author conducted a 1-proportion test which tells whether the proportion is equal to the target value for each time span.

$$H_O: Proportion(lost\ inventory \mid pataway\ cycle\ time\ span) =$$
$$average(lost\ inventory \mid putaway\ cycle\ time\ spans)$$
$$H_a: Proportion(lost\ inventory \mid putaway\ cycle\ time\ span) \neq$$
$$average(lost\ inventory \mid all\ putaway\ cycle\ time\ spans)$$

Putaway cycle time spans were defined by looking at the distribution of putaways and grouping them into natural time spans. such as 0-30 minutes, which are defined as extremely fast confirmations; 30-60 minutes, defined as fast; 1-7 hours, defined as typical; 7-9 hours, which corresponds to the end of the duty day (Table 1). Since putaway time does not pause during shift breaks, putaways conducted within 10-24 hours most likely correspond to early the next calendar day. For example, if an inbound delivery for a materiel is processed on Monday at 2:00 PM and that materiel is put away the following day at 10:00 AM then it would fall in the 10-24 hour time span. 24-48 hours represents one or two calendar days. The next time span extends to seven days while the last groups all putaways confirmed after seven days.

Time Span	Definition
0 - 30 Min	Very fast
30 - 60 Min	Fast
1 - 7 Hr	Typical
7 - 9 Hr	End of duty day
10 - 24 Hr	Usually next calander day
24 - 48 Hr	1 or 2 calander days
48 Hr - 7 Days	Long duration
7+ Days	Very long duration

Table 1. Time span

If the null hypothesis is rejected, it will provide evidence that the risk of loss is not independent of time. Policy makers and system designers can then use this information to develop metrics which will influence behavior to minimize future losses. Test results are presented in the next section.

4.4 Hypothesis test results

The null hypothesis tested was that the proportion of loss over a given putaway time period is equal to 14.5%, which was the proportion lost for all time periods. The alternative hypothesis states that the proportion of loss for a given time period is not equal to 14.5%.

$$H_O: Proportion(lost\ inventory \mid putaway\ cycle\ time\ span) = 14.5\%$$

$$H_a: Proportion(lost\ inventory \mid putaway\ cycle\ time\ span) \neq 14.5\%$$

Table 2 presents the results of the hypothesis test or each time span. The Losses column is defined as the number inventory counts when a loss was recorded. Inventory counts is the total number of inventory counts. The 95% CI column presents the range of likely values for the population proportion. The p-value denotes the significance level; a significance level of .05 indicates a 5% risk of concluding that a difference exists when there is no actual difference. Time spans were color coded based on the risk level of loss for a given time span; red for high risk if the proportion lost was significantly higher, white for average risk if there was no difference and green for low risk if the proportion lost was significantly lower.

The results of the 1-proportion tests for each time span revealed two periods of higher than average inventory loss: less than 30 minutes and greater than 7 days (Table 2). The following time periods are not statistically different than the average: 30-60 minutes, 7-9 hours and 2-7 days. Time periods from 1-7 hours, 10-24 hours and 1-2 days had a loss rate that was significantly lower than the average loss.

Time Span	Losses	Inventory Counts	95% CI	P-Value
0 - 30 Min	224	1027	(0.193, 0.244)	0.000
30 - 60 Min	56	330	(0.131, 0.214)	0.241
1 - 7 Hr	502	4040	(0.114, 0.135)	0.000
7 - 9 Hr	38	245	(0.112, 0.207)	0.717
10 - 24 Hr	154	1598	(0.082, 0.112)	0.000
24 - 48 Hr	152	1287	(0.101, 0.137)	0.005
48 Hr - 7 Days	367	2562	(0.129, 0.157)	0.822
7+ Days	398	1940	(0.187, 0.224)	0.000

Key:
High Risk
Average Risk
Low Risk

Table 2. 1-proportion test results

A graphical presentation (Figure 9), presents the loss rate per time span against the average putaway loss rate of 14.5%. The bars are color coded in the same manner as *Table* 2.

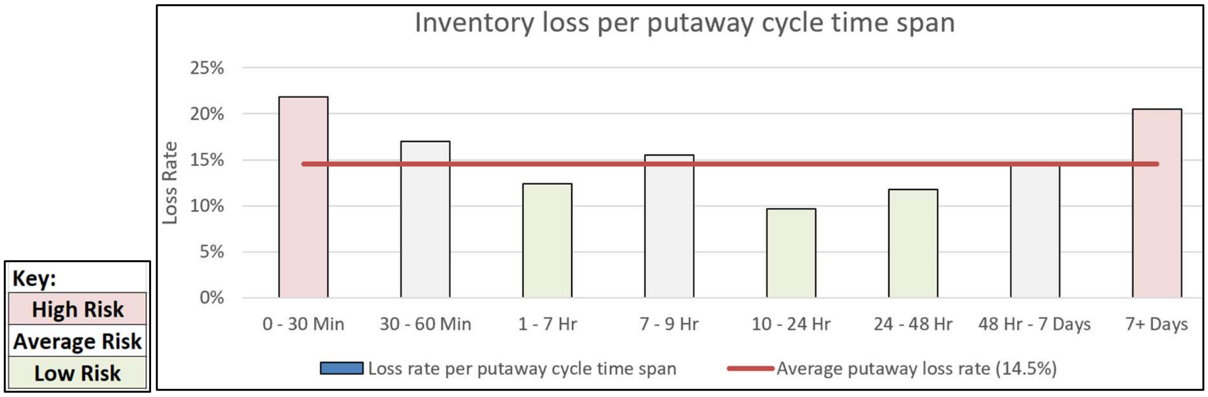

Figure 9. Loss rate per putaway cycle time span

4.5 Probability of inventory loss – discussion

The results of the hypothesis testing confirmed the importance of synchronizing information and materiel flows because periods of high loss correspond to time frames in which it is more likely that there is a mismatch between the physical inventory and the information flow.

Putaways confirmed in under 30 minutes represent a quadrant 2 mismatch (materiel not moved; information sent). There are several reasons why they get lost: (1) the Soldier assigned the work of physically putting away a confirmed putaway may get distracted, resulting in the materiel never reaching its destination; (2) a high percentage of putaways confirmed within 30 minutes were for 'found on installation' materiel, which is materiel added to the inventory record without an inbound delivery. The 'found on installation' process is commonly used to reconcile over-counts or to process deliveries that arrive without an open order to receipt against.

An SSA subject matter expert stated that putaways not confirmed in 7+ days, and not placed in the bin without confirmation, would likely never make it to the bin which is representative of a quadrant 2 mismatch (materiel not moved; information sent). Mostly, the remedy is to 'inventory them out' for the loss to be acknowledged. The subject matter experts confirmed that having parts, slated for putaway, in a work in progress area creates an opportunity for pilferage, damage, or loss of the material. In addition, it may cause printed putaway instructions to be damaged or lost, as such, could cause the SSA to reprocess a false receipt of the material via 'found on installation' receipt processing which would generate a a quadrant 3 mismatch (materiel moved; information not sent) (P. Offor, personal communication, April 2, 2020).

Although the spike in losses between 7 and 9 hours is not statistically significant, it may correspond to a tendency for Soldiers to rush to complete work at the end of a duty day. This tendency cautions against setting a standard that is too aggressive, incentivizing units and Soldiers to prematurely confirm putaways in order to receive favorable performance metrics.

4.6 Probability of inventory loss – recommendations

At the strategic level, the US Army can establish a putaway key performance indicator and standard that is briefed as part of an SSA's performance in order to influence behavior at the tactical SSA level. Even though putaway time is a standard key performance indicator in civilian warehouses, the Army did not seek to measure it because it was not possible to measure this metric in the legacy sustainment information system (M. Wilson, personal communication, April 2, 2020). The Army can benefit from taking advantage of new metrics made available through the digital transformation. Publications such as CASCOM's virtual terrain walk suggest informal standards; however, there are no reports targeted for senior managers who do not have domain expertise managing SSAs (CASCOM, 2019).

Since the most important factor for the Army is accurate inventory counts, the author recommends establishing a two duty-day upper bound standard for all putaways. The standard is specifically stated as two duty-days instead of 48 hours to discourage statistical performance manipulation in which putaways are confirmed on a Friday with the intent of being completed following a weekend. A two duty-day goal would provide operational flexibility and may prevent units from manipulating performance statistics by confirming putaways without completing the physical movement.

Training material emphasizing the importance of the materiel flow and information flow matching is vital to discourage confirmations being entered before a physical putaway is completed. Currently, the Army provides SSAs with tablets the size of chrome books and cumbersome to use. Synchronized putaways may be more likely to occur if lighter and faster bar code scanners are available for use at the putaway storage bin.

The Army's digital transformation enables the creation of a putaway cycle time key performance indicator that can be monitored to influence behavior in a manner that will reduce inventory losses.

5 APPLYING THE THREE-FLOW LENS TO THE POST GOODS RECEIPT STEP

This chapter applies the methodology introduced in Chapter 3 to the final step in the Army's requisition cycle. The final step is known as a Post Goods Receipt (PGR) because customers 'post,' or send information, confirming the receipt of goods (materiel). Materiel that has not been received has an open inbound delivery document number in GCSS-Army. The inbound delivery document number is the key information signal and serves as the functional equivalent of a tracking ID alerting a customer that their order has been shipped. Inbound deliveries are generated whenever a national level vendor issues materiel to a dedicated order, or the SSA completes a Post Goods Issue to a customer order after a pick from stock or a crossdock of materiel that was shipped to the SSA. When units confirm the inbound delivery, they complete a PGR, which triggers the reconciliation of any payments associated with the transaction and moves stock on hand to the receiving customer's inventory record.

When materiel is not moved but customers complete a post goods receipt, GCSS-Army automatically adds the materiel to customers' inventory record, creating a mismatch at this intersection (Figure 10 quadrant 2). The author spent 15 months in command of an SSA and identified that the most common reason units confirm receipt of materiel but do not remove it from an SSA is inadequate logistical support. On rare occasions, units no longer need the property, so they leave it at the SSA until they can prepare documentation to return it through the Army's reverse logistic pipeline that starts at their SSA. This mismatch has revealed itself as a local management issue rather than a digital transformation gap, so it will not be covered in further detail.

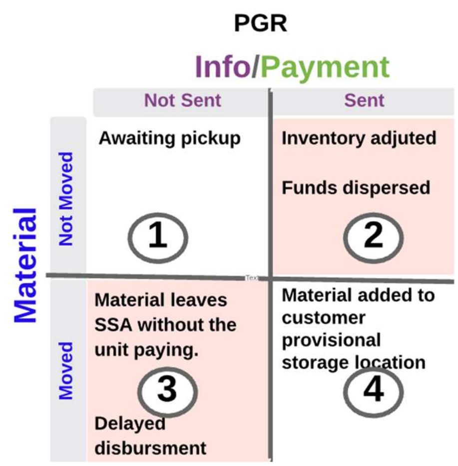

Figure 10. Post Goods Receipt 2 x 2 matrix

The mismatch at the intersection of materiel moved and information not sent (Figure 10 quadrant 3) results in inaccurate inventory for the SSA, the customer, and a failure to finalize payment for goods received.

The author examined 11 - M88A3 Recovery Vehicles that were issued to customers of a specific SSA but not received after nearly two years. M88A3 Recovery Vehicles cannot be easily pilfered because they require a crew of three to operate and weigh over 55 tons. An inbound delivery was generated on 7 March 2018 to units in an armored brigade combat team. However, the transfer was not accepted in the system of record; instead, the transfer was recorded using manual paperwork procedures, DA Form 3161, on 12 April 2018. On 9 May 2018, the brigade property book officer added the recovery vehicles to record via a 'found on installation' procedure, which resulted in duplicating on-hand inventory in the Army's system of record (Table 3).

Timeline	7-Mar-18	12-Apr-18	9-May-18	20-Feb-20
Event Description	**Inbound delivery creation**	**Physical receipt**	**'Found on Installation' process**	**Data collection date**
Tank Recovery Vehicle location	In-transit	Unit	Unit	Unit
Inbound delivery quantity	11	11	11	11
Unit property book quantity	0	0	11	11
Total quantity	**11**	**11**	**22**	**22**

Table 3. 'Found on installation' example

The proper procedure is for the property book officer to post goods receipt the inbound delivery on the day of physical receipt of the 11 tank recovery vehicles to the unit's property book (inventory record) (Table 4).

Timeline	7-Mar-18	12-Apr-18	20-Feb-20
Event description	**Inbound delivery creation**	**Physical receipt & PGR**	**Data collection date**
Tank Recovery Vehicle location	In-transit	Unit	Unit
Inbound delivery quantity	11	-11	0
Unit property book quantity	0	11	11
Total quanity	**11**	**11**	**11**

Table 4. Correct Post Goods Receipt example

A review of the original transaction paperwork revealed that receiving document numbers on the paperwork matched the found-on-installation document numbers in GCSS-Army. When the top technical expert for property accountability serving in the Department of the Army's supply policy division reviewed the error, she stated, "I'm assuming the PM (program manager) did not notify the PBO (Property Book Officer) of the inbound or the PM added it after the fact"(C. Bartly, personal communication, February 13, 2020). Since the issuing document numbers did not match the numbers created by the vendor in GCSS-Army, it is likely that the program manager's issuing agent was unaware that an issuing document number had been created in GCSS-Army, because the issuing agent chose to use the manual system rather than utilizing the digitized work process. The presence of this kind of mismatch results in the creation of millions of dollars in phantom inventory and prevents GCSS-Army from achieving the goal stated in its implementation order: to "provide commanders… with near real-time logistics and financial data" (DA G-4, 2015).

Section 5.1 discusses the data sources used to measure the mismatch. Subsequent sections, 5.2 presents the results, 5.3 provides the discussion and recommendation.

5.1 Data sources to measure the PGR mismatch

The data used for this research was sourced from the inbound delivery monitor report (VL06i) for all units supported by SSAs that are located in the continental United States during garrison operations. The initial dataset consisted of 47,166 records. All entries with issued materiel within 180 days were removed from the data set because SSAs frequently relocate across the globe, resulting in predictable time lapses where post goods receipt by SSA customers are not possible. Key informational fields include the document number, inbound delivery number, unit identification code, delivery date, materiel number (SKU) and quantity.

The value of the materiel and its class of supply (standard defense department grouping of supplies) were not available in the inbound delivery monitor report, so the Federal Logistics

Database (FEDLOG) was queried by materiel number in order to retrieve the cost and class of supply field.

In addition, all 'found on installation' transactions for receiving units were extracted from the Materiel Document List transaction code, ZMB59, in GCSS-Army for materiel numbers not received in over 180 days. 23,204 'found on installation' documents matched the original query.

The following section examines how the data provides insight into desynchronized materiel and information flows in the post goods receipt process.

5.2 Post goods receipt flow – results

The analysis showed that $508M in inventory had been issued but not received by customers in over 180 days. To better understand the causes of this problem, the data was organized three ways: (1) by corps and division echelons of command, (2) by funding mechanism and requisition method, and (3) by the timeframe a matching 'found on installation' receipt was processed.

5.2.1 Post goods receipt results by corps and division

Army divisions consist of approximately 10,000 to 25,000 Soldiers and report to corps which have 3 – 4 subordinate divisions. This thesis compared the Army's two largest corps and subordinate divisions. Although the primary modes of transportation for Soldier in their formations differ, they are both commanded by three-star generals and subordinate to the same Forces Command commander.

Despite the similarities, 2.9% of all inbound deliveries were open for more than 180 days in Corps_Q (name changed for publication) compared to 0.1% for Corps_W. Corps_Q requires subordinate units to report how they are addressing open inbound deliveries over a 60-day threshold which may explain the disparity.

Unit	Open Inbound Delivery Count	Annual Inbound Delivery Count	% Total Inbound Deliveries
Corps_Q	7,218	259,382	2.9%
Corps_W	103	203,738	0.1%

Table 5. Inbound deliveries over 180 days by corps

Within Corps_Q, the problem is concentrated in the Division_E and Division_R which had rates of 2.9% and 3.4% respectively (Table 6). Divisions E and R do not monitor open inbound deliveries whereas Divisions T and Y have implemented reporting requirements similar to Corps_W.

Unit	Open Inbound Delivery Count	Total Inbound Delivery Count	% Total
Division_E	4,332	71,096	6.5%
Division_R	2,447	77,468	3.3%
Division_T	327	46,101	0.7%
Division_Y	112	64,717	0.2%

Table 6. Inbound deliveries over 180 days in Corps_Q

The difference in value (Table 7) is subject to greater variation because outlier materiel such as six phantom Apache Helicopters valued at $150M may skew the results.

Unit	Open Inbound Delivery Count	Value
Division_E	4,332	$ 174,179,782
Division_T	327	$ 169,506,956
Division_R	2,447	$ 69,238,070
Division_Y	112	$ 59,503,676
Division_U	79	$ 3,586,779
Division_I	24	$ 2,797,378
Division_O	0	$ -
Division_P	0	$ -

Table 7. Inbound delivery value by corps and division

Results by unit are indicative of special cause variation that will be discussed in section 5.3.1.

5.2.2 PGR results by funding mechanism and requisition method

The Army is allocated funds in multiple accounts by the United States Congress, this allocation has ramifications for the information and payment flow in GCSS-Army. For instance, when major equipment, such as tanks and helicopters, is ordered, payment is issued by the Department of the Army using Procurement Funds, whereas repair parts are purchased by the unit consuming the part utilizing Operations and Maintenance Funds (Berton, 2020). Although GCSS-Army utilizes the same database structure to maintain accountability of major equipment and repair parts, payment for major weapon systems are typically managed outside of the GCSS-Army via other ERP systems. As a result, most major equipment transactions recorded in GCSS-Army do not have any payments associated with their post goods receipt. 95%, or $480.6M, of the outstanding value of materiel with open inbound deliveries over 180 days were for items procured and paid for at the Department of the Army level via other ERP systems (Table 8).

Fund	Value	Percentage
Procurement, stock fund, etc.	$ 480,673,433	95%
Operations and Maintenance	$ 27,653,472	5%

Table 8. Funding mechanism of open inbound deliveries

The data associated with this multiple account situation has revealed additional oversight issues. The major percentage of spend, in this case, procurement, stock fund, 95%, is not being actively managed to ensure that payment processes are being executed according to best practice, while the operations and maintenance, 5%, payment processes are being managed effectively. One result of this research will be to provide recommendations for a solution to enable adequate oversight to all areas. Currently payment process management for the largest percentage of spend is not occurring, recommendations to achieve this critical oversight will be addressed further in section 5.3.2.

Most requisitions are supported by SSAs, which means the SSA generated the inbound delivery to customers after processing a crossdock from receiving or a pick from storage. The other requisition method is known as a dedicated order and is most commonly used for major equipment and, or units operating in geographically isolated areas. Dedicated orders such as tanks and weapons must be received and secured in specially designated yards. 99% ($500 M) of the open inbound deliveries were for dedicated orders (Table 9).

Requisiton method	Value	Percentage
Standard SSA order	$ 6,073,243	1%
Dedicated orders	$ 502,253,663	99%

Table 9. Requisition method of inbound deliveries

Results by class of supply, funding mechanism, and requisition method are indicative of special cause variation that will be discussed in section 5.3.2.

5.2.3 'Found on installation' transaction - processing timeframe

Units can add materiel to their inventory without linking it to an order via a transaction known as a 'found on installation.' For purposes of this research, 'found on installation' transactions were matched to the creation date of inbound deliveries occurring within 60 days based on the unique materiel number (SKU) and storage location (unique company identifier). The value of materiel processed as 'found on installation' before the inbound delivery was created was $59M compared to $180.4 that was processed as 'found on installation' after the inbound delivery creation (Table 10).

Found on installation timeframe	Value	Inbound Delivery Count
Before inbound delivery creation	$ 58,993,017	72
After inbound delivery creation	$180,446,492	269

Table 10. 'Found on installation' timeframe

A compounding reason for the 'found on installation' problem may be the Army's reliance on a secondary system, the Decision Support Tool (DST), to direct the lateral transfer of major equipment between Army units. DST monitors completion of lateral transfers based upon the change in major equipment counts of a unit's inventory and does not rely on the closure of inbound deliveries. As a result, a transfer may appear to have happened error free when in fact phantom inventory was created in GCSS-Army.

Since many of the items processed as 'found on installation' are valued at over $250K and are key pieces of equipment for unit readiness it is highly unlikely that these items were truly lost. Recommendations associated with the 'found on installation' process will be addressed in section 5.3.1 and 5.3.2.

5.3 Discussion and recommendation

The desynchronized flow of materiel, information and payment at the PGR step results in the Army failing a completeness audit mandated in the 2010 Defense Appropriations Act. This section will (1) examine how desynchronized materiel and information flows can enable units to receive materiel before an inbound delivery is created and (2) study best practices from divisions with a low number of open inbound deliveries.

5.3.1 Desynchronized materiel and information flows before the PGR step

$58M in materiel was processed as 'found on installation' and added to a units' inventory prior to the creation of a corresponding inbound delivery, because the flow of materiel and information was desynchronized with the steps occurring prior to the post goods receipt.

If ordered materiel is on hand at the SSA, the SSA will be issued a pick transfer order which directs materiel to be moved from a storage bin to the customer's bin. A mismatch exists (Figure 11 quadrant 3) if SSA clerks do not confirm the pick and subsequent post goods issue, GCSS-Army will not create an inbound delivery, resulting in the customer being unable to receive the materiel.

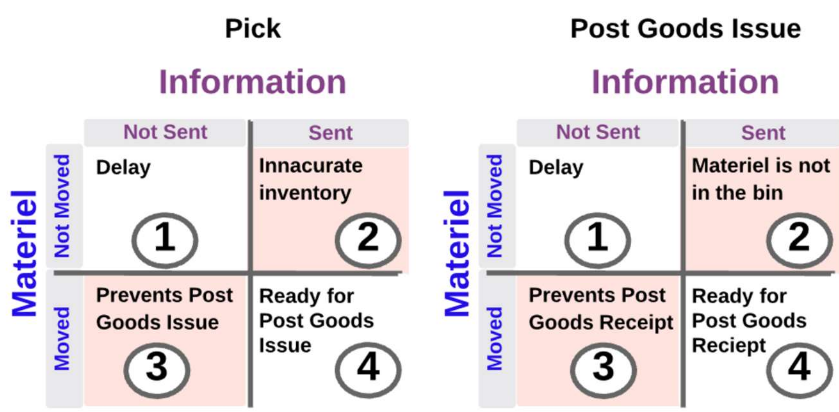

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Figure 11. Pick and Post Goods Issue 2x2 matrix

If an SSA cannot fill an order from its inventory, the customer's order, based upon a prioritization qualifier, may be consolidated with orders from other units and sent to a national level vendor. Upon shipment, national vendors send an advanced shipment notification which results in GCSS-Army creating an inbound delivery. Whenever this materiel arrives at the SSA, clerks confirm the inbound delivery number with a Post Goods Receipt then GCSS-Army determines if there are open customer orders which can be filled by a crossdock post goods issue. If the information flow is not confirmed, mismatches are created which cascade to subsequent steps in the requisition process (Figure 12 quadrants 3 and 7).

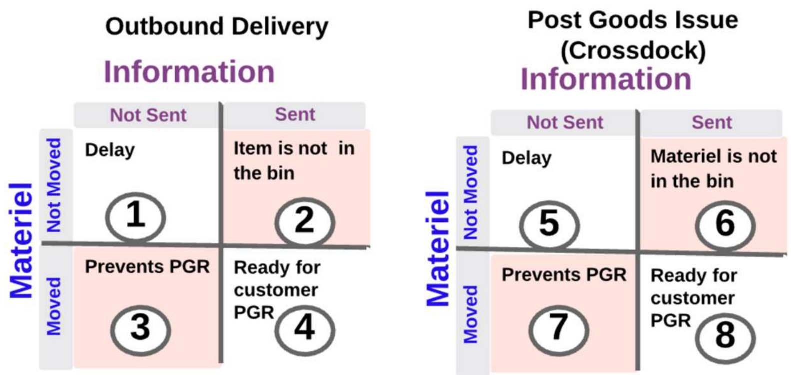

Figure 12. Crossdock 2x2 matrix

The consequence of the desynchronized information and materiel flow prior to PGR is that payment for materiel cannot be reconciled and the materiel is not automatically added to the inventory. Army culture places a premium on vehicle readiness, so many units define success as retrieving the part. This cultural definition of success is currently misaligned with the requirements for audit success. Clerks process the materiel utilizing the 'found on installation' workaround, which establishes it on their inventory record. However, the second order effect and consequence is the creation of phantom inventory. The system of record states inventory is on hand at the SSA or in transit from a national vendor and duplicate inventory is at the unit location. Later, when units process the inbound delivery to pay for the materiel, they must remember to decrement the phantom inventory from their stock account. Given human memory, it is unlikely that accurate inventory decrement occurs.

This thesis recommends changing GCSS-Army to enable customers to receive any requisition followed by a supported digitized routine that allows for the information flow to be retroactively inputted. This will add flexibility to the system to ensure that auditability goals are met while supporting customer’s operational needs to retrieve parts for maintenance. An added benefit of establishing this procedure is that a key performance indicator measuring the ratio of items received by units without a corresponding inbound delivery to total inbound deliveries received can be developed (Equation 1). Use of this KPI would encourage accurate post goods issuing of materiel, which is the precursor to a customer PGR that triggers payment reconciliation and automatic addition of stock to the customer’s inventory.

$$Item\ Recieved\ in\ Full = \frac{Items\ recieved\ without\ an\ inbound\ delivery}{total\ inbound\ delivieries\ recieved}$$

Equation 1. Items received in full KPI

5.3.2 Post goods receipt flow discussion and recommendation

When the flow of materiel and information is not synchronized during the post goods receipt step, payment transactions are not reconciled, and phantom inventory may be created.

A majority of the value, 95% ($481M), not received in over 180 days was for procurement or stock funded items, which are a special class of supply managed by individuals known as property book officers. The author identified a gap in training material for the property book officer community because the Army Logistics University student guide does not include instructions for receiving inbound deliveries in GCSS-Army, nor does it direct property book officers to monitor the inbound delivery of materiel (Calibre, 2019). Since monitoring inbound deliveries is critical to maintaining auditability, the author recommends adding instructions for monitoring inbound deliveries to the student training guide.

An effective training program must have a mechanism to identify individuals that need to be trained. Senior materiel managers in the Corps_& and subordinate divisions report the status of open inbound deliveries over 60 days to senior organizational leaders. However, the report is generated by the unit's resource managers so it only included orders that were funded by the unit's operations and maintenance accounts. As a result, major equipment that was purchased with Department of the Army procurement or stock funds were excluded from their oversight process. This explains the entire $3.5M in open inbound deliveries for the Division_*. Conversely, the two divisions that were not monitoring open inbound deliveries accounted for 92% of the open inbound deliveries.

Another oversight gap with respect to the requisition method occurs because the Army considers the amount of time it takes for customers to Post Goods Receipt SSA issued material in its SSA performance statistics. Therefore, SSA monitor the closure of inbound deliveries for materiel they issue. Dedicated orders are shipped directly from a national level vendor to the SSA's customer and do not reflect on an SSA's performance so they are ignored by SSA personnel.

The author recommends that logistics officers responsible for the sustainment of brigades and divisions review utilize SAP's Business Intelligence reporting options to generate a status report of open inbound deliveries regardless of funding source or requisition method. The author also recommends that the Department of the Army adopt US Army Europe's best practice of monitoring and taking action on open inbound deliveries after 45 days for repair parts and 75 days for all other classes of supply. In order to ensure compliance, commanders must monitor and hold subordinates accountable to this metric. The report would add significant value by increasing visibility to causal process errors. Use of SAP reporting in addition to the report from the Excel tool derived from GCSS-Army data would result in a best practice.

The goal of report development will be to generate results that are intuitive for the end user. One suggested improvement would be to identify units by name and the unit function for those units that placed the order rather than relying solely on four-digit alpha-numeric codes. For example, maintenance inbound deliveries for the 62nd Quartermaster Company, 553rd Combat Support Sustainment Battalion are identified by the storage location code 0WRS and unit supply orders are identified by the storage location code 0WRR. The sole use of these very similar identifiers compounds the risk of error. The report should also be customizable for individual organizations. For example, an SSA may want to monitor what materiel they have issued that has not been received by their customers whereas SSA customers and materiel managers need to have visibility to direct deliveries and standard SSA orders.

By gaining an appreciation for the flow of materiel, information and payment the Army can get closer to realizing GCSS-Army's stated goals.

6 CONCLUSION

The synchronized flow of materiel, information and payment is critical to ensuring that supply chain digital transformations meet expectations. This thesis examined the Army's digital consolidation of 14 sustainment systems into one and the reasons the digitally transformed solution did not achieve the intended goal of ensuring an auditable transaction record.

Even though the Army's supply chain is designed to operate in austere wartime environments, its structure, policies and procedures mirror civilian supply chains. For instance, many large organizations such as a hospital network establish a central receiving warehouse and distribution center that consolidates purchases and receipt of inventory. The inventory is then distributed across the healthcare system utilizing an intra-company sales process identical to the Army SSA receipt and inventory management processes.

Maintaining accurate inventories of stock is a primary function of supply chain ERP system. If there is a mismatch between the physical and information flow, then the chance of inaccurate inventory increases. Analysis of putaway time spans for an Army warehouse showed that if materiel putaways are confirmed extremely fast (less than 30 minutes) or slow (more than 7 days) then the inventory is more likely to be lost. The flow of materiel and information must be proactively monitored; the author recommends that companies monitor putaway work in progress and incentivize accuracy. Challenges related to the accurate management of putaways exist and the Supply Chain Council has developed metrics to monitor and reward warehouse staff for accurate entry of all inventory flows into the ERP system (Trujillo, 2016).

Previous studies examining digital transformation have identified an adaptable culture as a prerequisite to achieving digital transformation success (Kane et al., 2019). This thesis demonstrated that cultural attitudes towards the synchronous flow of information and materiel impact digital transformation results. For instance, GCSS-Army introduced new process steps that require the confirmation of inbound deliveries to trigger the movement of inventory and reconcile payment. However, evidence suggests that personnel commonly use a ‘found on installation’ workaround to add materiel to their inventory instead of receiving the inbound delivery. As a result, phantom inventory is created, which prevents GCSS-Army from achieving its auditability goal. Since many units do not require inbound deliveries to be monitored, it sends the message that the work arounds are acceptable. Extensive evidence exists within civilian industries, for example Toyota, that utilizing ongoing monitoring metrics creates a culture that actively ensures accuracy and continuous quality improvement (Toyota, 2020).

Civilian companies must track the flow of material for payment and auditability requirements as well. For instance, medical supply chains must track joint implants to the patient recipient. Subsequently, the implantation confirmation data triggers the creation of a patient bill and the eventual payment, for the device, to the healthcare system by an insurance payer. If hospital employees were to use work arounds to receive inventory the consequence would be an underpayment by the patient’s insurance provider to the healthcare system for the implanted device. Additionally, if consignment implant inventory is in use, which is often the case, creating duplicate inventory would result in double payment for the implants by the hospital to the device manufacturer. Work arounds to the prescribed flow of material information would be financially disastrous for the healthcare system. The author recommends that supply chain ERP designers assess how de-synchronized flows could impact the business model and implement appropriate safeguards and monitoring systems.

Some companies may have robust systems for property receipt of materiel from outside vendors but follow less stringent procedures for intra-company sales and distribution. Accurate intra-company sales are vital to ensuring audit readiness and inventory positions. To improve supply chain accuracy, companies must monitor all transfers that are in progress.

Another insight from this thesis is that companies can benefit by taking advantage of new information to implement more useful key performance indicators. While strategic KPIs may stay the same for an organization, more granular data collection presents an opportunity to implement KPIs that tactical level managers can utilize to optimize and drive strategic performance improvement.

The first significant recommendation for the Army is to create a two duty-day performance standard for putaways and monitor this process by establishing a new key performance indicator. The goal of the KPI is to achieve realistic time frames for items to be putaway. The time frames established, in the KPI, ideally do not encourage Soldiers to rush the data entry, recording the data prior to putting an item away and conversely do not punish an Soldier if an item is not put away by the end of a shift. The addition of a metric examining 'putaway work in progress' improves the process and ensures that the flow of materiel and information is accurate.

The next recommendation is to enable units to confirm receipt of any open order, subsequently, triggering a requirement to complete all the intermediate information flows associated with the materiel issued to ensure compliance to audit requirements. This recommendation seeks to strike a balance between customer preferences to receive materiel quickly and ‘move at the speed of war’ with the requirement to have an auditable distribution network.

The final recommendation is to monitor open inbound deliveries that have not been confirmed and implement an associated KPI. The research found that divisions and corps benefited when they developed incentives to ensure the accurate flow of materiel and information across all business areas. Without incentives, users may revert to old habits which are noncompliant with the business rules of GCSS-Army.

Within the context of this thesis, there were additional analyses that may have been insightful. For example, the amount of time it takes to confirm a pick may impact the loss rate. It is possible that an unconfirmed pick would lead to the materiel being picked twice. Additionally, open inbound deliveries matched to ‘found on installation’ transactions at the battalion and brigade level may have provided additional perspective given that redistribution within units is common. The materiel, information, and payment flow lens can also be applied to other steps within the requisition process such as direct shipments from vendors to SSAs or customers.

With respect to the Army’s supply chain, the author also recommends applying the three-flow lens to the Army’s reverse logistics pipeline, as well as to the inventory records in the Army’s maintenance and supply rooms given the parallel nature of these supply pipeline processes.

The findings of this research support the claim in the literature that digital transformation failure is rarely due to technological challenges. This research also provides operational insight, concluding that supply chain digital transformations are more likely to meet expectations when they ensure the synchronous flow of materiel, information and payment.

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