Common Authorized Stockage Lists for the U.S. Army's Brigade Combat Teams

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About This Report

This report documents research and analysis conducted as part of the projects entitled *Common ASL [Authorized Stockage List]: Implementation, Sustainment, and Expansion* and *Common ASL: Expansion and Support to the Army,* sponsored by the U.S. Army Materiel Command and U.S. Army Sustainment Command (ASC). The purpose of the former project was to support the Army's initiative to implement common authorized stockage lists (CASLs) across like brigade combat teams (BCTs) that will support high operational tempo (OPTEMPO) in austere logistical environments. The purpose of the latter project was to support the update of CASLs for the armored, infantry, and Stryker BCTs; leverage lessons learned to identify the best course of action for expansion of CASLs to other types of units; and support the use of the CASL algorithm for single-ASL (i.e., non-CASL) reviews to reduce the number of changes—referred to as *churn*—during ASL updates. This report should be of interest to Army logisticians and, more generally, to all logisticians who are involved in the periodic update of spare parts inventories.

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Summary

When the combat and tactical vehicles in the Army's brigade combat teams (BCTs) break down, maintainers require repair parts to restore their readiness. This can happen quickly if the parts are on hand in the BCT's own Supply Support Activity (SSA). The Army's solution to this equipment readiness challenge is the *authorized stockage list* (ASL), a carefully calculated list of the repair parts that is periodically recalculated, reviewed, and updated. Each SSA should keep an ASL on hand for the equipment in the supported BCT.

In 2016, the U.S. Army Deputy Chief of Staff, G-4 (then General Gustave F. Perna) laid out a vision of common ASLs (CASLs)—that is, single ASLs for each of the three BCT types (armored [ABCT], infantry [IBCT], and Stryker [SBCT])—that would provide higher ASL performance to (1) better support readiness of critical equipment in high-tempo operations, (2) enable SSA mobility on the battlefield, and (3) reduce the workload required to reconfigure storage locations and redistribute parts that are no longer authorized for stockage.

To achieve these objectives, RAND researchers developed a new approach to computing ASLs that fundamentally changed both how the demand history was used and the analytic method. Rather than using the demand history of each BCT for each ASL review, the new approach pools the demand history for repair parts across all BCTs of the same type. Replacing the traditional two-step approach driven by heuristic business rules was a mathematical optimization approach that uses a mixed-integer programming (MIP) algorithm.

Table S.1 shows how the new approach affected the three objectives laid out by the Army. Pooling demands across BCTs of the same type provided additional periods of high-intensity training events, better information on part demand variability, more data to determine a robust mix of low-demand parts, and a reduced likelihood that atypical part demands at one or two BCTs would drive ASL changes. A single, pooled demand stream made the CASL possible, resulting in a standard storage configuration across BCTs of the same type. Using mathematical optimization to simultaneously determine the number and quantity of parts allowed the use of a weighted benefit function while enforcing storage constraints to ensure SSA mobility. The benefit function captured the demand history of each part but also allowed for weighting of mission-critical equipment for better parts support. Additional weighting factors were introduced to capture the percentage of parts demands for parts on high-priority work orders, which favored maintenance-significant parts (MSPs), and the number of BCTs that had demand for the part, as well as to control the costs of transitioning from the current ASL to the recommended ASL. The research team conducted simulation analysis to verify the

TABLE S.1
The Shift to CASLs Involved Two Changes with Multiple Benefits

Change to ASL Review Process	Improve ASL Performance	Ensure SSA Mobility	Reduce ASL Churn
Pool part demands from BCTs of the same type	• More data about demands during high–operational tempo events are included. • More data are included to inform a robust mix of slow-moving parts.	Storage configuration at SSAs is standardized.	ASL composition is not overly influenced by atypical part demands at a single BCT.
Shift from two-step heuristic to mathematical optimization	• Each solution is optimized to deliver the most readiness benefit for available resources. • Emphasis is placed on mission-essential equipment.	Constraints by storage category and location are enforced.	Use of explicit churn weights and trade-off analysis is possible.

benefits in Table S.1. In Table S.2, for each BCT type (row), the last four columns show that the CASL would significantly increase ASL performance versus preconversion ASLs for both class IX (repair parts) and MSP fill rate. Simulation analysis was also used to verify that the higher performance could be maintained at reduced ASL churn (last column in Table S.1) by leveraging the weighting factors used to control the transition costs for CASL updates.

Table S.2 gives the range in terms of number of storage locations, the extended cube of the requirements objective (RO), and the extended value of the RO in the preconversion ASLs by BCT type. By comparison, the CASL was the same for all like BCTs, which allowed for the development of a standard storage configuration of field pack units (FPUs) and flat racks that could be rapidly picked up and moved using the Army's load-handling system (LHS),[1] ensuring SSA mobility. Army Sustainment Command (ASC) developed a detailed storage configuration plan, referred to as a *planograph*, for each type of BCT that mapped all the parts on the CASL to a specific location. Detailed storage constraints are enforced during CASL updates, ensuring SSA mobility (third column in Table S.1) going forward.

In April 2017, ASC changed the inventory type of the parts on the CASL for the active component ABCTs, IBCTs, and SBCTs.[2] Figure S.1 shows the accommodation rate for MSPs by ABCT. Prior to the CASL, there was considerably more variation in accommodation rate by ABCT and over time for the same ABCT. Once the CASLs were posted in March 2017, the accommodation rate increased to just above the forecasted level of 80 percent. The thickness of the line represents the monthly volume, so where there is still variation after March 2017, this occurred in ABCTs with low monthly volume.

A staggered schedule extending through the end of calendar year 2017 was established to implement the CASL inventory levels, and the ASC Stockage Determination Branch (ASC-SDB) worked with the BCTs to manage the schedule and post the CASL levels to the Global Combat Support System—Army (GCSS-A). The staggered schedule reflected (1) the training schedule of the BCTs and SSA availability, (2) the availability of the FPUs to store the parts, and (3) the desire to spread out the impact of replenishment orders and returns on the supply chain and increase the potential to reutilize inventory. At each BCT, deletions and decreases of inventory levels were posted first to free up space, empty storage locations in the SSA and get any on-hand excess retrograded out of the SSA and moved up the supply chain for potential reutilization as quickly as possible.

The staggered schedule used to implement the CASL inventory levels affected the satisfaction and fill rate ASL performance metrics. Figure S.2 shows the ASL performance for MSPs summed across all the ABCTs. The three lines representing the MSP supply performance rates are read off the left axis; the gray area chart represents the volume (the number of purchase orders received at the ABCT SSAs each month) and is read off the right axis. The blue accommodation line in Figure S.2 combines the lines shown in Figure S.1, weighted by volume, as a single line. As noted, the accommodation rate increased immediately in April 2017, as the MRP type of the CASL parts were set. The satisfaction rates did not increase until the inventory was ordered, shipped, receipted, and stowed to location. The red satisfaction line represents the percentage of accommodated purchase orders (POs) that were satisfied from on-hand inventory. Satisfaction rates initially go down in April 2017 as the many parts being added to the ABCTs did not have stock on hand. The satisfaction rates then rise over the next 12 months as inventory was receipted and stowed to location. Satisfaction rates con-

[1] The FPUs can be picked up rapidly, without the need for additional materiel-handling equipment, by trucks equipped with the Army's LHS. Bulk storage items were stored on flat racks, which were already on the unit's table of organization and equipment and are also compatible with the Army's LHS.

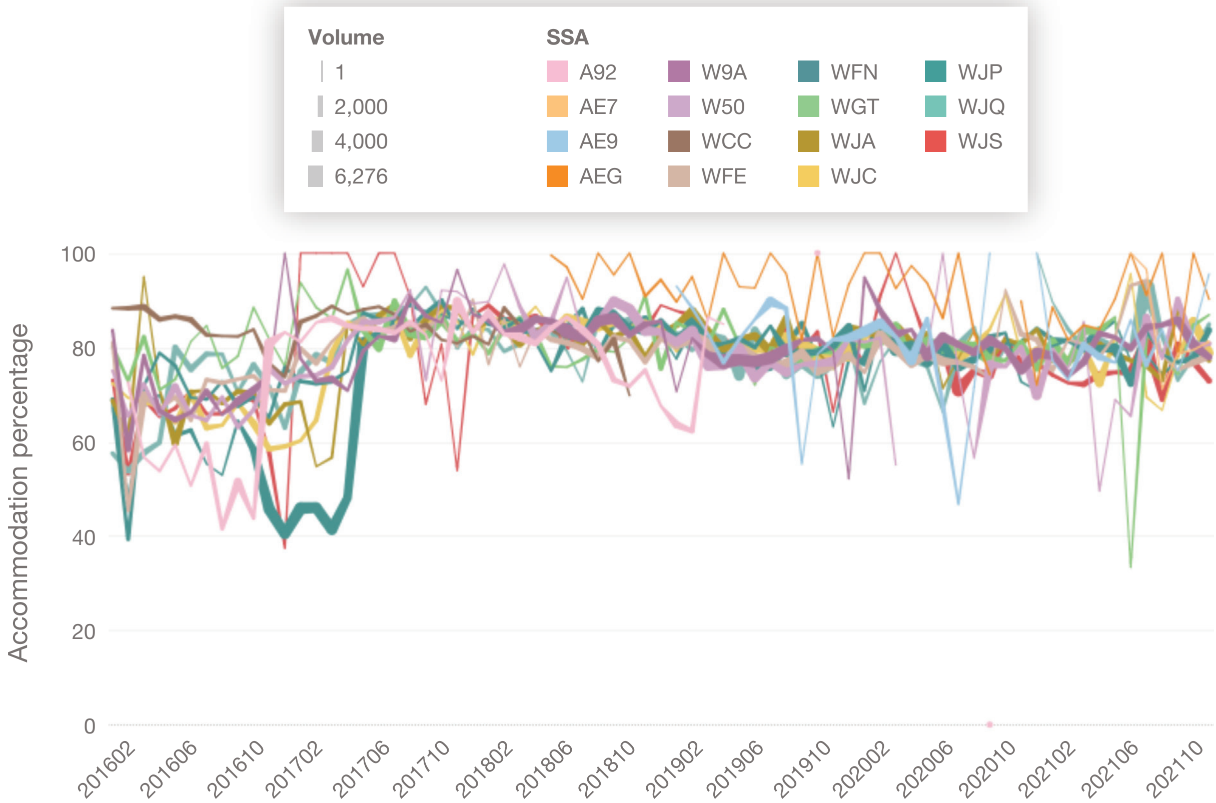
[2] The CASLs were posted across all BCTs in April 2017 as material resource planning (MRP) type double V hull (VV) (the VV code implies that the item was part of the CASL). This allowed any on-hand assets for CASL parts to be retained in the SSA. The updated inventory levels for the CASL were not set until later based on the training schedule of each BCT. This ensured SSA personnel were available to turn in inventory no longer on the CASL and receipt and store incoming inventory.

TABLE S.2
CASL Versus Preconversion

		# of Storage Locations		Extended RO Cube		Extended RO Value			MSP Fill Rate		Class IX Fill Rate	
BCT Type	# of BCTs	CASL	Preconversion Range	CASL (cu ft)	Preconversion Range (cu ft)	CASL	Preconversion Range	Change in RO Value	CASL (%)	Preconversion (%)	CASL (%)	Preconversion (%)
ABCT	11	4236	1600–4000	11.1k	8.0k–20.0k	$13.1M	$9.0M–$26.0M	–$21M	75	55	55	36
SBCT	7	3153	1600–3900	7.3k	5.4k–17.0k	$7.9M	$6.0M–$13.0M	–$7M	75	53	55	37
IBCT	14	2208	1000–2800	3.4k	1.6k–6.4k	$1.8M	$1.0M–$1.9M	+$7M	75	57	55	39

SOURCE: RAND Arroyo Center analysis of GCSS-A data.
NOTE: cu ft = cubic feet.

FIGURE S.1
MSP Accommodation Rate for ABCTs

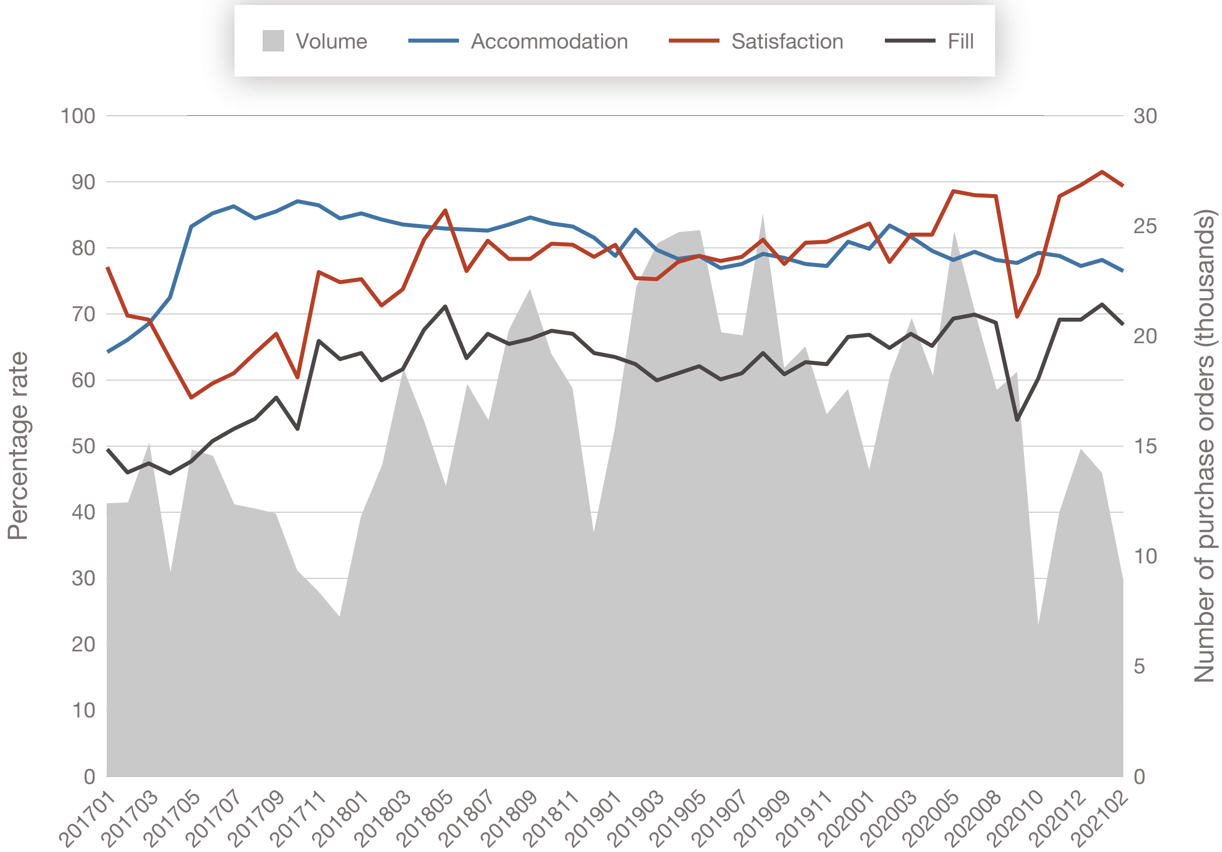


SOURCE: RAND Arroyo Center analysis of GCSS-A data.

tinued to trend up toward the target level throughout 2019. Analysis showed that this was due to improved national-level supply availability.

Updates to the CASLs allow trade-off analysis across multiple dimensions. Improved storage configuration constraints representing the planograph developed by ASC were used to trade off the workload required to adjust the storage configuration versus the improvements to ASL performance. For example, the most-recent CASL update showed that most parts in bin and shelf locations could be limited to the current storage capacity with almost no impact on ASL performance. Trade-off analysis also showed that weighting mission-critical equipment for better parts support was possible with very little impact on overall ASL performance.

FIGURE S.2
MSP Fill, Satisfaction, and Accommodation Rates for All ABCTs



SOURCE: RAND Arroyo Center analysis of GCSS-A data.

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CHAPTER 1

Introduction

Motivation and Background

The operational effectiveness of the Army's brigade combat teams (BCTs) depends critically on their tactical and combat equipment being available and mission ready. When equipment breaks down, maintainers require repair parts to restore equipment availability. This can happen quickly if the parts are on hand in the BCT's own Supply Support Activity (SSA). When critical parts are not available in the SSA, maintainers must wait for parts, repairs are delayed, and equipment remains unavailable for use in operations.

Ensuring that the right repair parts are stocked in the SSA is challenging for many reasons. Each BCT has a wide variety of equipment for which there are tens of thousands of different repair parts; the likelihood that any part will fail depends on many factors; and there is limited space to store repair parts because SSAs must be mobile. The U.S. Army's solution to this equipment readiness challenge is the authorized stockage list (ASL), a carefully calculated list of the repair parts that each SSA should keep on hand to support the equipment in its BCT and that is periodically recalculated, reviewed, and updated.

For over two decades, the Army has improved the methods used to calculate ASLs to capitalize on changes to its supply and maintenance information systems and to keep pace with advances in data collection and integration, inventory management metrics, and analytic methods:[1]

- In 1998, the Army implemented dollar cost banding (DCB) to update ASLs.[2] DCB refined the trade-off between frequency of demands for parts and their relative costs and storage requirements to determine which parts to include on the ASL, and it improved the methodology used to calculate how many of each part to store in the SSA.[3]
- In 2006, the Army implemented enhanced DCB (EDCB), an ASL algorithm initially piloted in 2002.[4] By incorporating readiness and maintenance data made available by the Equipment Downtime Analyzer, EDCB considered not only the cost and size of repair parts but also their potential impact on equip-

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[1] This work was initiated as part of the RAND Corporation's analytic support of the Army's Velocity Management initiative to improve logistics processes. Velocity Management applied a three-step method (define-measure-improve) to key logistics processes, including inventory management. This method's continual improvement of processes was embedded in the Army's stockage determination process with heavy reliance on metrics to measure performance and suggest improvements. See John Dumond et al., *Velocity Management: The Business Paradigm That Has Transformed U.S. Army Logistics*, Santa Monica, Calif.: RAND Corporation, MR-1108-A, 2001.

[2] Kenneth J. Girardini, Arthur W Lackey, Kristin J. Leuschner, Daniel A. Relles, Mark E. Totten, and Darlene J. Blake, *Dollar Cost Banding: A New Algorithm for Computing Inventory Levels for Army Supply Support Activities*, Santa Monica, Calif.: RAND Corporation, MG-128-A, 2004.

[3] The Army refers to the number of unique parts on the ASL as the *breadth* of the ASL. *Depth* refers to the quantity of each part on the ASL.

[4] Kenneth J. Girardini, Arthur W Lackey, and Eric Peltz, *Stockage Determination Made Easy*, Santa Monica, Calif.: RAND Corporation, RP-1272, 2007.

ment readiness.[5] The Army made it policy to use EDCB for ASL reviews in October 2006 and focused ASL performance metrics on readiness driver fill rate rather than overall fill rate. To support this policy change, a dedicated team conducted all ASL reviews across the Army, allowing local supply and maintenance managers to focus on applying their subject-matter expertise to reviewing the recommendations rather than the mechanics of generating the recommendations.[6]

- In 2012, the Army had to change its method for calculating ASLs again as it began fielding a new enterprise resource planning (ERP) system for logistics called Global Combat Support System—Army (GCSS-A). The new algorithm, Authorized to Forecast (ATF), largely mimics EDCB in terms of how parts for the ASL are selected, and the logic was implemented in the ERP system. The quantity desired for each item on the ASL is also like that used in EDCB, but to avoid more customization, this logic was executed outside the ERP. After review, the inventory levels are posted to GCSS-A.

With each change of supply and maintenance information system and the data made available by those systems, the Army updated the algorithms used for computing ASLs. Yet the potential remained for additional improvement, not only in effectiveness but also in efficiency. Because ASLs were SSA specific, the Army faced the burden of periodically calculating and updating ASLs for each of over one hundred SSAs, including around 40 SSAs supporting ground maneuver BCTs. Moreover, although ASL performance improved after each ASL review, there was still considerable variability in performance across BCTs of the same type and at each BCT over time. Each time the Army reviewed and updated ASLs using the most-recent data, the personnel at the SSAs shouldered the workload of reconfiguring their storage locations to accommodate changes to the ASL and redistributing repair parts no longer authorized for stockage.

Research Objective and Approach

Objective

In 2016, the Army Deputy Chief of Staff, G-4 (then General Gustave F. Perna) laid out a vision of *common ASLs* (CASLs)—that is, single ASLs for each of the three BCT types (armored [ABCT], infantry [IBCT], and Stryker [SBCT])—that would provide higher ASL performance to better support readiness of critical equipment in high-tempo operations, enable SSA mobility on the battlefield, and reduce the workload required to reconfigure storage locations and redistribute parts no longer authorized for stockage during periodic updates.

Approach

In response to the desire for CASLs, RAND researchers developed a new approach to computing ASLs that fundamentally changed both how the demand history was used and the analytic method that was used.

Rather than using only the demand history of each BCT for each ASL review, the new approach pools the demand history for repair parts across all BCTs of the same type (i.e., for ABCTs, SBCTs, and IBCTs).

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[5] Eric Peltz, Patricia Boren, Marc Robbins, and Melvin Wolff, *Diagnosing the Army's Equipment Readiness: The Equipment Downtime Analyzer*, Santa Monica, Calif.: RAND Corporation, MR-1481-A, 2002. The Army implemented the Equipment Downtime Analyzer tool in the Integrated Logistics Analysis Program in 2002.

[6] The original team was established as part of Army Materiel Command (AMC) Logistics Support Activity (now the Logistics Data Analysis Center), where they had been known as the Army Expert Authorized Stockage List team. In 2018, the stockage determination capabilities and responsibilities were transferred to Army Sustainment Command (ASC) Stockage Determination Branch (SDB).

Pooling demands across BCTs allows the Army to develop ASLs based on a larger and more-robust demand history that includes more training events and other high-tempo activities. Including the demands from these high–operational tempo (OPTEMPO) events results in a robust ASL that is more likely to contain the repair parts that BCTs will need when they deploy.

Historically, the Army has used heuristic rules to decide whether to add or retain repair parts on each BCT's ASL and then calculated the depth using separate logic. For CASL, the Army has moved to a mathematical optimization approach, executed using a mixed-integer programming (MIP) algorithm, to simultaneously determine the breadth and depth of parts to maximize the readiness benefit of the ASL. Using a mathematical optimization approach has several advantages:

- It allows the Army to stress the mission criticality of different types of equipment in the BCT.
- It allows for storage constraints to ensure the CASLs are mobile.
- It allows the use of weighting factors to reduce the number of changes to the ASL and, hence, SSA workload required for CASL updates.
- Varying weighting factors and storage capacity constraints enables rapid analyses of trade-offs across multiple dimensions (e.g., transition costs to update the CASL, storage configuration, mobility, and performance).

Overview of Results

The Army converted ABCTs, IBCTs, and SBCTs to CASLs, after which ASL performance improved. Furthermore, after conversion, CASL updates retained the performance advantage and allowed for mobile standardized storage configurations by BCT type while dramatically reducing the up-front inventory investment, distribution costs, and workload at SSAs required for periodic updates. The new approach was institutionalized by transferring the computer code to execute CASL updates to the analytic cell in ASC that executes all Army ASL reviews. Leveraging the more-detailed data available from the Army's new maintenance and supply information system, the research team extended the capabilities of the new algorithm to place emphasis on mission-critical equipment and execute trade-off analysis during CASL updates. The more-detailed data also enabled new ASL performance metrics and simulation capability, based on work order fill rates, that were more closely tied to equipment readiness.

Organization of This Report

The remainder of this report is organized into four sections. Chapter 2 provides more detail of the advantages of pooling the demand histories across BCTs of the same type and the shift from the two-step heuristic to mathematical optimization. Chapter 3 provides an explanation of the mathematical optimization formulation in nontechnical terms. Chapter 4 provides a description of the Army's initial conversion to CASLs for the active component ABCTs, IBCTs, and SBCTs and the improvements in ASL performance. Chapter 5 provides a description of the trade-off analysis used to update the CASLs.

CHAPTER 2

Benefits of Shifting to CASLs

The Army has several goals for wanting to transition from unique ASLs for each BCT to CASLs for BCTs of the same type:

- Further improve ASL performance in providing the repair parts that maintainers need to keep critical equipment ready and available, particularly in high-tempo operations where equipment is more likely to fail and require repair.
- Ensure SSA mobility on the battlefield by constraining the amount of storage for the ASL, thereby limiting the ASL to the repair parts most likely to be needed to maintain readiness of critical equipment.
- Limit the number of changes—referred to as *churn*—during ASL updates and thereby reduce up-front inventory investment, distribution costs, and workload at SSAs.[1]

To achieve these three goals, the shift to CASLs required making two major changes to the legacy ASL review process (see Table 2.1). One involved changing how the Army used available data on the demand for repair parts. The second involved changing the approach for analyzing the demand data and determining the best mix of parts to stock on the ASL for each type of BCT.

TABLE 2.1

The Shift to CASLs Involved Two Changes with Multiple Benefits

Change to ASL Review Process	Improve ASL Performance	Ensure SSA Mobility	Reduce ASL Churn
Pool part demands from BCTs of the same type	• More data about demands during high-OPTEMPO events are included. • More data are included to inform a robust mix of slow-moving parts.	Storage configuration at SSAs is standardized.	ASL composition is not overly influenced by atypical part demands at a single BCT.
Shift from two-step heuristic to mathematical optimization	• Each solution is optimized to deliver the most readiness benefit for available resources. • Emphasis is placed on mission-essential equipment.	Constraints by storage category and location are enforced.	Use of explicit churn weights and trade-off analysis is possible.

[1] Changes to the ASL during periodic updates that result in significant ASL performance are beneficial, but large numbers of changes that have very modest impacts on ASL performance can result in inventory churn. Churn can refer to the addition or deletion of items from the ASL or the increase or decrease of the depth of an item that remains on the ASL. Limiting inventory churn brings numerous benefits throughout the supply chain:

- reduces the amount of obligation authority (OA) required up front to fund the ASL update
- reduces the costs to order, distribute, and receive parts added or increased and the redistribution costs associated with parts that are deleted or decreased
- reduces the workload required in the SSA to reconfigure storage location.

This section provides a description of both changes (the rows of Table 2.1) and their advantages (the columns of Table 2.1) in relatively nontechnical terms. Empirical results validating the improvements are given in Chapters 4 and 5.

Pool Part Demands from BCTs of the Same Type

The transition to CASL involved pooling data on demanded repair parts from BCTs of the same type, for example, using the demand history across all ABCTs in a single ASL review rather than conducting separate ASL reviews using the demand history of each ABCT. Pooling demands across BCTs of the same type allows the Army to develop ASL recommendations from a larger data set. Whereas a single BCT provides 24 months of demand history for each part, 10 BCTs of the same type provide 240 months of demand history for each part. That larger data set leads to the advantages listed across the first row of Table 2.1.

Improve ASL Performance

The Army uses several metrics to evaluate ASL performance:

- *Accommodation rate*: the percent of part requests for which the needed repair part is stocked on the ASL (i.e., has a positive inventory level). The breadth of repair parts stocked on the ASL determines the accommodation rate.
- *Satisfaction rate*: the percent of orders for stocked repair parts that are on hand and available for issue at the SSA when needed (i.e., a request is satisfied). The depth of inventory for repair parts stocked on the ASL determines the satisfaction rate.
- *Fill rate*: the percent of part requests that are filled from the ASL. The fill rate is the product of the accommodation and satisfaction rates.

Pooling demands across BCTs of the same type to create a larger data set has two primary benefits that allow for higher ASL performance. First, the pooled demand history includes more data from periods in which BCTs were operating at a high tempo; these high-OPTEMPO data are valuable because they are representative of the demand for repair parts in deployed operations. Second, the pooled demand history also has more information about repair parts with low demand rates (i.e., slow-moving parts).

Having additional high-OPTEMPO events in the demand history leads to better estimates of demand variability. Each BCT's two-year history might include only limited periods of high OPTEMPO due to the nature of each BCT's training events and operational assignments.[2] Better estimates of demand variability enable more-informed decisions about the appropriate inventory level needed for each repair part.[3] Appropriate inventory levels are needed for each part stocked on the ASL. As indicated above, determining the appropriate depth of inventory helps to ensure that when a maintainer requests a part, the request can be satisfied.

Having more information about demands for slow-moving parts is beneficial because forecasting the likely demand for these repair parts requires analysis of more data than one BCT can provide. Parts with lower demand rates pose a particular problem when executing single SSA reviews because of insufficient informa-

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[2] For example, depending on timing of the ASL update, some BCTs might have participated in fewer major training events (e.g., at one of the Army centers capable of hosting brigade-level operations) or rotational deployments.

[3] Inventory levels are set to mitigate the risk of out-of-stock events caused by uncertainties in supply and demand.

tion to determine the true demand rate.[4] Pooling demands by BCT type results in more data, enabling the identification of a robust mix of slower-moving parts for inclusion on the CASL. This benefit is reflected in higher ASL accommodation rates. This is often referred to as *setting the breadth* of the ASL. Determining the appropriate mix of parts—or ASL breadth—helps to ensure that, when a maintainer requests a part, the part is stocked on the ASL.

Ensure SSA Mobility

SSA mobility is dependent on the number of different parts and quantity of each part stocked on the ASL and the storage configuration. When the Army calculated a unique ASL for each BCT, the size of the ASL (in terms of the number of different parts and the quantity of each part) and, hence, the storage configuration and mobility, varied dramatically across BCTs of the same type.

When all BCTs of the same type share a CASL based on their pooled demand history, the Army can define a standardized storage configuration. During the conversion to CASL, ASC developed a standard storage configuration (referred to as a *planograph*) for each BCT type. Basing storage on a planograph means that, across BCTs of the same type, each part on the CASL is stored in the same location, that is, in the same container, container section, module, shelf, and bin.[5] Using standardized storage configurations across SSAs of BCTs of the same type makes it easier to ensure SSA mobility across the Army's BCTs.

Reduce ASL Churn

When the Army based ASLs on the demand history of single BCTs, there was the potential for atypical demands for a repair part to have a disproportionate effect on the composition of the ASL. This risk was particularly true for slow-moving repair parts that experienced atypical demands during the review period. By contrast, because the Army bases each CASL on a pooled demand history, demands that are atypical or localized to one BCT's experience are counterbalanced by the collective demand history of other BCTs of the same type. As a result, atypical demands are less likely to disproportionately change the ASL.

An additional advantage of converting to CASLs is that the ASC-SDB has fewer ASLs to update, leaving more time for conducting trade-off analyses to ensure that proposed changes to the ASL result in meaningful performance improvements. The mathematical optimization formulation—discussed in detail below—makes this trade-off analysis more straightforward.

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[4] Demand rates for each part are derived from several factors: (1) failure rate of the part when the equipment is used (a part can be used on more than one equipment model), (2) quantity of that part in the equipment (e.g., more track pads are used than engines in each tank), (3) usage rate of the equipment (e.g., number of times the equipment is dispatched and mileage per dispatch), and (4) density of the equipment fleet (e.g., more high-mobility multipurpose wheeled vehicles (HMMWVs) than specialized construction equipment). Prior to implementation of the CASL, 40 percent to 50 percent of all repair parts on the Army's ABCT ASLs were stocked in only a single ASL. Moreover, the ASLs of ABCTs had only about 10 percent to 15 percent of their parts in common, the fastest-moving parts. Even these fastest-moving parts were stocked at dramatically different inventory depths across ASLs of different ABCTs.

[5] To store CASLs, the Army ordered for each BCT type a standard configuration of field pack units (FPUs)—20-foot containers with full-width access on each side and configured with storage aids, including such high-density storage aids as cabinets with shelves and dividers. Although FPUs can also be used for bulk storage, the more-common application is bin and shelf storage. The former consists of cabinets with drawers of various depth and equipped with dividers for creating locations, or bins. Shelving units of various configurations are used to organize storage of items too large for bins but too small to be secured in bulk storage. Bulk inventory was slotted on existing *flat racks*—the floor structure of a container with only one or two end walls, used for bulk storage. Both the FPUs and flat racks are compatible with the Army's load-handling system (LHS), so the ASL can be rapidly picked up and repositioned. The LHS uses an integrated arm with a hook to rapidly upload and drop FPUs and flat racks to and from either the truck or a trailer without additional materiel-handling equipment.

Shift from the Two-Step Heuristic to Mathematical Optimization

The Army's inventory algorithms have traditionally involved a two-step process. The first step used heuristic business rules to determine which items to stock on the ASL. The second step was to separately calculate how many of each part to stock.

The first step focused on establishing the breadth of the ASL. The Army used heuristic rules to decide which items to add to an ASL, retain on the ASL, and delete from the ASL. These decisions were based on the number of demands for each part during the review period. The *add threshold* specified the number of demands in the review period that were required to add a part not currently stocked to the ASL; the *retain threshold* specified the number of demands in the review period required to retain a part currently stocked on the ASL. If a part on the ASL did not achieve the retain threshold, it would be deleted from the ASL. To reduce the inventory churn, the number of demands required to add a part was set higher than the number required to retain a part. Additional heuristic rules were used to adjust the add and retain thresholds according to such factors as unit price, unit cube, and whether the item was considered a maintenance-significant part (MSP) or was used primarily on low-density equipment.[6]

The second step focused on establishing the depth of inventory for each part stocked on the ASL. Once the decision was made to stock an item (either add or retain), separate logic was used to calculate the depth. Because the two decisions (breadth and depth) were made independently, there was limited capability to trade off the decision to stock an item against the mobility or cost impact of the depth.[7]

The move to CASL afforded the opportunity for the Army to shift from this two-step heuristic approach to a more-flexible and more-effective mathematical optimization approach using a MIP algorithm.[8] The MIP algorithm can enforce storage constraints to ensure SSA mobility and can use weighting factors to control CASL churn. Rather than calculate breadth and depth independently, the MIP executes an automated search algorithm that finds the breadth and depth of the highest-performing ASL that meets the desired constraints. Furthermore, varying the values for the constraints and weighting factors across MIP runs allows analysis of trade-offs in CASL performance, CASL cube (which drives SSA mobility), and CASL churn. The advantages of using the MIP algorithm to achieve the goals set by Army leadership for the CASL—the second row of Table 2.1—are discussed below.

Improve ASL Performance

A comparison of the ASLs produced using the two-step heuristic approach and the CASLs produced by the MIP showed that, for the same level of SSA mobility and inventory churn, the MIP-determined CASLs provided higher ASL performance (i.e., both overall higher MSP fill rate and higher MSP fill rates for critical equipment).[9] The MIP solutions are superior because the trade-offs analyzed by the MIP are more refined and exhaustive versus the two-step approach using add and retain criteria and a separate depth calculation.

[6] Whether a part is an MSP is determined by how often parts are requested on high-priority work orders Army-wide over the prior three years.

[7] Indexing the depth calculation based on such part characteristics as unit price and unit cube allowed some control of this trade-off, but it was still a rough approximation.

[8] MIP is a generalized algorithm in which the values to be determined can be continuous or limited to integer values. In the case of determining a CASL, all the values to be determined are integer.

[9] Given a demand history, the two-step heuristic approach defines a single ASL. One can then set the constraints and churn-weighting functions for the MIP to achieve the same levels for two of the three dimensions of (1) performance, (2) cube (which determines SSA mobility), and (3) inventory churn (measured as the value of adds and increases). If cube and churn are held constant in the MIP to that achieved with the two-step heuristic, the resulting ASL performance over the demand history will

Another advantage of the MIP is that it can be adjusted to provide higher or lower part support (ASL performance) for different types of equipment in the BCT. When the Army used the two-step heuristic approach, the recommended ASLs provided better parts support to whatever equipment had the highest demands, which is typically the equipment with the highest density in the BCT. For example, the HMMWV, which has the highest equipment density in the BCTs, would typically have the most parts that qualified to be stocked on the ASL based on the add and retain criteria. By contrast, using the MIP, weights can be assigned to specific equipment to drive higher or lower parts support by equipment type and focus ASL performance on the most mission-critical equipment in the BCT.

Ensure SSA Mobility

Under the heuristic approach, the recommended ASL would expand or shrink based on the number of demands in the review period. If a BCT experienced higher OPTEMPO during the period under review than under the preceding review period, the demand for parts would also typically be higher. This would result in recommendations that would increase the size of the ASL, both in terms of the breadth of parts that were recommended (which would increase the number of storage locations required in the SSA) and in the depth or number of each part (which might increase the size of each storage location) and hence reduce SSA mobility. The heuristic approach had no mechanism for enforcing SSA mobility constraints, other than an after-the-fact manual review. By comparison, the MIP algorithm enforces constraints based on the storage configuration of the SSA and, hence, the mobility of the SSA. The MIP algorithm performs an automated search for the ASL with highest performance for the given storage constraints (so only feasible solutions are considered). Also, by making multiple runs of the MIP while varying the storage constraints, it is possible to analyze the trade-off between SSA mobility and ASL performance.

Reduce ASL Churn

Mathematical optimization also permits the Army to closely manage inventory churn during the periodic updates of the CASLs. This is done using churn-weighting factors that, when increased, will reduce the changes from the current CASL to the recommended CASL.[10] As the churn-weighting factors are increased, only changes that have the largest benefit in ASL performance are incorporated into the update recommendations. Making multiple runs at different churn-weighting factors allows the Army to establish the trade-off between ASL performance and ASL churn during the periodic ASL update process.[11]

be higher for the MIP. One could also configure the MIP to get the same ASL performance and cube at lower ASL churn, or the same ASL performance and churn at reduced cube (e.g., a smaller CASL).

[10] Two weighting factors are used, one for Army-managed items (AMIs) and one for non-AMIs (NAMIs). Two weighting factors are used because the availability of OA needed up front to fund ASL changes can be different for AMI and NAMI.

[11] The CASL for each type of BCT involves a subset of fast-moving parts, which must be on the CASL to achieve high performance, and a choice among a much larger population of slower-moving parts. The churn-weighting factors control the amount of change in the latter population while allowing changes that have a more-significant impact on ASL performance. Because the slower-moving parts do not have as large an impact on ASL performance, it might not be worthwhile to make many changes during a CASL update that results in only modest increase in ASL performance. Churn-weighting factors can be adjusted to trade off slightly lower ASL performance to dramatically reduce the need for up-front OA and workload required at each BCT SSA to reconfigure storage, receive and stow new items, and redistribute items no longer on the CASL.

Summary

This section described in nontechnical terms the two major changes made to convert to CASLs: pooling data across BCTs of the same type and replacing the two-step process with mathematical optimization. These changes helped the Army to achieve the three goals of improving performance, ensuring SSA mobility, and reducing inventory churn during the periodic update process. The next chapter provides more detail on the mathematical optimization formulation.

CHAPTER 3

The Mathematical Optimization Formulation

The prior chapter detailed how pooling demand histories across BCTs of the same type and shifting from a two-step process to a mathematical optimization formulation addressed the three goals the Army had laid out for the CASL. This chapter provides a more-technical explanation of the formulation.

Mathematical optimization involves selecting the best solution with respect to some criterion (often referred to as the *objective function*) from some set of available (i.e., feasible with respect to some constraints) alternatives. For the CASL, the mathematical optimization formulation is based on the parts and the quantity of each part on the ASL. Hence, the decision variable and primary output of the MIP algorithm is the inventory level assigned to each part. In this report, we refer to the inventory level as the *safety stock* (SS), which matches the CASL implementation in GCSS-A.[1] If the SS is set to zero, that part will not be stored on the ASL. The MIP algorithm uses an automated search algorithm to set the SS for each part to maximize a weighted readiness benefit function subject to storage configuration and value constraints. Hence, the solution is the mix and quantity of parts to be stored in the CASL, represented by an SS for each part.[2]

This section has three subsections:

- The first subsection focuses on the objective function—how the benefit associated with each part is computed and how this benefit can be weighted to increase parts support to more-critical equipment, to emphasize parts that are used more frequently on high-priority maintenance work orders, and to reflect the costs of inventory churn.
- The second subsection focuses on the constraints that determine the set of available solutions. This includes storage configuration constraints to ensure that the CASL is mobile and constraints on the value of the CASL.
- The third subsection provides a brief description of the MIP algorithm used to solve the mathematical optimization formulation.

Weighted Readiness Benefit

The Benefit Function

The benefit function for each part is constructed to reflect the number of demands that would be filled as the SS is increased. The benefit function is derived from the pooled demand histories. The demand quantities are summed by BCT month for each part. Table 3.1 gives an example of the ABCT monthly demand quantities for an individual part. The ABCTs are listed in the first column, and the months are labeled Q1

1 In GCSS-A, each part on the CASL is assigned an SS . If the SS is greater than zero, then the part is also assigned a minimum lot size (MLS). The system will initiate a replenishment equal to the MLS when the inventory position (on-hand plus due-in minus due-out) for a part drops below the SS.

2 In this formulation, the SS for each part on the CASL is referred to as the *decision variable* for the mathematical optimization.

TABLE 3.1

Twenty-Four Months of Demand for a Part at 11 ABCTs

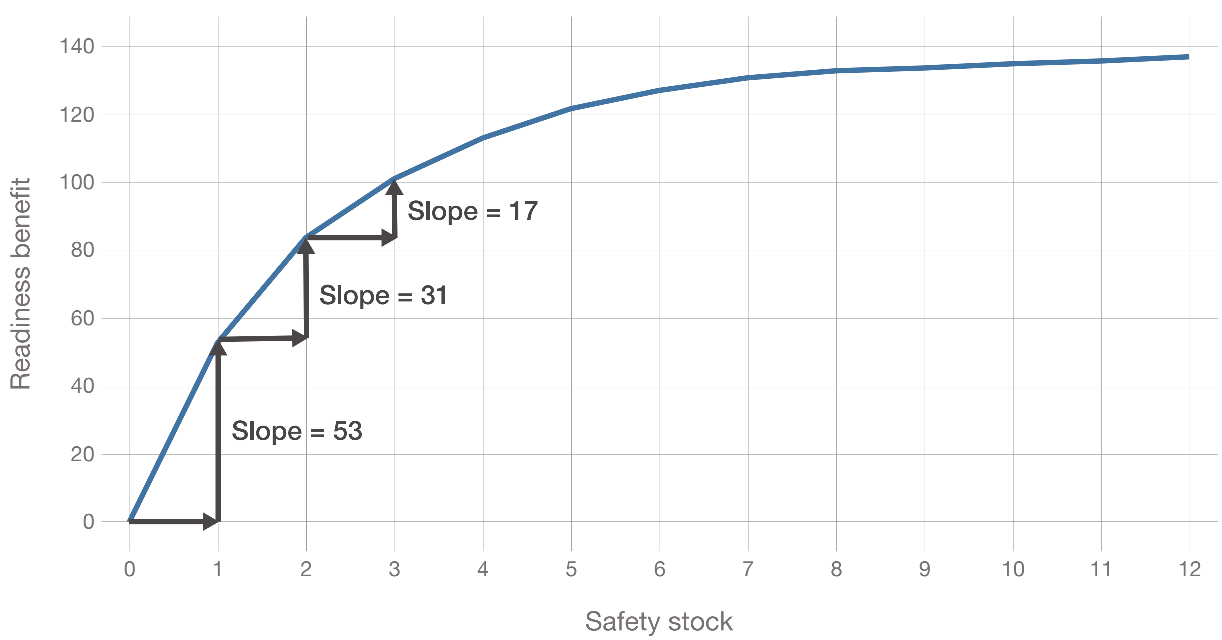
ABCT	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Total Q	# Mo.
1	0	6	0	4	0	0	1	0	0	0	1	2	2	0	0	0	0	0	0	0	0	0	0	0	16	6
2	1	0	0	2	0	0	0	0	7	1	0	0	1	0	7	0	0	0	1	0	0	5	0	0	25	8
3	0	1	0	0	0	8	0	0	0	2	0	2	1	0	3	0	0	0	0	0	0	0	0	0	17	6
4	0	0	0	0	0	0	0	0	0	12	0	0	0	0	3	0	0	0	0	0	0	0	0	0	15	2
5	0	5	0	0	0	0	0	0	3	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	10	4
6	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	4	2
7	0	1	0	0	0	0	1	0	1	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	6	5
8	0	0	0	0	0	0	4	1	1	1	0	0	1	5	0	0	0	0	1	0	0	0	0	0	14	7
9	0	0	0	0	0	0	0	0	2	2	0	0	0	0	4	0	0	0	2	0	0	0	0	0	10	4
10	0	0	0	2	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	1	0	0	0	7	4
11	0	2	0	0	0	0	0	0	1	5	0	0	3	0	0	0	0	0	2	0	0	0	0	0	13	5
																									137	53

SOURCE: RAND Arroyo Center analysis of GCSS-A data.
NOTE: Mo. = months; Q = quantity.

thru Q24 (where Q is short for quantity) along the first row.[3] The cells of the table provide the demand quantities for each of the 24 months for each of the 11 ABCTs.[4] For most ABCT-month cell entries, the demand quantity is zero (211 of the 264 cells). The greatest demand quantity for any BCT over the 24 months is 12 (at the intersection of row four, labeled "ABCT 4," and month 10, labeled "Q10"). The 53 ABCT-month combinations with a positive demand quantity are highlighted in green. The last two columns give the summed quantity (Total Q) and the number of months (# Mo.) with a positive demand quantity for each ABCT. These values demonstrate how each ABCT might make a different decision on whether to stock this part and, if so, how many of this part to stock, if the calculation is based only on demands at each ABCT. The final row of Table 3.1 provides a sum of the last two columns, which gives the total quantity demanded by all ABCTs during the 24 months (137) and the number ABCT months that had a positive demand value (53).

Figure 3.1 displays the resulting cumulative benefit function for the part demands depicted in Table 3.1. In Figure 3.1, the x-axis indicates the SS for the part, that is, the decision variable in the mathematical optimization (solved for by the MIP algorithm). The y-axis indicates the cumulative benefit. As the SS is increased, the cumulative benefit function has a decreasing slope (i.e., it has progressively less added benefit for each increase in SS). The benefit of increasing the SS by one unit is computed by counting the number of periods the item could have been issued from stock to fill customer demand. The following are examples:

FIGURE 3.1
Readiness Benefit Versus Safety Stock for a Part



SOURCE: RAND Arroyo Center analysis of GCSS-A data.

3 At the time, there were nine active-component ABCTs and two rotational ABCTs. The rotational ABCTs included SSAs, and forward-positioned equipment personnel from Overseas Permanent Change of Station–based units would fall in on and use the equipment.

4 Table 3.1 gives an example of the increased data that comes from pooling demands across BCTs of the same type. Analyzing the data by ABCT—running 11 individual ASL reviews—could result in different decisions on whether to stock this part and different decisions on the appropriate inventory level.

- Increasing the SS from zero to one would result in 53 issues (one for each of the 53 ABCT-month combinations with a positive demand quantity). Hence, the slope of the net benefit function is 53 from zero to one. At an SS of one, the cumulative benefit is equal to 53.
- Increasing the SS from one to two would have filled customer demand in only 31 periods (the number of periods in which the demand was greater than one). The slope from one to two is 53 – 22 = 31. Adding a second part to the SS would not add any benefit in the 22 demand periods in which the demand quantity was only one. So, at an SS of two, the cumulative benefit is equal to 84 (53 + 31).
- Increasing the SS from two to three would have filled customer demand in only 17 periods (the number of periods in which the demand was greater than two). The slope from two to three is 53 – 22 –14 = 17. Adding a third part to the SS would not add any benefit for the 22 demand periods in which the demand quantity was only one or the 14 periods in which the demand was only two. So, at an SS of three, the cumulative benefit is equal to 101 = 53 + 31 + 17.

The result of arraying the periods in decreasing quantity and computing the benefit in this way is a piecewise linear function with decreasing slope (defined as a convex function) as the SS increases.[5] A benefit function like that shown in Figure 3.1 is generated from the demand history for each repair part.

Weighting the Benefit Function

The benefit function is weighted by additional factors (besides demand) that either increase or decrease each of the piecewise linear slopes of the benefit function. An increased slope makes the part more desirable for stocking on the ASL compared with other parts. The weighting factors include the following:

1. The fraction of demands for a part on high-priority work orders that can render the equipment inoperable (referred to as *deadlined*): The higher this fraction, the more critical it is to stock the part on the ASL to maintain equipment readiness. A part with a higher fraction of high-priority work orders will get a weight that makes the slope steeper compared with a part with a low fraction of demands on high-priority work orders. The fraction is computed from Army-wide empirical data over the most recent three years.[6]
2. MSPs: A weighting factor to place emphasis on items that are MSP is chosen by the subject-matter expert (SME) at ASC-SDB executing the run.[7] The SME sets this weight by comparing overall ASL fill rate with the fill rate on the subset of MSPs to make sure enough emphasis is placed on MSPs.
3. Weight on the fraction of BCTs with demand: The fraction of the BCTs that had a demand for the part is computed from the pooled demand history and is the count of rows in Table 3.1 where the entry # Mo. is greater than zero (e.g., for the part in Table 3.1, this value is equal to 11/11 = 1). This weighting factor is used to place emphasis on parts that get demand across a large proportion of the BCTs versus parts that have many periods of demand in fewer BCTs (the latter are more likely to be atypical demands). The SME at ASC-SDB sets the weight applied to this fraction.
4. SME-entered equipment weighting factors: A weight can be entered for each type of equipment that the BCTs supports. If no value is entered for a type of equipment, the default is one. A weight greater

[5] A linear function is single constant slope line. A piecewise linear function is a function whose graph is made up of linear (straight-line) segments (see Dantzig, 1963, p. 482).

[6] The fraction must be less than or equal to one and is not allowed to be zero (the minimum value allowed is 0.01).

[7] MSPs are determined using the same empirical data used to compute the fraction deadlining (Army-wide data over three years). The designation of MSP is based on thresholds on the number or percentage of deadlining demands applied by equipment model. If a part exceeds the thresholds for any model, it is designated as an MSP.

than one is used to increase parts support for mission-critical equipment (e.g., M1A2 in an ABCT). A value less than one could be used to reduce the parts support for equipment that is not as mission critical but might have high parts support because of the high density of that type of equipment in the BCT (e.g., HMMWVs in an ABCT). The equipment weights are used to compute an equipment importance weight for each part.[8]

5. SME-entered churn factors: There is a separate weighting factor for AMIs and for NAMIs. These factors are described in more detail below. The SME will typically make multiple runs at different levels of churn-weighting factors to establish the trade-off between CASL performance and the transition costs to execute the CASL update. The final decision on the trade-off is typically determined with guidance from higher-level headquarters.

Weighting factors 1 through 4 above are multiplied to obtain a single weight for each part, which is applied to the benefit function for that part. So, each slope of the piecewise linear function is multiplied by the same scalar value. Because the weights vary by part, this changes the trade-offs across parts by affecting their relative slopes. Consider a part 1 and a part 2 that both have the same demands as in Tables 3.1. Table 3.2 gives the weighting factors for part 1 and part 2: The weighting factors for part 1 multiplied together give the combined weight of 1.5, and the weighting factors for part 2 multiplied together give the combined weight of 0.4.

Figure 3.2 shows the resulting cumulative weighted readiness benefit function for each part and the slopes of the piecewise linear segments. In this case, after the weighting factors are applied, part 1 looks more attractive than part 2. Comparing the slopes of the cumulative benefit functions, one would raise the SS for part 1 from zero to three before raising the SS of part 2 from zero to one. That is, the slope for increasing the SS of part 1 from two to three is 25.5, which is greater than the slope of 21.2 associated with increasing the SS for part 2 from zero to one.

The AMI and NAMI churn factors are applied differently from the other weighting factors. As described in the previous section, the intent of the churn weighting factor is to limit change on the ASL unless the change results in enough performance improvement to justify the associated cost and workload. To discourage change that does not meaningfully improve performance, the churn weighting factors are used, changing the slope of the benefit function above and below the current SS for a part so that (1) the benefit of increasing the SS (or adding the part to the ASL if it is not currently stocked) is reduced and (2) the reduction in benefit of decreasing the current SS is larger.[9] Hence, it becomes more desirable in terms of the net weighted benefit function to keep the SS at the current level.

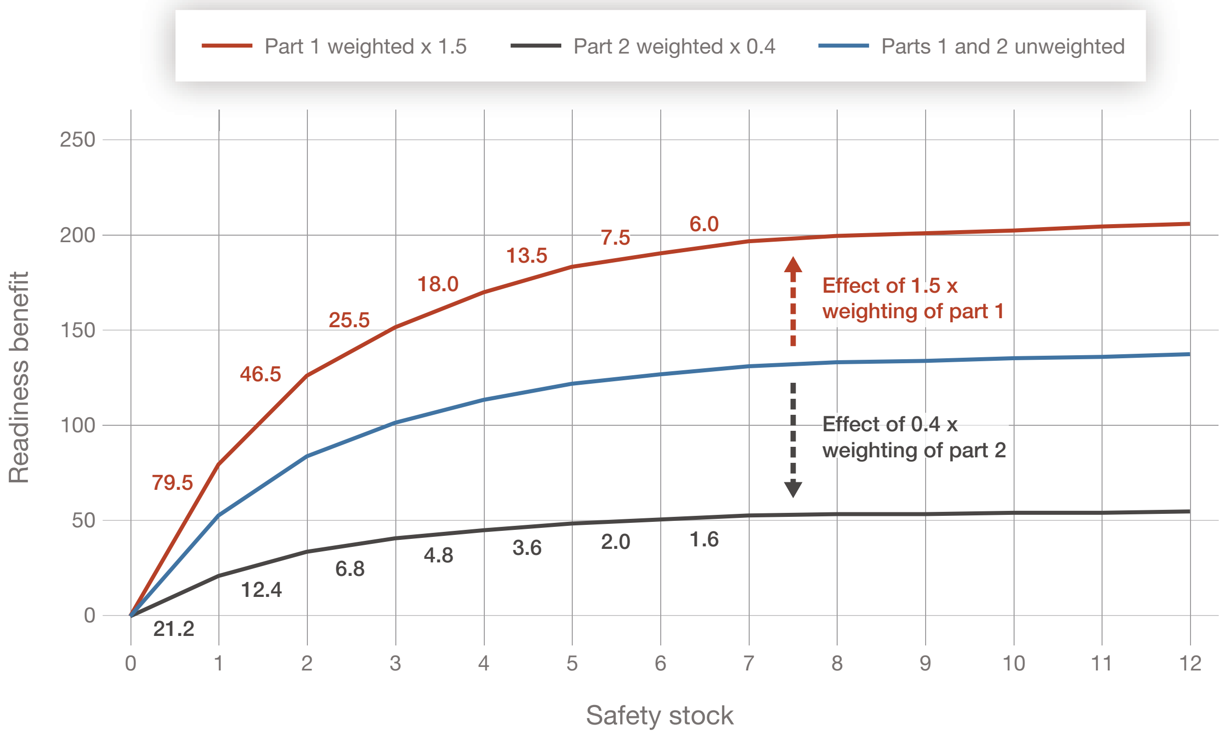
TABLE 3.2
Weighting Factors

Weighting Factor	Part 1	Part 2
Fraction of deadlined demands	0.75	0.2
MSP weight	1	1
Fraction of BCTs with demand	1	1
Equipment weight	2	2
Combined weight	**1.5**	**0.4**

8 In GCSS-A tables, parts are linked to work orders, and work orders are linked to the equipment type being worked on. These links are used to sum across all work orders and part orders to translate the equipment weights to part weights.

9 The current SS for all parts on the ASL is referred to as the *set point*. Increasing the churn weights controls how much the recommendations will change from the set point.

FIGURE 3.2
Effect of Weighting on Readiness Benefit of Two Parts with Same Demands



SOURCE: RAND Arroyo Center analysis of GCSS-A data.

Assume the part with demands shown in Table 3.1 has an SS of three. Applying a churn factor of two would multiply the slopes from zero to three by two and divide the slopes from three to 12 by two. Figure 3.3 shows how the original benefit function given in Figure 3.1 is translated by the churn factor of two. The effect of the churn factor of two is to make the SS value of three the "knee of the curve." That is, the curve will rise very sharply from zero to three and then flatten out beyond three as the churn factor is increased.

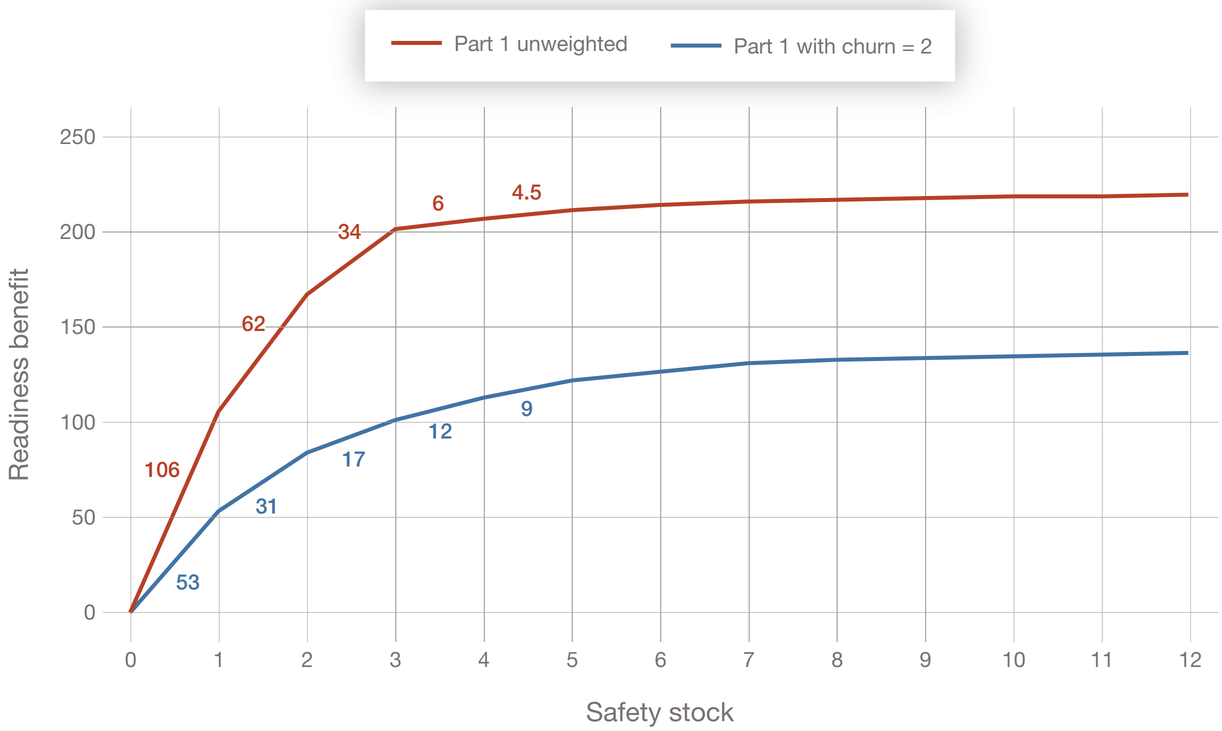
Constraints

When searching for the SS levels that produce the highest-performing ASL, the mathematical optimization must stay within the available set of solutions. The available set of solutions is defined by linear constraints on storage configuration and capacity and value.

Storage Configuration and Capacity

The SSs that are searched to maximize the weighted readiness benefit function must adhere to the SSA's storage configuration. The storage configuration is defined by the number of storage locations (the number of parts with an SS over zero) and the extended cubic feet (the maximum number of parts expected to be in storage times the unit cube summed over all parts). Both constraints can be summed and enforced over all parts. Both constraints can also be enforced by storage categories. The CASL formulation currently uses three

FIGURE 3.3
Effect of Churn Factor of Two on the Readiness Benefit



SOURCE: RAND Arroyo Center analysis of GCSS-A data.

storage categories, bin, shelf, and bulk, that reflect the common types of storage capabilities in SSAs. Parts are assigned a storage category based on part characteristics (e.g., unit cube) and an estimate of the extended cube (quantity times unit cube) that is expected to be in the storage location. The SME can set the number of locations and the extended cube constraint values for the overall ASL and for each storage category. However, unless there is guidance to either expand or reduce SSA storage, the constraint values are typically computed from the existing CASL to avoid having to reconfigure the SSA storage locations.

Whereas the MIP solver assigns the SS for each part (the decision variable), the storage constraints are based on the requirements objective (RO). The RO is the maximum quantity of a part expected to be on hand before any issues to customers. The RO is defined as the SS plus an MLS minus one.[10] The MLS is defined as the minimum quantity desired for each stock replenishment order for the SSA. For many parts, the MLS is equal to one; in these cases, RO = SS. A replenishment order is automatically initiated by the GCSS-A each time the inventory position drops below the SS. For example, if the SSA issues an engine to a maintainer, GCSS-A will order another engine to replenish the SSA inventory back up to the RO. However, for smaller, less-expensive items, the MLS will typically be greater than one to reduce the number of replenishment

[10] The MLS is computed using the Wilson economic order quantity (EOQ), which trades off inventory holding and ordering costs. The MLS is computed for each part using the following parameters: (1) the unit price of the part, (2) annual demand quantity of part, (3) the cost of replenishment order, and (4) the annual inventory holding cost expressed as a percentage of the unit price. The Wilson EOQ was developed for commercial applications, so some additional business rules have been added to better reflect the mobility and constrained storage environment of an SSA.

receipts (a component of SSA workload) required at the SSA. For example, a small, inexpensive washer or bolt would typically have an MLS greater than one.

For the CASL, the bin and shelf storage categories can include information on the maximum quantity that can fit in the existing storage location, referred to as the *opening capacity*. So, for parts stored in bin and shelf locations, we can also define an upper bound for the SS equal to the open capacity minus the MLS.

Value Constraints

There are two ways to address constraints on the value of the inventory. The first is constraining the total value of all the parts on the ASL. This is simply the sum of the SS times the unit price, which is a single linear constraint involving the SS levels (the decision variables).[11] One can then execute the MIP at different levels of inventory value and compare the ASL performance.

A second approach applies if the value of the current inventory is considered a sunk investment. Then, the problem is one of marginal (or transition) cost of updating the ASL versus improving ASL performance (i.e., this approach focuses on the problem of how best to get from the current inventory to an improved inventory). All that matters from a cost constraint perspective is the cost to update to the new recommended SSs from the current SSs. There is no constraint used for this approach; rather, the churn-weighting factors are integrated into the weighted benefit function and used to control the transition costs. The transition costs can be monetary (e.g., the costs required to add new parts or increase the SS of parts already on the ASL) or related to workload (e.g., reconfiguring storage in the SSA). If the constraints on value remain constant, the value of SS additions and increases will be offset by deletions and decreases. The transition cost for the upgrade can be computed from the current inventory, represented by the parts on the ASL and the associated SSs (the set point), to the new parts and associated SSs (recommendation) output from the MIP. As shown in Figure 3.3, increasing the churn-weighting factors makes the current set point look more favorable, and the resulting optimal solution will have lower transition costs. Varying the churn-weighting factors allows the SME to analyze the trade-off of ASL performance and the transition costs when executing a CASL update.

Execution of the MIP Algorithm

Numerous commercial-off-the-shelf MIP algorithms exist.[12] We used the MIP algorithm that is part of the SAS/OR statistical package. This was seamless because we also used SAS to process the data extracts, compute the weighted benefit function and constraints, and put the data in the format required by the MIP solver. The data processing includes cleansing to detect and trim outlier values (e.g., outliers on demand quantity) and correct other data quality problems.

The MIP algorithm uses an automated search procedure (branch and bound) and solves multiple noninteger (i.e., where the SS can be fractional) piecewise linear optimizations to determine the integer SS values that maximize the readiness benefit function while satisfying the constraints.

The output of the MIP algorithm is a list of parts and their associated SS values. Extensive postprocessing and simulation are then executed in SAS to compare the MIP output and the set point (i.e., current ASL) in terms of the multiple dimensions of performance, storage, and value and to compute transition costs.

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[11] Other options include summing the SS and MLS minus one multiplied by the unit price (i.e., RO multiplied by the unit price). One can also use the unit price minus the unserviceable credit in place of the unit price in either case.

[12] Because all the SSs must be integers (cannot be a fraction of a part), this is formally an integer programming problem. However, MIP solvers are generalized code that can handle problems with all integer decision variables or a mix of integer and continuous decision variables.

CHAPTER 4

Conversion of the Army's Armored, Infantry, and Stryker BCTs to CASLs

Because of the significant variation (in terms of which parts were on the ASLs and the depth of each part) across ASLs for BCTs of the same type, the Army recognized that conversion to a CASL would require an upfront investment in inventory. This section provides a brief description of how the mathematical optimization was formulated for the initial conversion, the forecast of the benefits of converting to CASLs, the implementation of the CASLs, and the tracking of ASL performance metrics after the CASLs were implemented.

Formulation for the Conversion Runs and Forecast Benefits

Analysis of the ASLs across each of the BCT types revealed that there was high variability in the ASLs across BCTs of the same type, both in terms of breadth and depth. Figure 4.1 shows each of the ASLs as different shapes. For each BCT, the initial conversion from an ASL (derived from a single BCT demand history) to a CASL typically involved a substantial update, both to the inventory stored in the SSA and to the SSA storage configuration.

To limit the upfront inventory investment and workload required at conversion, it was desirable to favor parts that were common across the ASLs of each BCT type. The set point and churn-weighting factors described in the mathematical optimization formulation were used to accomplish this. Business rules based on the number of BCTs that stocked a part and the part's characteristics (unit cost, unit cube, and whether the part was MSP) were used to develop a composite ASL for each type of BCT. Analysis showed that using the composite ASL as the set point along with the churn-weighting factors when executing the MIP algorithm led to similar CASL performance but could dramatically reduce conversion costs.[1]

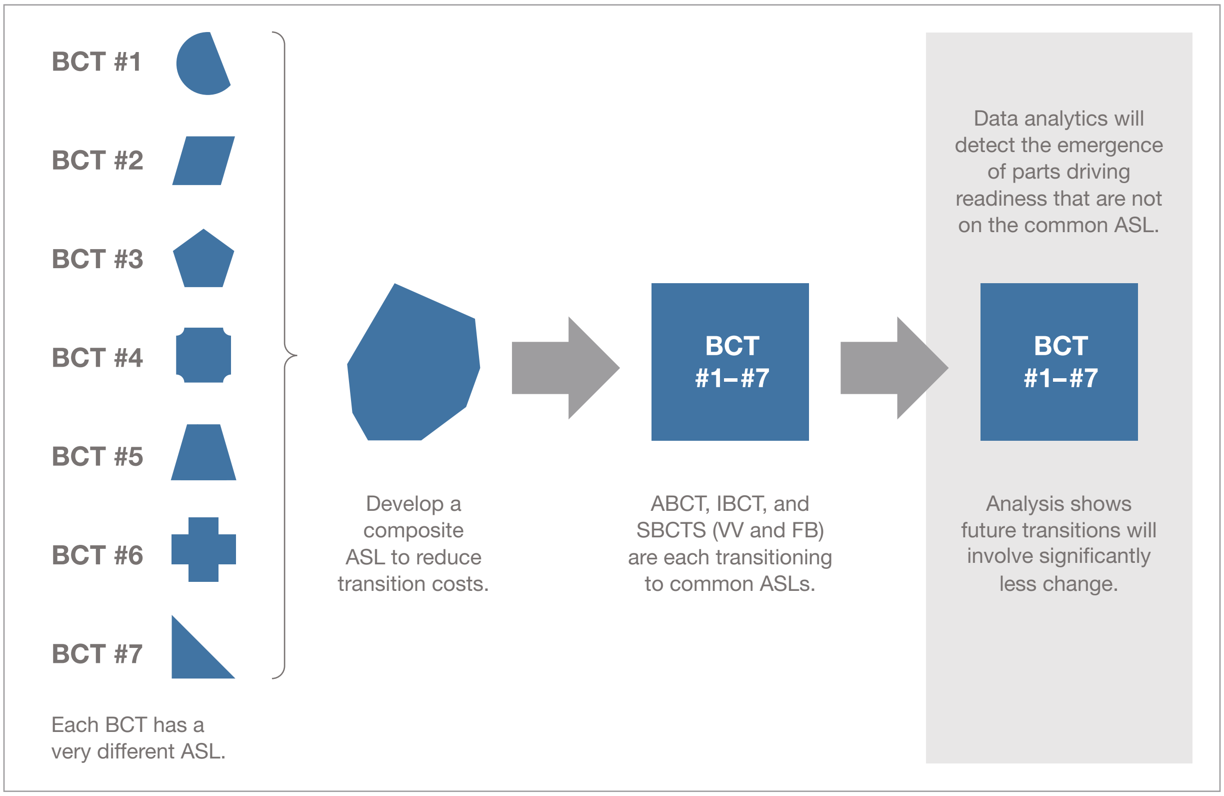
Because no BCT had an ASL that was identical to the composite ASL, the calculations of the upfront costs of *add and increase* (ADD/INC) *actions* (that is, added and increased inventory levels), which were different for each BCT, were computed and summed. Likewise, for the delete and decrease actions.

Because they had different ASLs, the storage configuration of each BCT of the same type also varied. As a result, during the initial conversion, the only storage constraints used were on the total number of locations and total extended cube. The constraints on the number of parts and extended cube were set by comparing the range of values at the current ASLs with the ASL performance desired by the Army.

The CASLs for each BCT type went through a review process by maintenance and supply SMEs at both unit and command levels. A small number of changes were made because of the SME reviews (e.g., for the ABCT, a small number of circuit cards were added to the CASL to support component repair). The SME changes

[1] Conversion costs included the dollar value of ASL additions and increases that would have to be funded by the Army Working Capital Fund (AWCF), the number and value of parts that would have to be redistributed due to ASL deletions and decreases, and the amount of workload at the SSAs.

FIGURE 4.1
Conversion to CASL and Then Update to CASL



NOTE: FB = flat bottom; VV = double V hull.

focused on a small number of more-expensive parts, so the result of the reviews was a modest increase the number of parts on the CASL and an increase in the value of the parts added during the conversion.

Table 4.1 gives a summary of the CASL for each BCT type along several dimensions compared with the range of values for each BCT ASL. The lines and cube targeted for the CASL were in the range of the preconversion range (except for a small increase in number of parts on the ABCT CASL). Moving to CASLs allowed for more-detailed planning to achieve a single storage configuration for each BCT type. The overall net change in RO value was a reduction of $21 million (M) compared with the sum of the RO value over all the BCT preconversion ASLs.

The ASL performance for the CASL was simulated against the pooled demand streams from each of the BCTs. The preconversion fill rates are the result of each BCT's ASL being simulated against its own demand stream.[2] For each BCT type, the CASL resulted in a significant increase in performance.

Although the total RO value for converting to the CASL was reduced by $21M, the Army was more interested in the value of upfront additions and increases to the inventory levels that would require changes to stock positioning and OA to complete the CASL conversion.[3] The Army also wanted to know how OA would

[2] The simulated fill rates tend to be higher than achieved rates in practice because the simulation computes performance assuming that the levels are always replenished on time (i.e., the simulation does not include the effects of any supply chain disruptions, such as national-level back orders). Although simulated accommodation rates tend to be very accurate, the simulated satisfaction rates tend to be higher than achieved rates in practice.

[3] If the total RO value stayed the same, there would be an equal value of delete and decrease actions.

TABLE 4.1
CASL Versus Preconversion

		# of Storage Locations		Extended RO Cube		Extended RO Value			MSP Fill Rate		Class IX Fill Rate	
BCT Type	# of BCTs	CASL	Preconversion Range	CASL (cu ft)	Preconversion Range (cu ft)	CASL	Preconversion Range	Change in RO Value	CASL (%)	Preconversion (%)	CASL (%)	Preconversion (%)
ABCT	11	4236	1600–4000	11.1k	8.0k–20.0k	$13.1M	$9.0M–$26.0M	–$21M	75	55	55	36
SBCT	7	3153	1600–3900	7.3k	5.4k–17.0k	$7.9M	$6.0M–$13.0M	–$7M	75	53	55	37
IBCT	14	2208	1000–2800	3.4k	1.6k–6.4k	$1.8M	$1.0M–$1.9M	+$7M	75	57	55	39

SOURCE: RAND Arroyo Center analysis of GCSS-A data.
NOTE: cu ft = cubic feet.

be affected as the CASLs were updated and how that compared with the current process for updating each BCT ASL independently. To assess the latter, the historical monthly ASL inventory levels were compared over three years to compute the average annual cost of inventory level additions and increases. The annual cost was computed by BCT type and broken out for AMI and NAMI. The results are given in Table 4.2 under the first data column, Legacy Annual ASL ADD/INC. These costs would recur each year if the legacy process was used to update the BCT ASLs based on each BCT's demand history. The cost of the CASL conversion is given in the second data column, CASL Conversion ADD/INC (one time). To estimate the costs of a CASL update, an additional year of demand history was used to convert to a CASL (a year earlier), and the most recent year of demand history was used to execute a CASL update. The results of the CASL update are given in the third data column, CASL Update ADD/INC.

For AMI, the value of ADD/INC actions from the one-time CASL conversion is less than that from the annual average legacy additions and increases (which recur each year). In subsequent years, the lower churn from CASL updates widens the advantage of the CASL. For example, after three years, the value of ADD/INC actions for the legacy process would be 3 × \$107.9M versus \$78.4M + (2 × \$16.7M) for a reduction of \$211.9M. Because SSA inventory is part of the AWCF, the benefit of the reduced churn in the SSA levels is not a dollar cost saving but a reduction of turbulence in stock positioning and national-level requirements (and the associated supply chain costs).

For the NAMI payback period, reducing the value of ADD/INC actions takes less than two years. After three years, the value for the legacy process is 3 × \$20.1M versus \$42.6M + (2 × \$3.8M) for a reduction of \$10.2M. For NAMI, assets must typically be purchased from the Defense Logistics Agency (DLA) Working Capital Fund by the AWCF, so adding or increasing inventory levels translates into a need for upfront OA.

The value of adding and increasing inventory will typically be offset by deleting and decreasing other inventory levels. The latter results in excess parts that can be left in place at the SSA and consumed through demands at the SSA or retrograded out of the SSA to an inventory point higher in the supply chain to allow access to Army-wide demands. So, although the reductions depicted in Table 4.2 do not represent dollar savings on inventory, as pointed out earlier, reduced churn in the inventory levels does typically result in reduced workload and supply chain costs. Also, larger periodic changes to inventory levels can whipsaw the supply chain and result in some of the parts excessed out of SSAs eventually being in excess nationally, reducing the chance of reutilization.

TABLE 4.2

Addition and Increase Costs for Conversion and Legacy

BCT Type	Legacy Annual ASL ADD/INC	CASL Conversion ADD/INC (one time)	CASL Update ADD/INC
AMI ABCT	\$60.3	\$52.5	\$11.0
AMI IBCT	\$7.6	\$8.9	\$1.5
AMI SBCT	\$40.0	\$17.0	\$4.2
AMI Total	**\$107.9**	**\$78.4**	**\$16.7**
NAMI ABCT	\$8.4	\$21.5	\$1.7
NAMI IBCT	\$6.9	\$14.1	\$1.5
NAMI SBCT	\$4.8	\$7.0	\$0.6
NAMI Total	**\$20.1**	**\$42.6**	**\$3.8**

SOURCE: RAND Arroyo Center analysis of GCSS-A data.
NOTE: All values are in millions of dollars.

Implementation of Levels

Based on the forecast improvements in ASL performance and reduced inventory churn, the Army issued the *Common Authorized Stockage List (ASL) Implementation Guidance* in May 2017.[4] EXORD 193-17 directed the active-component ground BCTs' ASLs to be converted to the CASLs and provided general information on how the implementation would occur and the responsibilities of applicable organizations in implementing the CASLs.

Before the CASL, BCTs of the same type had sometimes dramatically different-sized ASLs (see the line and cube ranges in Table 4.1). The storage configurations also varied dramatically. Some SSAs relied partially on fixed storage (e.g., shelving units) inside buildings, and there was a wide variety of FPUs, which were equipped with different storage aids. AMC leadership was adamant that each type of CASL was to have a standard storage configuration of FPUs and flat racks that could be rapidly picked up and moved using the Army's LHS, ensuring SSA mobility.[5] ASC developed a planograph for each type of BCT that mapped all the parts on the CASL to a specific location, which would be the same for each BCT, standardizing the FPU requirements for each BCT type.[6] AMC ordered the FPUs (the BCTs had enough flat racks on their table of organization and equipment [TOE] for bulk CASL storage).

A staggered schedule extending through the end of calendar year 2017 was established to implement the CASL inventory levels, and ASC-SDB worked with the BCTs to manage the schedule and post the CASL levels to GCSS-A. The staggered schedule reflected (1) the BCTs' training schedule and SSA availability, (2) the availability of the FPUs to store the parts, and (3) the desire to spread out the impact of replenishment orders and returns on the supply chain and increase the potential to cross-level inventory. At each BCT, deletions and decreases to the inventory levels were implemented first to free up space and empty locations in the SSA and get any on-hand excess retrograded out of the SSA and moved up the supply chain as quickly as possible.

Tracking ASL Performance

Figure 4.2 shows the accommodation for MSPs by ABCT. Prior to the CASL, there was considerably more variation in accommodation rate by ABCT and over time for the same ABCT. However, once the CASL were posted as stocked items in April 2017, the accommodation rate increased to just above the forecast level of 80 percent.[7] The thickness of the line represents the monthly volume, so where there is still variation after April 2017, this occurred in ABCTs with low monthly volume.

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[4] Headquarters, Department of the Army, *Common Authorized Stockage List (ASL) Implementation Guidance*, HQDA EXORD 193-17, 2017, Not available to the general public.

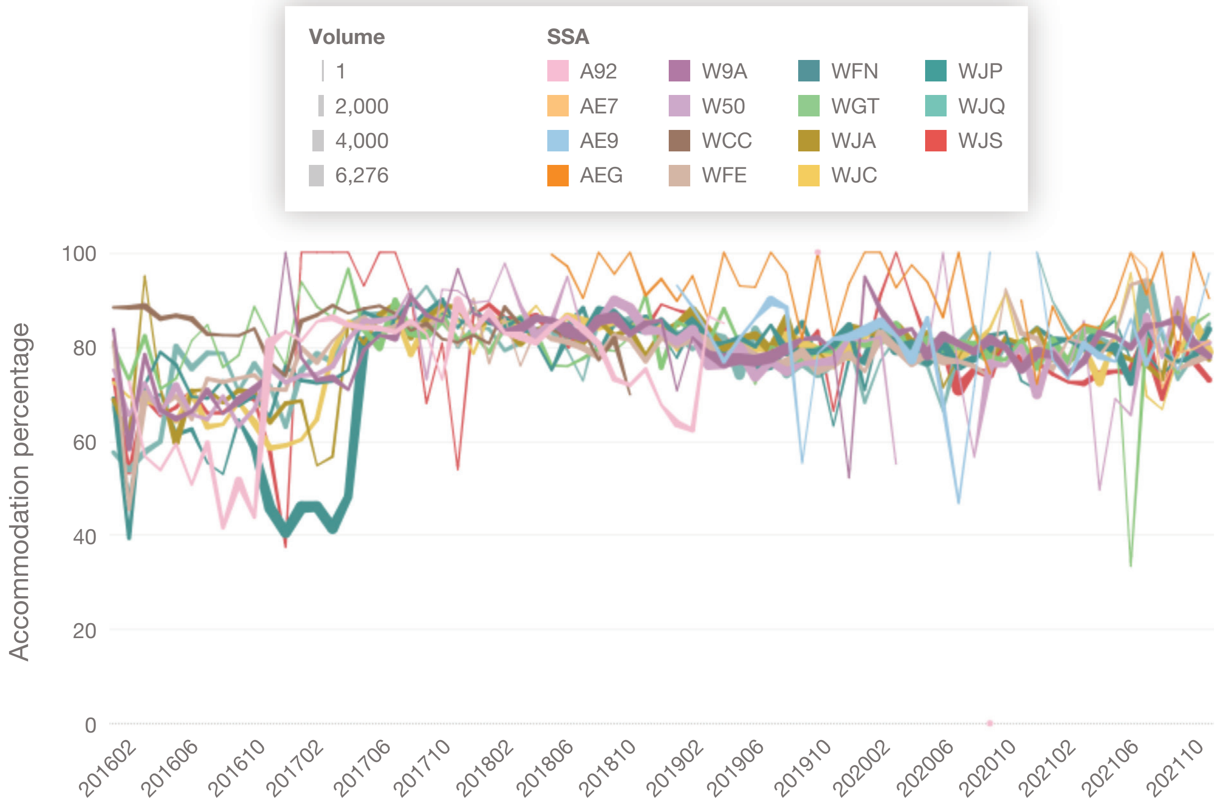
[5] The FPUs can be picked up rapidly, without the need for additional materiel-handling equipment, by trucks equipped with the Army's LHS. Bulk storage items were stored on flat racks, which were already on the units TOE and are also compatible with the Army's LHS.

[6] This also made it possible to formulate and enforce the more-detailed storage configuration constraints described in Chapter 3 for use during future CASL updates.

[7] The parts on the CASL were posted across all BCTs in April 2017 as material resource planning (MRP) type VV (implying that the item was part of the CASL). This allowed any on-hand assets for CASL parts to be retained in the SSA. However, the inventory levels (SS and MLS) for added items were set to zero initially so no inventory was ordered. The inventory levels for the CASL ADD/INC actions were later set in line with the staggered fielding schedule by BCT. Under the GCSS-A supply performance business rules, any demand for a part with MRP type VV was considered accommodated, so the accommodation rates immediately reflected the CASL conversion. However, the satisfaction rates rose over time as inventory levels were set at each BCT by ASC-SDB.

FIGURE 4.2

MSP Accommodation Rate for ABCTs

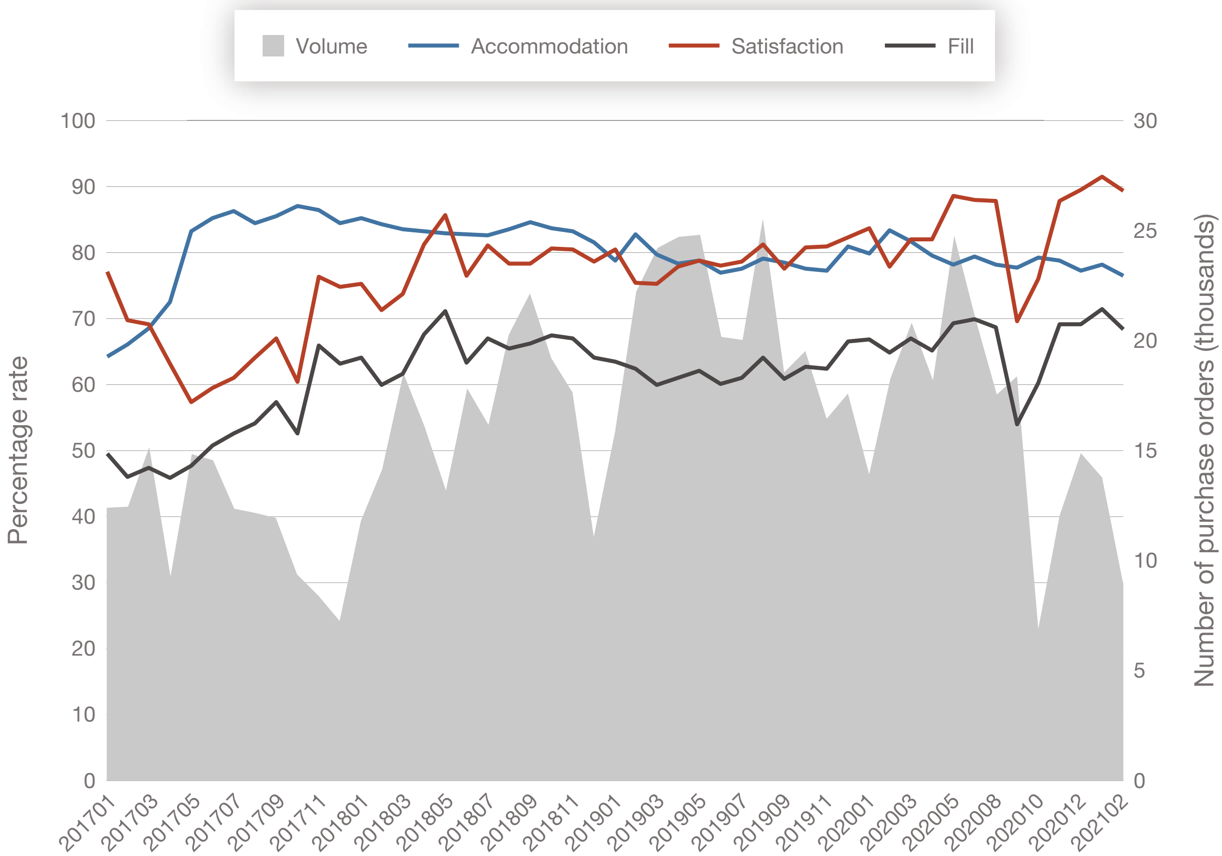


SOURCE: RAND Arroyo Center analysis of GCSS-A data.

The staggered schedule used to implement the CASL inventory levels affected the satisfaction and fill rates of the ASL performance metrics. Figure 4.3 shows the ASL performance for MSPs summed across all the ABCTs. The three lines representing the MSP supply performance rates are read off the left axis; the gray area chart represents the volume (the number of purchase orders received at the ABCT SSAs each month) and is read off the right axis. The blue accommodation line in Figure 4.3 combines the lines shown in Figure 4.2, weighted by volume, as a single line. As noted, the accommodation rate increases immediately in April 2017 as the MRP type of the CASL parts were set. The red satisfaction line represents the percentage of accommodated POs that were satisfied from on-hand inventory. Satisfaction rates initially go down in April 2017 as parts being added to each ABCT had no stock on hand. The satisfaction rates then rise over the next nine to 12 months as the inventory levels were posted at each of the ABCTs and inventory was ordered, receipted, and stowed to location. Satisfaction rates continue to trend up throughout 2019. Analysis showed that this was due to improved national-level supply availability. The sudden decrease in satisfaction rates in September 2020 was due to end-of-fiscal-year financial constraints that delayed ASL replenishments.

National-level supply availability was especially problematic for the ABCTs. In the years prior to conversion to the CASL, much of the tracked fleet in ABCTs had reduced OPTEMPO as the Army focused on operations in Southwest Asia. As OPTEMPO increased and demands went up, part forecasts still reflected the lower historical OPTEMPO. This was especially true for more-complex AMI parts that have longer lead times. Figures 4.4 and 4.5 give the MSP ASL performance for AMI and NAMI parts, respectively. Simula-

FIGURE 4.3
MSP Fill, Satisfaction, and Accommodation Rates for All ABCTs

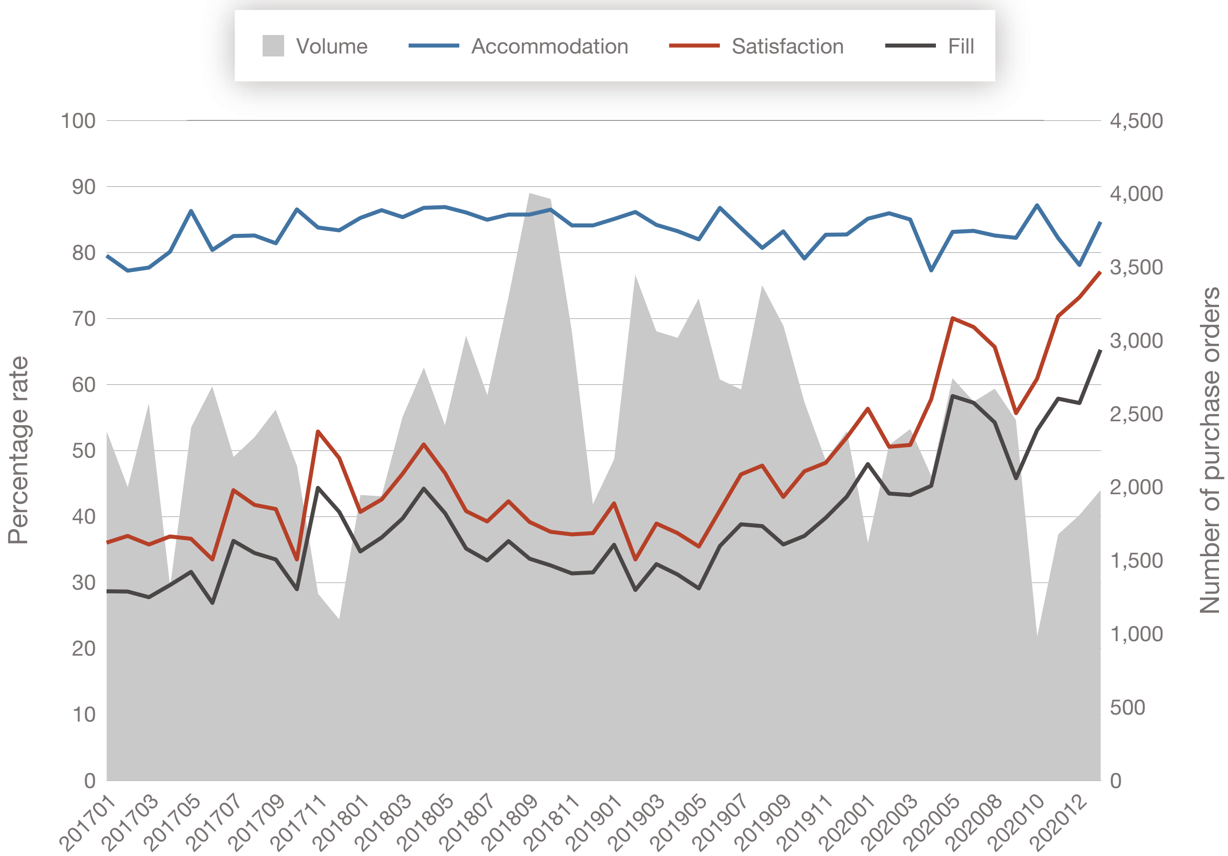


SOURCE: RAND Arroyo Center analysis of GCSS-A data.

tion of the inventory levels verified that the low satisfaction rates were the result of low national-level supply availability. When ASL replenishments do not occur on the expected timelines (30 days for the CASL calculations), the results are low satisfaction rates and low fill rates (accommodation rates are not affected by supply chain disruptions).

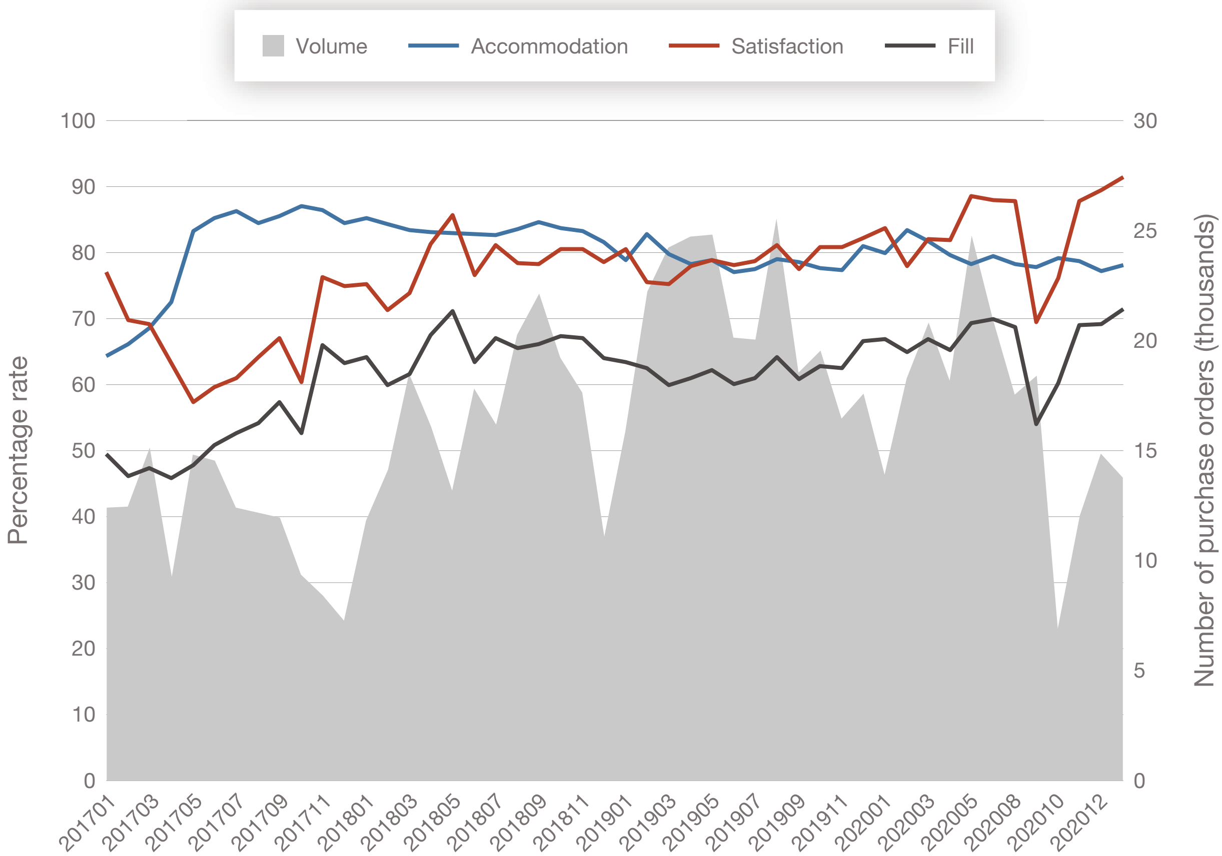
The conversion from different ASLs to a CASL for BCTs of the same type is a one-time process. Once the CASL is in place, subsequent updates use the current CASL as the set point, and the churn-weighting factors can be used to establish the trade-off between update costs and CASL performance. Also, during a normal CASL update, the storage configuration is the same across BCTs of the same type, so the storage constraints by category and storage location capacities can be enforced. The CASL update process is shown in the shaded area on the right side of Figure 4.1 and is discussed in more detail in the next chapter.

FIGURE 4.4
MSP Fill, Satisfaction, and Accommodation Rates for AMI Parts for All ABCTs



SOURCE: RAND Arroyo Center analysis of GCSS-A data.

FIGURE 4.5
MSP Fill, Satisfaction, and Accommodation Rates for NAMI Parts for All ABCTs



SOURCE: RAND Arroyo Center analysis of GCSS-A data.

CHAPTER 5

Updates to the Common ASL

The purpose of this section is to highlight some of the trade-offs that can be analyzed using examples from a CASL update—SSA storage configuration, weighting of mission-critical systems, and churn-weighting factors—and to summarize the results of the most-recent CASL update.

SSA Storage Configuration

Improved modeling of SSA storage configuration through the storage constraints described in Chapter 3 directly affects the workload required in the BCT SSAs to execute a CASL update and the mobility of the SSA. As pointed out in Chapter 4, in the initial conversion to the CASL, SSAs for each BCT type had very different storage configurations. Hence, the initial conversion to the CASL used only two constraints to model SSA storage: the number of locations and the extended cube of the parts. Chapter 3 gave the current formulation of the storage constraints, which adds location and cube constraints by three storage categories (bin, shelf, and bulk) and a capacity constraint for each bin and shelf location.

Table 5.1 provides results for the ABCT CASL update. The entry in the first column for each row of Table 5.1 briefly describes the input parameters used to drive the model, followed by simulated ASL performance for the subset of MSPs and then for all repair (class IX) parts. Figure 5.1 depicts the MSP and class IX fill rates in Table 5.1 as a line chart.

The first four rows of Table 5.1 highlight the effects of adding additional SSA storage configuration constraints on ASL performance (the fifth and sixth rows will be addresses in the next subsection on weighting mission-critical systems). The first row of Table 5.1 is for the current common ABCT ASL, which is used as the set point in each of the subsequent runs. The second row, labeled "+ total line/cube/value," gives the results of having just two constraints describing the storage configuration, total number of storage locations, and total extended cube along with a constraint on total value. Although the performance improved, more-detailed analysis showed that updating with these limited constraints resulted in a solution that would be very difficult for the SSAs of the ABCTs to implement in their existing standard storage configuration. The storage category breakdown showed that this result devoted bulk storage cube (typically on flat racks) to parts that are assigned to shelf and bin locations in FPUs. The third row, labeled "+ category line/cube," gives the results of adding line and cube constraints by storage category to the update. The reduction in ASL performance for MSP fill rate from 74.6 percent to 73.2 percent suggests that there is potential to increase performance if ASC can refine the planograph to fit more parts (increased depth and, potentially, increased breadth) in the same footprint (i.e., the same number of FPUs).

The addition of the line and cube constraints by storage category constrained the update to the same amount of storage locations and cube by storage category. However, it still allowed individual locations in those storage categories to change size. The update resulted in 265 bin or shelf parts exceeding their opening capacity. Across the Army, 15 ABCTs had implemented the CASL, so the update would require reworking 15 × 265 = 3,975 locations, a significant workload.

TABLE 5.1
Performance Effect of Adding Storage Constraints and Equipment Weighting

	MSP			All Class IX		
Storage Constraints	Accommodation (%)	Satisfaction (%)	Fill (%)	Accommodation (%)	Satisfaction (%)	Fill (%)
Set point	77.7	89.5	69.5	57.4	89.4	51.3
+ total line/cube/value	80.5	92.7	74.6	59.4	92.7	55.1
+ category line/cube	80.2	91.3	73.2	59.1	91.2	54.0
+ opening capacities	80.1	91.1	73.0	59.1	91.1	53.8
+ weight critical equipment	80.5	90.6	72.9	59.4	90.5	53.7
+ increased weight	80.2	90.2	72.3	59.3	90.2	53.5

SOURCE: RAND Arroyo Center analysis of GCSS-A data.

The fourth row of Table 5.1 shows the effect of adding the quantity constraints for the shelf and bin locations. As seen from Table 5.1, and shown graphically in Figure 5.1, enforcing the upper bound on bin and shelf locations had almost no effect on ASL performance (MSP fill rate went from 73.2 percent to 73.0 percent), suggesting there was little benefit to the SSA workload of reworking the 3,975 locations across the Army's ABCTs.

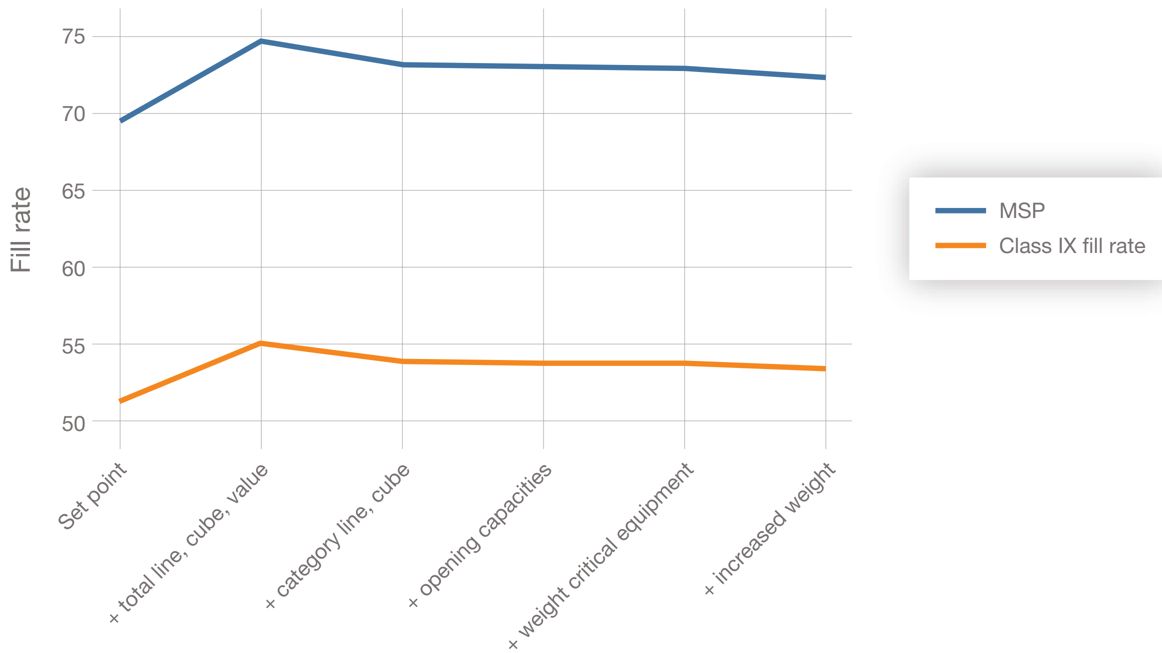
Weighting of Mission-Critical Systems

GCSS-A wave 2 extended GCSS-A below the SSA to include maintenance, supply, and property book activities in the unit motor pools. When sufficient data history was available from GCSS-A wave 2, it was possible to add weighting factors by equipment model to the weighted benefit function described in Chapter 3. The overall ASL performance results for these two runs are given in the fifth and sixth rows of Table 5.1 and fifth and sixth x-axis entries in Figure 5.1. As can be seen in both cases, the overall performance drops slightly as the equipment weights are introduced. However, Figure 5.2 gives more details on the ASL performance. In Figure 5.2, the left y-axis shows high-priority job fill rate, graphed as grouped columns.[1] Each group of four columns represents the first row of Table 5.1 (set point), followed by rows four, five, and six. The right y-axis gives the number of high-priority jobs (across all ABCTs in the review period), graphed as a line chart (and sorted in decreasing number of jobs). The x-axis gives the equipment type, grouped into similar equipment families (e.g., the HMMWV label includes result for high-priority work orders across all the HMMWV models in the ABCT).[2] Below the graphic are the equipment weights that were applied to the runs in the fifth and sixth rows of Table 5.1. Equipment weights less than one will deemphasize parts

[1] With the addition of GCSS-A wave 2 data, the postprocessing of the results simulates the set point and recommended inventory levels down to the maintenance job. Job fill rates are defined at the maintenance job (or work order) level. For a job to be filled, all parts on the job must be filled. If even one part is not filled from the SSA, the maintainer must wait for the due out to the SSA to be filled by national-level supply. Focusing on high-priority jobs places more focus on maintenance jobs that the mechanic indicates can deadline equipment. Hence, high-priority job fill rates are more closely correlated with equipment readiness than MSP or class IX fill rates.

[2] The grouping was done only to keep the number of x-axis entries readable. One can use different weights for different HMMWV models (the weights are by end item National Item Identification Number). For example, one could choose to deemphasize the M1097A2 but not the M997 (ambulance) or HMMW ECV (up armored) models.

FIGURE 5.1
MSP Fill and Class IX Fill Rates for a Series of Input Parameters



SOURCE: RAND Arroyo Center analysis of GCSS-A data.

support for the equipment—the smaller the value, the less parts support.[3] Equipment weights greater than one emphasize parts support—the greater the weight, the more parts support.

Table 5.1 and Figure 5.1 show that overall ASL performance measured in terms of MSP and class IX fill rates goes down slightly when equipment weights are introduced. However, Figure 5.2 shows that this slight decrease in overall performance is the result of an increase in job fill rates for mission-critical tracked systems (e.g., Tank M1, M2 IFV, and RECV M88) offset by lower job fill rates for HMMWVs. The mission criticality of the tracked systems implies the weighted solutions are more desirable.

Churn-Weighting Factors

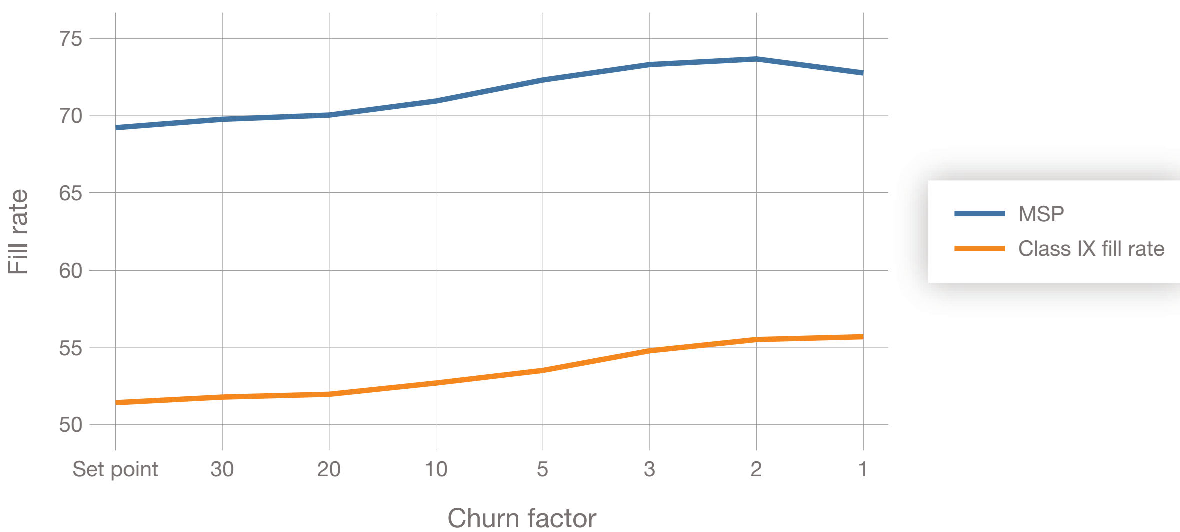
Chapter 3 provides a description of how the churn-weighting factor (AMI and NAMI) and the set point are used to modify the weighted benefit function for each part. In this analysis, the AMI and NAMI churn factors are set to the same value. All these runs used the same input parameters as the sixth row in Table 5.1, which used a churn weight of five. Figure 5.3 shows the MSP and class IX fill rates for the set point (first row in Table 5.1) and several churn factors along the x-axis. As the churn factor increases (right to left), the recommended inventory levels approach the set point, and the fill rates approach the fill rates for the set point.

[3] If a weight of zero is used for an equipment model, parts used for that model will not get stocked unless they are also used on some other model with an assigned equipment weight greater than zero. This weighting can be used to eliminate parts support for equipment that has been transitioned out of the BCTs but still has demands in the review period.

FIGURE 5.2
Job Fill Rates by Equipment Type

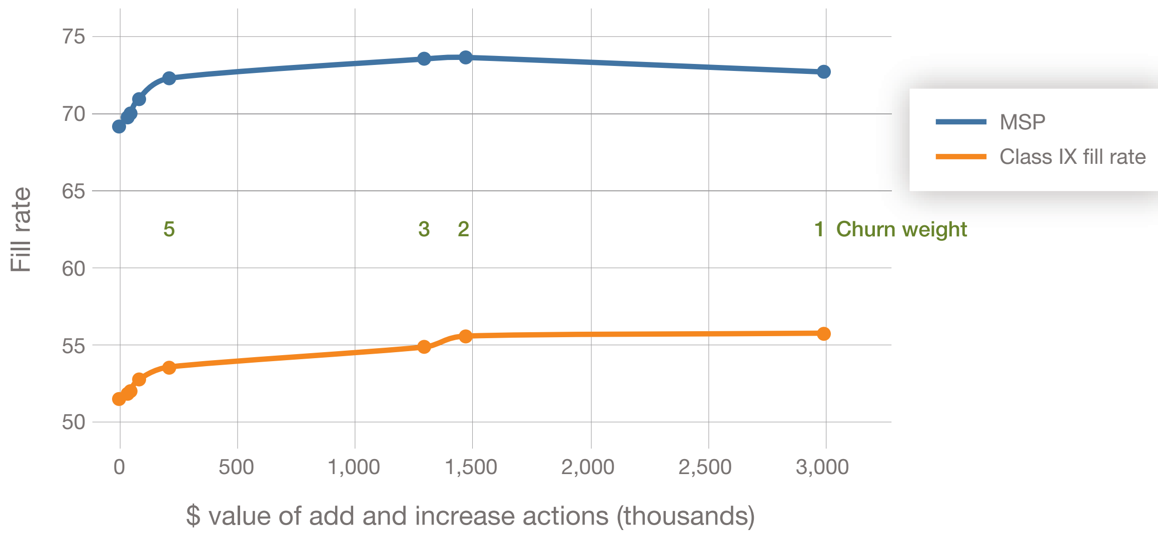
SOURCE: RAND Arroyo Center analysis of GCSS-A data.

FIGURE 5.3
MSP Fill and Class IX Fill Rates for a Different Churn Weights



SOURCE: RAND Arroyo Center analysis of GCSS-A data.

FIGURE 5.4
MSP Fill and Class IX Fill Rates Versus Dollar Value of Add and Increase Actions



SOURCE: RAND Arroyo Center analysis of GCSS-A data.

Figure 5.4 shows the MSP and class IX fill rates versus the value of added and increased inventory levels. The churn weights associated with the rightmost points on the graph are also given in the middle of the graphic. The set point is on the y-axis (associated with cost = 0). The churn factors of 10, 20, and 30 approach the y-axis and are too close to label. The graph shows that a churn weight of five (which is the sixth row from Table 5.1) is at or near the knee of the curve and that decreasing the churn weight leads to a large increase in the value of the ADD/INC actions with only small increases in either MSP or class IX fill rate.

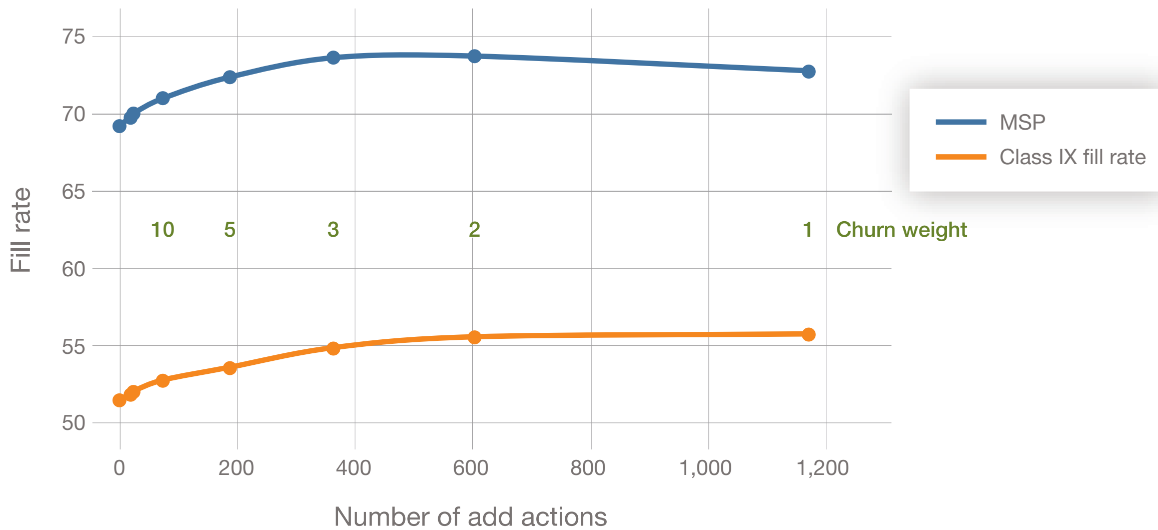
Figure 5.5 shows the MSP and class IX fill rates versus the number of add actions (i.e., parts that are not on the current CASL but will be on the updated CASL). The number of add actions is important because it drives workload needed to adjust the storage configuration in the SSA (increase actions do not result in change in storage configuration if the opening capacity constraints are used). Again, the set point is on the y-axis (associated with 0 add actions). The churn factors of 20 and 30 approach the y-axis and are too close to label. The results are like those in Figure 5.4 in that increasing the churn weight reduces the number of add actions as the recommendations get closer to the set point. Meanwhile, decreasing the churn weight below five rapidly increases the number of add actions. Reducing the churn weight from five to three more than doubles the number of add actions, and a churn weight of one results in a sixfold increase with little improvement in ASL performance in either case.

Overall CASL Updates

This section has provided examples of the trade-off analysis done for the most-recent CASL update for ABCTs. The other BCT types went through a similar trade-off analysis to determine the storage configuration constraints, how to weight the equipment for repair parts support, and how to adjust the churn weights to establish the trade-off between transition costs and ASL performance.[4] Because ADD/INC

[4] Because of differences in repair parts required for FB and VV Stryker vehicles, a CASL is computed for the two different types of Stryker BCTs.

FIGURE 5.5
MSP Fill and Class IX Fill Rates Versus Number of Add Actions



SOURCE: RAND Arroyo Center analysis of GCSS-A data.

actions for each BCT type can affect the AWCF, adjusting the churn weights might involve shared goals across the types of BCTs. Table 5.2 gives the results of the value of ADD/INC actions across each of the BCT types. At just over $10M, this compares favorably with the forecast for CASL update costs of $20M from Table 4.2 (even though Table 5.2 includes national guard BCTs, which increase the total number of BCTs). However, the value of the ADD/INC actions has shifted toward NAMI versus AMI compared with Table 4.2. This has occurred as the Army has transitioned additional consumable parts to DLA. The shift from AMI to NAMI has been more significant for the SBCTs. At the time of the initial CASL conversion, most of the consumable parts that supported the Stryker were still under Army management (having transitioned from contract logistics support). Now they are under DLA management and counted in the NAMI totals of Table 5.2.

Extending to Additional Applications

ASC-SDB has done analysis to convert Combat Aviation Brigades (CABs) and Air Defense Artillery Brigades to CASLs. Additionally, the MIP algorithm is being used in setting inventory levels for umbrella ASLs (UASLs).[5]

The analysis summarized in this chapter reflects the second CASL update conducted by the ASC-SDB for ABCTs, IBCTs, and SBCTs. This was the first CASL update with the improved SSA storage configuration constraints and equipment weighting, which increased the utility of the trade-off analysis (see Figures 5.1 and 5.2). The trade-off analysis presented in this section would also be useful for single SSA runs.

[5] Setting UASLs requires including demands from rotational SSAs or units whose demands are not directly aligned with the SSA operating the UASL. Because the ATF process in GCSS-A is limited to using direct support unit consumption, it cannot be used to set UASL inventory levels. Similar limitations for ATF would have occurred in deployed operations in Southwest Asia when units rotated into forward operating bases supported by one or a limited number of SSAs. As units and the equipment support changed, the consumption history at the forward SSA was less relevant than the demand history of the units deploying to theater.

TABLE 5.2
Value of Add and Increase Actions for CASL Update

	NAMI		AMI				
BCT Type	Add	Increase	Add	Increase	Per BCT	# of BCTs	BCT Total
ABCT	$128,260	$64,003	$22,698	$117,953	$332,914	16	$5,326,624
IBCT	$49,222	$18,832	$28,120	$1,460	$97,634	15	$1,464,503
SBCT (FB)	$79,885	$95,983	$92,674	$118,173	$386,715	5	$1,933,576
SBCT (VV)	$99,489	$77,711	$121,214	$106,620	$405,034	4	$1,620,135
						Total =	**$10,344,838**

SOURCE: RAND Arroyo Center analysis of GCSS-A data.

Although single SSA applications would not benefit from pooled demands, using the mathematical programming formulation (i.e., the MIP) to replace the current two-step process would still provide the benefits in the second row of Table 2.1 and would enable increased analysis of the trade-off between transition costs and ASL performance.

Abbreviations

ABCT	armored brigade combat team
ADD/INC	add and increase
AMC	Army Materiel Command
AMI	Army-managed item
ASC	Army Sustainment Command
ASL	authorized stockage list
ATF	Authorized to Forecast
AWCS	Army Working Capital Fund
BCT	brigade combat team
CASL	common authorized stockage list
DCB	dollar cost banding
DLA	Defense Logistics Agency
EDCB	enhanced dollar cost banding
ERP	enterprise resource planning
FB	flat bottom
FPU	field pack unit
GCSS-A	Global Combat Support System—Army
HMMWV	high-mobility multipurpose wheeled vehicle
IBCT	infantry brigade combat team
LHS	load-handling system
M	million
MIP	mixed-integer programming
MLS	minimum lot size
MRP	material resource planning
MSP	maintenance-significant part
NAMI	non-Army-managed item
OA	obligation authority
OPTEMPO	operational tempo
RO	requirements objective
SBCT	Stryker brigade combat team
SDB	Stockage Determination Branch
SME	subject-matter expert
SS	safety stock
SSA	Supply Support Activity
TOE	table of organization and equipment
UASL	umbrella authorized stockage list
VV	double V hull

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