Strategic Analytics for NATO Supply Chain Operations

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ABSTRACT

"Strategic Analytics", the alignment of analytical methods and Operations Research models with the "ends-ways-means" strategy paradigm, is introduced. To fully capitalize on advances in information technologies and data sciences, the complementary power of operations research, data sciences, and management innovation will be essential. Strategic Analytics integrates the intellectual capacities, strategic planning acumen, and diverse analytical skills represented across our profession. Functional components and enabling disciplines are described including decision support capabilities and dynamic strategic planning to focus organizational effort, assess performance, monitor progress, and create flexible designs for adaptability in complex enterprise systems. Inherent in this ambitious project is an "engine for innovation" to encourage and guide transformational endeavors. This paper describes the application of Strategic Analytics to the US Department of Defense materiel sustainment enterprise system. To understand seemingly intractable logistics challenges, the US Army established the project to Transform Army Supply Chains (TASC). An overview of the origination, evolution, and outcomes derived from applying Strategic Analytics to the TASC Project is presented. Benefits include dramatic improvement in forecast accuracy, reduced tactical-level workarounds, cost savings on the order of tens of billions of dollars, and the ability to relate resource investments to readiness outcomes.

1. STRATEGIC ANALYTICS: AN OVERVIEW

Strategic Analytics is an innovative concept to align optimization algorithms, predictive models, and descriptive methods with the "ends-ways-means" national security strategy paradigm. This analytic framework incorporates imaginative and creative ways to address many persisting problems that confront us. To fully capitalize on advances in information technologies and data sciences, the complementary power of operations research, data sciences, and management innovation will be essential. Strategic Analytics integrates the intellectual capacities, strategic planning acumen, and diverse analytical skills represented across our OR profession, and focuses them on formidable national and international security challenges [1].

Military organizations, especially successful ones, are renowned for their strong cultures. Yet the long history of military innovation reveals those cultures can also become impediments to adaptation when failure looms imminent or is actually even evident. Change has always provoked resistance, especially in large bureaucracies that require conformity. To overcome both bureaucratic inertia and paralysis induced by disruptive chaos, cultures must have sources of innovation they can embrace. Some mechanism is needed to challenge the underlying logic of current practices, and to also demonstrate better ways ahead. Strategic Analytics can provide such a mechanism. For example, it offers a practical approach for understanding the military logistics system which has been categorized as "high-risk" by the U.S. Government Accountability Office for the past three decades due to persisting inefficiency, ineffectiveness, and inadequate strategic planning. Logically structured using descriptive, prescriptive, and predictive analytics, cutting-edge supply chain theory, powerful analytical methods, and innovative strategic planning and management concepts are applied to this seemingly intractable national security resource challenge.

This paper is subsequently developed in two parts. First, a Strategic Analytics overview including foundational building blocks is provided and then, second, a military logistics application of Strategic Analytics to the materiel sustainment enterprise is presented.

1.1 Information Technologies

We now have an increasingly powerful link between Big Data and Analytics, the extensive use of data, statistics, and quantitative algorithms for descriptive (explanatory), predictive (forecasting), and prescriptive (optimization) modeling and analyses. Through sensor technology, RFID, ERP systems, and the internet, IT has expanded to capture, track, monitor and make visible data in near-real time across disparate, dislocated entities comprising the entire enterprise, thereby providing total asset visibility. But we have yet to fully integrate *analytical architecture* into our enterprise system challenges. Complementary decision support systems have not yet been developed to capitalize on all this (overwhelming) enterprise data and, using analytically-based methods, dramatically improve performance for defense enterprise systems.

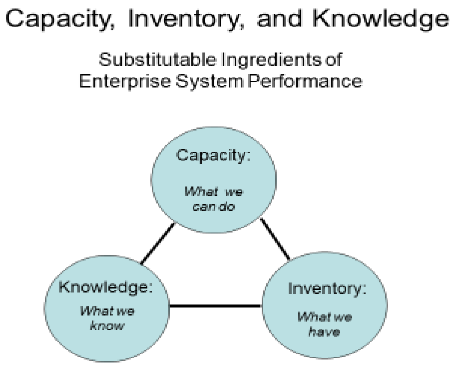


Figure 1-1: Substitutable capabilities for enterprise system performance.

The concept of Strategic Analytics is motivated by a fundamental truth graphically portrayed in Figure 1. If uncertainty is viewed as the complement of knowledge, then for a fixed demand the three quantities shown (inventory, capacity, and knowledge) are substitutes in the following sense: If more of one is available, then less of one or both of the others is necessary for the same level of system performance needed to meet that demand. This trade-off suggests a fundamental truth: if the amount and timeliness of useful data and good information for actionable decisions improves (i.e., increased knowledge or “what we know”), then with the same capacity (“what we can do”) as before, it now becomes possible to improve system performance with fewer resources (“what we have”).

1.2 Decision Support Systems

Empirical studies have consistently shown that “IT solutions” alone, even when implemented with the best information systems tools, have *not* produced desired or expected results without accompanying business process changes. Although so-called “IT solutions” have ubiquitous appeal and enormous investment levels, without using the analytical, integrative power of OR to focus business process reengineering on desired outcomes, this obsession with IT results in growing complexity, exceeding the interpretive capacities of organizations responsible for developing and using them. The effects of this information and cognitive overload has been termed an “ingenuity gap”. To bridge this gap, a complementary relationship between decision support systems (DSS) and management information systems (MIS) – both symbiotic and synergistic – is needed.

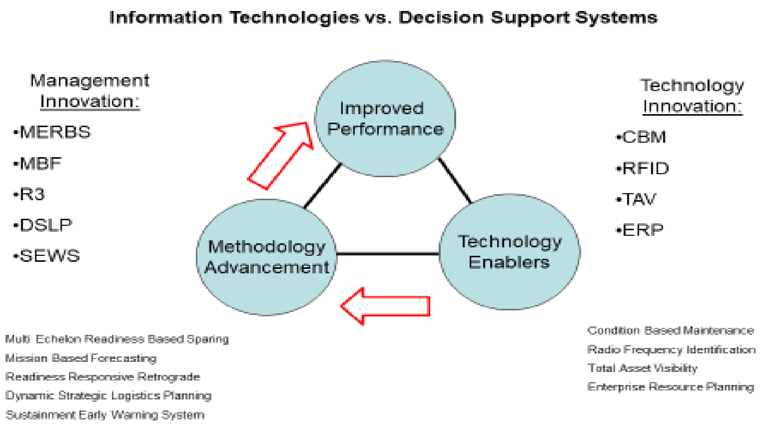


Figure 1-2: Differentiating technology from management innovation.

Ultimately, this *management innovation* approach will enable senior leaders and managers to generate knowledge and better decisions from the growing amounts of information and improved situational awareness made available by advances in information systems technologies. The goal should be effective integration of Analytics into management policies for organizational decision making. Hence, for large-scale complex organizations, the greatest return on investment is derived from incorporating relevant analytical tools (OR) *with* the appropriate IT. Acknowledging these needs and developing the capacity to address them represent first steps toward Strategic Analytics.

1.3 The Internet of Things

Early in World War II, one of the emerging technologies that provided impetus for creating and rapidly developing OR was Radio Detection and Ranging, now simply known by its acronym “radar”. Today, the Internet of Things (IoT) offers another disruptive opportunity for OR to integrate new technologies into enterprise systems. The Internet, which evolved from mainframe computers, to connecting personal computers, then mobile devices, is now linking digital with physical worlds using interconnected networks.

Defined as networks of devices, objects, and people, IoT reflects the convergence of multiple technologies, including: real-time analytics, machine learning, sensors, and embedded systems including wireless networks, micro-control systems, and automation. This next wave of the IT revolution is integrating human with machine intelligence by connecting digital and physical worlds to improve performance through greater automation and sensor-based analytics across consumer, commercial, industrial, and infrastructure applications**.** IoT is also enabling a variety of prognostic early warning systems which capitalize on predictive analytics to anticipate change, then pre-empt system degradation or failure through proactive management interventions in large-scale enterprise systems. One such IoT applications for defense enterprise systems is described further in the Strategic Analytics application section: “connecting” Condition-Based Maintenance (CBM) to military supply chains for a Sustainment Early Warning System;

1.4 Dynamic Strategic Planning

Most system design methods generate a precise, “optimized” solution based on a set of very specific conditions, assumptions, and forecasts. While these conditions and assumptions may be appropriate in the short term for tactical operations, a practical limitation of these techniques is that they are rarely valid over

longer planning horizons as strategic designs for technological systems.
In contrast, Dynamic Strategic Planning (DSP) instead presumes forecasts to be inherently inaccurate ("the forecast is always wrong") and therefore incorporates flexibility as part of the design process. Originally developed, refined, and applied at MIT by the Engineering Systems Division led by Professor Richard de Neufville and his colleagues, this method incorporates and extends earlier best practices including systems optimization and decision analysis. It has evolved by adapting "options analysis", now commonly associated with financial investment planning. DSP allows for the optimal policy, which cannot be preordained at the beginning of the undertaking, to reveal itself over time while incorporating risk management: a set of "if-then-else" decision options evolving as various conditions unfold that, even when anticipated, cannot be predicted with certainty.

The goal of DSP is to optimize expected performance by building flexibility into the project to enable adaptability to changing circumstances that inevitably prevail. DSP incorporates flexibility into the system design to accommodate and respond to changes as they occur in the real world, even though we cannot predict exactly when or how they may occur. This built in flexibility actually creates additional value for the system, and in many cases this additional value can be quantified.

As implementation evolves, and subsequent events occur, a mechanism is needed to routinely update the current solution. This "optimal" solution will inevitably change over time due to an inability to perfectly forecast future conditions, or the consequences of past decisions that do not always reveal the results expected. And, as well, opportunities provided by adaptation and innovation will materialize, offering improved solutions requiring new decisions. This DSP capacity for adaptation enables a resilient enterprise system that can adjust gracefully as needed, rather than fail catastrophically.

1.5 Engines for Innovation

Innovation is typically accompanied by the disruptive consequences resulting from the synergistic effects of multiple inventions converging in time. Hence, the phrase "creative destruction" originated by the esteemed Austrian economist Joseph Schumpeter. How, then, can innovation be better understood and then accelerated in a controlled way to minimize the debilitating effects of disruption? A virtual test bed is needed to provide a synthetic, non-intrusive environment for experimentation and evaluation of innovative ideas and concepts. This synthetic environment, or micro-world, guides and accelerates transformational change along cost effective paths while providing the "analytical glue" to integrate and focus what otherwise would be disparate initiatives and fragmented research efforts.

While institutional adaptation requires a culture of innovation, inertia remains a powerful bureaucratic force within organizations. Consequently, sources to enable and encourage innovation must exist for the culture to embrace. An EfI provides such a source by building a capacity for low-risk, low-cost experimentation using a synthetic environment where analytically rigorous cost-benefit analyses can be performed to differentiate between desirable objectives and attainable (affordable) ones that can actually be implemented.

The organizational construct for an EfI consists of three components which comprise core competencies:

(1) an R&D model and supporting framework to function as a generator, magnet, conduit, clearinghouse and database for "good ideas";

(2) a modeling, simulation and analysis component which contains a rigorous analytical capacity to evaluate and assess the improved performance, contributions and associated costs that promising "good ideas" might have;

(3) an organizational implementation component which then enables the transition of promising concepts into existing organizations, agencies and companies by providing training, education, technical support and

risk reduction/mitigation methods to reduce organizational risk during transformational phases.

The purpose of this deliberative, cyclical discovery process is to sustain continuous improvement through experimentation, prototyping, field testing, and rigorous analysis. The EfI provides low-risk, low-cost, high-velocity experimentation, thereby accelerating organizational *learning*. They offer capabilities to invent, innovate, and diffuse innovation, thereby encouraging *both* technological and *social ingenuity*.

1.6 Analytical Architectures

Strategic planning and management frameworks are also essential to ensure strategies achieve intended operational results. Organizations must define and monitor metrics tied to strategic enterprise objectives that properly align behavioral incentives with these objectives. In organizations with strong cultures, especially our military services, these performance incentives must be designed to attain desired institutional outcomes. The value of an objective hierarchy is multi-fold and serves several purposes by collectively aligning strategy, processes and metrics. And, although often neglected, such frameworks enable *learning* within organizations.

Strategies must then be developed to attain these desired goals and objectives. They provide “ways” to relate “means” available to desired “ends,” and may consist of major programs and new policies, initiatives, procedures, or concepts. They also provide mechanisms for reacting to, as well as creating, change when necessary. Appropriate performance measures identify, capture, and quantify the value that has been achieved by adopting and implementing particular strategies. In addition to defining performance, delineating accountability, monitoring progress toward strategic objectives, and providing means for management control, they also establish feedback mechanisms necessary to change a course of action when needed**.**

Furthermore, metrics that rely on *average* values provide little insight into what is actually driving performance, especially in large-scale, complex socio-technical systems subject to uncertainty and variability. Systems with interdependent components are characterized by information lags, feedback delays, and nonlinearities, where small changes can amplify with large effects. Averages mask variability in performance, yet those areas most afflicted by high variability, volatility, and uncertainty clearly point to directions for improved performance. This cycle of identifying key performance parameters and then detecting, understanding, explaining, and taking action based on *variability* in performance—rather than *average* performance— enables learning. What is needed is not merely a measurement system but a management system to motivate improved performance, ensure progress, and encourage learning.

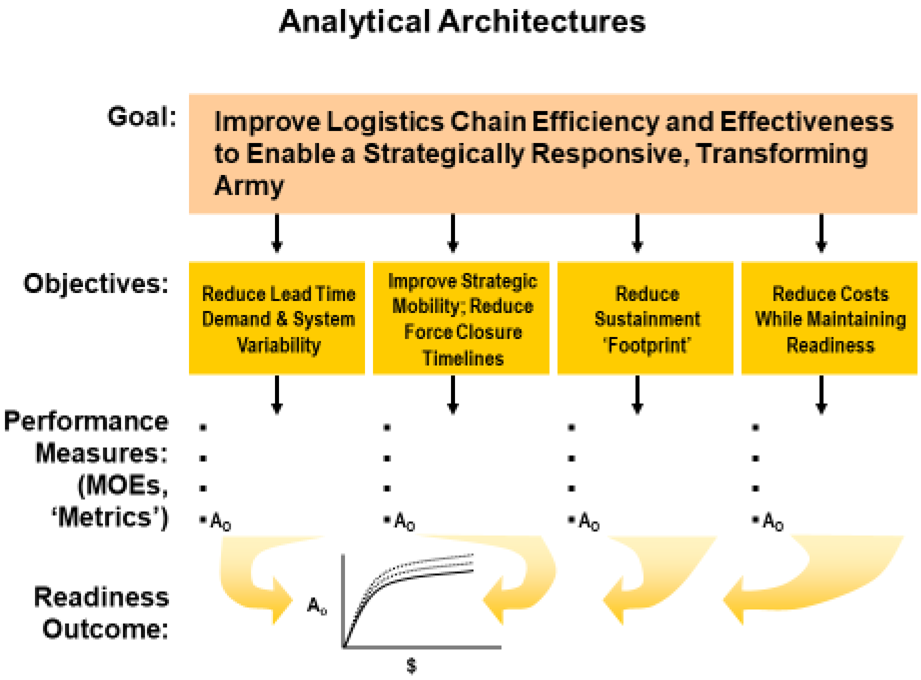


Figure 1-6: Objective hierarchy

2. STRATEGIC ANALYTICS: AN APPLICATION TO MILITARY LOGISTICS

So, how could these new concepts and methods for Strategic Analytics be applied to some of our current challenges? At US Army Materiel Command we developed an enterprise framework to facilitate analysis, synthesis, evaluation and design for the Army's sustainment enterprise. Several “catalysts for innovation” were identified then tested to measure their respective contributions to enterprise objectives for effectiveness, efficiency, and resilience. This effort came to be known as the Project to Transform US Army Supply Chains (TASC). A comprehensive description of the original project and its contributions is provided at reference [2], and a recent update is available at reference [3].

A multi-stage model of the logistics structure segmented and guided our strategic “ends-way-means” approach. Descriptive analytics were used to systematically diagnose structural disorders, perform root-cause analysis, and identify enabling remedies - “means”. Integration challenges were addressed using prescriptive methods to attain policy objectives for desired “end” states. Design and evaluation incorporated predictive analytics and analytical architectures (“ways”) to ensure change management efforts generated and accelerated continual improvement toward desired “ends”. Inherent in this ambitious project was an “engine for innovation” to encourage and guide progress.

Empirical results from analytical demonstrations, experiments, and field tests revealed that operational readiness could be improved with significantly reduced costs if specific “catalysts for innovation” are adopted. Dynamic Strategic Logistics Planning (DSLP) was also developed to support defense planning scenarios including, for example, overseas pre-positioned stock requirements for expeditionary operations. The remainder of the paper summarizes several of the “catalysts” and DSLP.

2.1 The "Production Function" for Combat Power

Unlike demand forecasting for commercial production where inputs for manufacturing and retail operations can either be controlled or exhibit high predictability, repair part demand rates needed for military readiness are a function of failure propensities and replacement rates rather than the speed of assembly line operations. The demand-generating processes for these two different production operations—commercial manufacturing and military readiness—exhibit dramatically different characteristics. Although both have stochastic elements associated with demand forecasting, the inherently predictable pattern of raw material requirements for finished goods enables relatively precise and definitive answers for inventory stock quantities. In contrast, consumption and replacement patterns for repair parts are highly volatile, reflecting greater variability in demand due to random failure patterns found in complex aerospace and defense systems including military aircraft and ground combat systems.

Consequently, and perhaps paradoxically, numerous manpower intensive work-arounds occur that substitute labor for capital, the opposite of what technology advances are intended to yield. Work-arounds become necessary alternatives for completing a repair action, since the supply system was unable to provide critical repair parts when needed. Typical work-arounds, which increase maintenance man-hour workload, include temporary repair, local fabrication or purchase, cannibalization, controlled substitution, and swapping. They frequently impose significant tactical level "burden" on combat units, yet routinely occur to compensate for requisition delays and parts shortages.

Our TASC project developed readiness equations for army aviation systems. Research indicates these work-arounds were occurring more than 25% of the time for unscheduled maintenance across the Army's aviation fleets. We estimated the likely reduction in aircraft readiness if these organizational work-arounds were *not* performed by tactical units. The impact of these work-arounds is indeed significant: *If work-arounds were eliminated, then estimated readiness would decline by 33%.* Evidence also showed that as customer wait time increased for on-order parts at unit level, work-arounds likewise increased. This effect masks what otherwise would have been declining readiness. This compensating action – resorting to work-arounds at unit level to achieve readiness goals- effectively isolates actual readiness results from wholesale supply system performance rather than illuminating the supply system's ability to affect equipment readiness.

2.2 Mission-Based Forecasting: Predictive Analytics for Military Operations

Both intuition and experience reveal that the differential effects of operational mission types (e.g., training, combat, stability operations, and humanitarian support) and environmental conditions (e.g., altitude, temperature, humidity and salinity, sand and dust) can be significant. Despite this recognition, these differences had not previously been measured by statistically evaluating the empirical consumption patterns associated with recent deployment operations.

To rectify this shortcoming, the TASC project developed a large experimental design to identify spare part consumption patterns and readiness "drivers" that change across operational missions and geographic locations, and how these replacement rates differed from peacetime training. The hypothesis was: "If empirically derived Class IX usage patterns, profiles, and trends can be associated with various operational mission types, then operational planning, demand forecasting, and budget requirements can be significantly improved to support a capabilities-based force."

The first portion of the hypothesis determined whether or not clearly discernable differences could be identified in spare and repair parts maintenance data at the tactical level. The project focused initially on intuitively derived factors (explanatory variables) that could be expected to influence consumption patterns. These included weapon system type, training or operational mission category, geographic location and environmental conditions, and system parameters including, for example, aircraft age. The results from this initial phase revealed not only distinct consumption patterns, but differences across operational missions and environments that proved more striking than originally anticipated.

The second phase of research determined whether or not relevant data for these descriptive, operations-driven demand patterns could be captured and used to generate improved demand forecast accuracy. For a particular weapon system, this method isolates and captures key explanatory variables (causes), including operational mission type and duration, force size, and environment, using actual part data from unit-level maintenance actions. Using a statistical regression approach, the method then estimates future demand (effects) for similar operational settings using the information contained in these empirically derived parts usage patterns. Since this new causal forecast method estimates future Class IX (supply) requirements to achieve equipment availability objectives for operational missions (demand), it has been referred to as "mission-based forecasting" (MBF).

To formally prove or disprove our research hypothesis, MBF was compared to several currently used forecasting methods. Results were truly remarkable: *across platforms and operational settings, MBF has consistently demonstrated nearly an order of magnitude (e.g., 100%) improvement in demand forecast accuracy*. Several TASC project analytical demonstrations and field tests indicate MBF will dramatically improve forecast accuracy, reduce both backorders and excess inventory, and eliminate costly work-arounds while increasing equipment readiness. MBF now provides, for the first time, accurate forecasts derived from operational usage patterns to meet equipment availability goals at the tactical level.

The TASC project developed, tested, refined, and evaluated MBF, a new demand forecasting concept for military operations and planning. This effort captures statistically significant factors influencing future demand using all of the information provided by the empirical evidence of recent experience. Innovative capabilities have been developed, including automated systems that align forecast methods to three primary demand segments: operational patterns for which causal models have been developed; intermittent demand which has been a persisting and pervasive challenge; and condition-based maintenance (CBM) prognostic demand for both the forward and reverse supply chains.

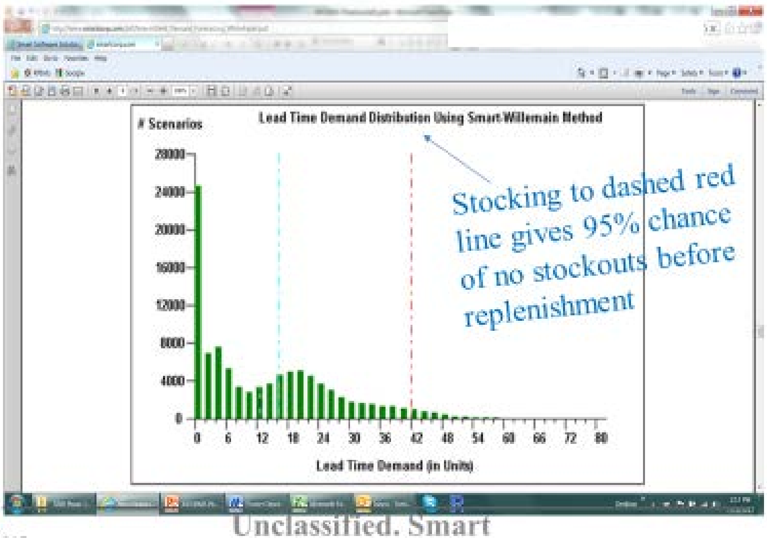
Originally developed for Army aviation, MBF has since been applied to Army ground systems and further tested with several combat platforms in the other Military Services as well. As data collection and analytical methods improve, promise exists for MBF to dramatically increase demand forecast accuracy not only for spares and repair parts (Class IX), but for other planning domains and classes of supply as well.

2.3 The Challenge of Intermittent Demand

Effective inventory management also requires accurate forecasts for so-called "intermittent", or sporadic demand, since many spares and repair parts exhibit such patterns. Unlike conventional demand patterns, intermittent demand exhibits rare event phenomenon. Typically containing a high percentage of zero values mixed with nonzero values of random size, this intermittent characteristic makes it extremely difficult to accurately forecast using classical methods. In addition to a large proportion of zero values, intermittent demand has other unusual characteristics. For example, many parts exhibit autocorrelated patterns where demand can be "streaky" with long quiet periods followed by high activity. Another is that the distribution of demand over a replenishment lead time rarely approximates the standard "bell shaped curve", or Normal distribution. Conventional (parametric) statistical methods for inventory control assume both a Normal distribution and demand that is not autocorrelated. Since these assumptions are not true for intermittent demand, alternative non-parametric forecasting methods must be considered.

The TASC project evaluated and tested one particular state-of-the-art approach to forecasting intermittent demand that uses a combined "Markov Bootstrap" model. The Markov portion of the model treats the demand as either zero or nonzero and takes account of any autocorrelation in the demand process. The Bootstrap portion of the model then converts future nonzero demands into specific numerical values by resampling from observed values of demand history. Together, the two methods generate scenarios depicting the most likely patterns of demand during the time required to receive a replenishment order. The final result is a histogram showing the distribution of lead time demand that might arise during a replenishment interval for one particular part. This output can be used to determine the reorder point that will guarantee a desired level of supply availability for any given part, such that the risk of stockouts while awaiting replenishment is as low as desired. These displays can also be used in a "what if" mode to analyze in detail trade-offs between part availability, stock level and inventory cost.

Output of Markov Bootstrap



Stocking to dashed red line gives 95% chance of no stockouts before replenishment

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Unclassified. Smart Software, I

Figure 2-3: Markov Bootstrap forecast distribution display for intermittent demand

By calculating reorder points and stock levels using this creative new methodology, organizations can simultaneously reduce excess inventory and increase supply availability especially for mission critical parts. In the commercial sector, customers have typically achieved inventory reductions of 10-20% without decreasing aggregate parts availability, and can better align availability levels with part criticality to support asset availability. Although the Markov Bootstrap model is now patented and has been successfully applied for over a decade in a variety of commercial organizations, it has not been exploited for military supply chains. Consequently, to demonstrate its potential the TASC project applied this Markov Bootstrap model to a large, expensive inventory of aviation and missile system spares managed by the Army's Aviation and Missile Command. An aggregate reduction of 20% was found, saving tens of millions of inventory dollars, while improving overall supply performance and better aligning service levels with part criticality to support mission readiness.

2.4 Retrograde: The Closed-Loop Reverse Pipeline

The reverse logistics pipeline, or retrograde process, constitutes the military's recovery operation for reparable spares (DLRs) and includes the vast majority of the value requisitioned by tactical combat units – the customer. Rare in the commercial world where products are normally consumed by the market, this stage constitutes the "value recovery" effort to maintain, repair, overhaul, upgrade, and return large subassemblies and replaceable units that are not “consumed” but used as capital assets. Although DLRs constitute less than 25% of the number of demand requisitions, they also represent more than 75% of total requisition value.

TASC's multi-stage supply chain model clearly revealed the importance of viewing the retrograde stage as a feedback loop impacting unit readiness. From theoretical perspectives, both system dynamics and control theory suggest the responsiveness of this retrograde stage should have considerable impact upon readiness “output” of the system. Operating within the larger logistics structure, this closed-loop creates internal dynamic system behaviors that can potentially be changed through feedback to regulate this dependent output variable of interest. The responsiveness of the reverse pipeline is especially crucial during deployed operations when higher failure rates often occur, resulting in temporary spikes or sustained surges in demand.

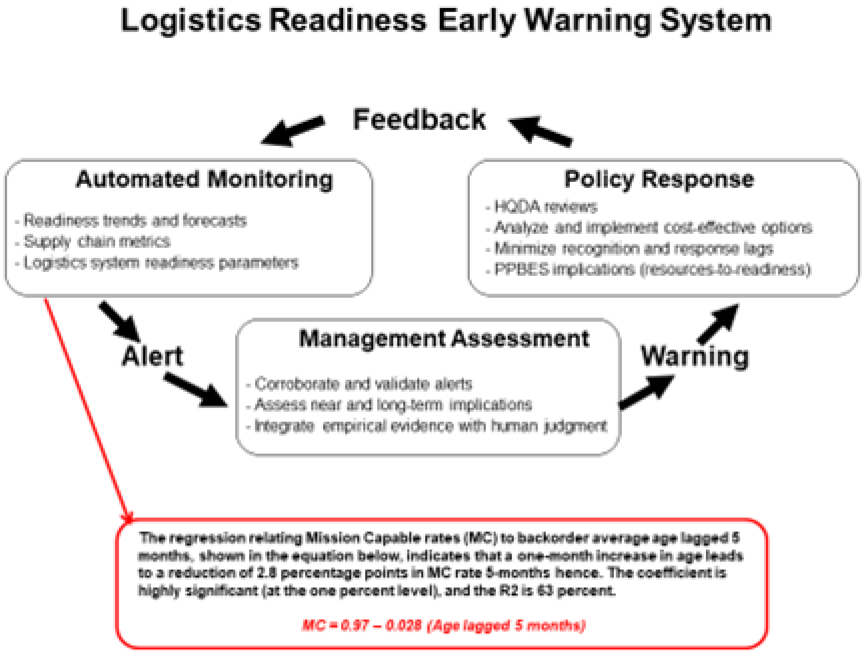
The initial TASC retrograde research phase focused on understanding these system dynamics and control theory perspectives, and then identifying, measuring, and quantifying delay times for DLRs awaiting retrograde in the reverse pipeline. We also developed methods to estimate the value of reparables delayed in the reverse pipeline. Historically, there had been no focus on defining the potential reduction in aggregate DLR inventory and quantifying the effects of reduced customer wait time on improved readiness that could potentially be achieved by synchronizing these reverse flows and depot operations with the forward supply chain. Enormous improvement becomes possible when reverse pipelines are viewed as closed-loop supply chains with dynamic “feedback loops” rather than as independently operating, disconnected operations with only linear, additive effects. Adopting Readiness Responsive Retrograde (R3) has tremendous potential to reduce total life-cycle costs and improve readiness.

2.5 Dynamic Strategic Logistics Planning

To continually improve supply chain performance, another consequential TASC initiative was developing and testing Dynamic Strategic Logistics Planning (DSLP). Within a “strategic analytics” (ends-ways-means) paradigm, DSLP provides the “ways” (concepts, policies, and plans) to link “means” (resources) with desired “ends” (objectives) in order to effectively guide supply chain transformation endeavors for the US Army and DoD. By developing this analytical architecture to sustain continual improvement, DSLP generates an efficient, increasingly effective, yet resilient global military supply chain network.

DSLP comprises four major modeling methods to sustain continual improvement: multi-stage optimization; dynamic strategic planning; risk management; and program development. In conjunction with testing, experimentation, and simulation, these complementary methods illuminate viable plans for implementation. Taking, as input, both the empirical evidence of ongoing operations (real-world results) and new contributions derived from experimental results and operational testing, DSLP then guides enterprise transformation toward strategic goals for effectiveness, efficiency, and resilience.

DSLP also includes a sustainment “early warning” system (SEWS). SEWS provides the ability to recognize, understand, and then pre-empt future system degradation through proactive, preventive management actions guided by supporting Sustainment Readiness Levels (SRLs). The potential magnitude of improvement is truly dramatic with billions of dollars in further savings likely. More importantly, it becomes possible to accurately forecast readiness by credibly relating investment levels to current and future capabilities. Collectively, these SRLs can yield a more effective, resilient, and efficient sustainment enterprise that achieves equipment readiness goals, is adaptive to change, and provides improved materiel availability at less cost.



The regression relating Mission Capable rates (MC) to backorder average age lagged 5 months, shown in the equation below, indicates that a one-month increase in age leads to a reduction of 2.8 percentage points in MC rate 5-months hence. The coefficient is highly significant (at the one percent level), and the R2 is 63 percent.

$MC = 0.97 - 0.028$ *(Age lagged 5 months)*

Figure 2-5: Components for a sustainment enterprise "early warning" system

3. STRATEGIC ANALYTICS: BENEFITS

Dramatic performance increases have been demonstrated, including improved tactical unit combat readiness and order-of magnitude reductions in forecast error. Costs savings for each of the various catalysts are estimated to be on the order of many multiples of $100M. Once fully implemented, their combined effects are estimated to annually save tens of billions of dollars resulting in an investment return of several orders of magnitude. Importantly, tactical work-around "burden" will be significantly reduced. These key catalysts enable DoD to better align the supply chain to actual readiness-driven demand thereby allowing "resource-to-readiness" relationships to be established, with budgets allocated to meet current mission needs and programs developed to achieve future capability goals. The National Research Council also adopted these TASC project catalysts as recommendations in a recent special study requested by the Army's senior civilian and military logistics leadership [4].

NATO can likewise expect several advantages by adopting these innovation catalysts as official policy. Among these are the abilities to: measure, understand, and accurately predict real customer demand using MBF; better align supply chain components to this actual customer demand using multi-echelon optimization methods; "synchronize" the closed-loop supply chain for retrograde operations; more efficiently, effectively, and responsively manage materiel support to meet force readiness requirements using DSLP; and early warning using SEWS to proactively assess the health, capacity, and responsiveness of the end-to-end sustainment enterprise.

Finally, although a challenging national security example has been emphasized here, the transformative power offered by Strategic Analytics clearly offers potential break-through solutions broadly applicable to paralyzing dilemmas currently faced by other public institutions and government bureaucracies as well

4. REFERENCES

[1] Author's note: The final decade of my military career focused on building, developing, and leading multi-disciplinary teams confronting major challenges in large, complex organizations including US Army Recruiting Command (USAREC), Army Materiel Command, and the Office of the Chief of Staff at Headquarters, Department of the Army. Central to each of these endeavors was the extensive application of Operations Research, data analytics, and management innovation for improved performance. Although the fundamental natures of these various transformational endeavors were vastly different, they all required an ability to organize, manage, and lead highly talented multi-disciplinary teams. For a more comprehensive description of Strategic Analytics and its application to these challenges, see chapter 20 “Strategic Analytics and the Future of Military Operations Research” in The Handbook of Military and Defense Operations Research, edited by Scala and Howard, CRC Press, 2020. https://www.taylorfrancis.com/books/e/9780429467219

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