Transforming US Army Supply Chains: An Analytical Architecture for Management Innovation

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I. Multi-stage Analysis of Systemic Challenges: A Summary

Conceptual Approach: Multi-Stage Logistics Model

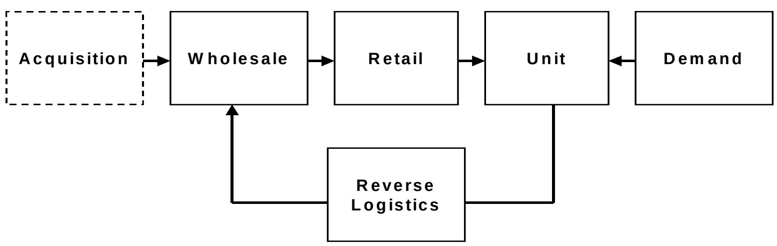


Figure 1

The US Army's logistics enterprise is truly enormous in scale and scope. However, it is not merely the size and complexity of the supply chain that causes difficulty, but rather the structure and policies within the system that are the root cause of persistent problems. Army aviation logistics has especially suffered from several disorders which are both systemic and chronic. This research project has previously illuminated these problems using inventory management theory, supply chain principles, and logistics systems analysis as key sources of diagnostic power. To summarize generally, these causal disorders and their respective effects include:

(1) lack of an aviation readiness production function which induces both uncertainty and variability at the point of consumption in the supply chain resulting in inappropriate planning, improper budgeting, and inadequate management to achieve readiness objectives;

(2) limited understanding of mission-based, operational demands and associated spares consumption patterns which contribute to poor operational and tactical support planning and cost-*in*effective retail stock policy;

(3) failure to optimize retail stock policy to achieve cost-efficient readiness (customer) objectives which results in inefficient procurement and reduced readiness;

(4) failure to proactively synchronize and manage reverse logistics which contributes significantly to increased DLR RO, excess inventory, and increased delay times (order fulfillment) with reduced readiness;

(5) inadequately organized depot repair operations that may be creating a growing gap in essential repair capacity while simultaneously precluding the enormous potential benefits of a synchronized, closed-loop supply chain for DLRs;

(6) limited visibility into and management control over disjointed and disconnected OEM and key supplier procurement programs which are vulnerable to boom and bust cycles with extremely long lead times, high price volatility for aerospace steels and alloys, and increasing business risk to crucial, unique vendors in the industrial base resulting in diminishing manufacturing sources of materiel supplies, and growing obsolescence challenges for aging aircraft fleets;

(7) independently operating, uncoordinated and unsynchronized stages within the supply chain creating pernicious "bullwhip" effects including large RO, long lead times, and declining readiness;

(8) fragmented data processes and inappropriate supply chain MOEs focusing on interface metrics which mask the effects of efficient and effective alternatives, and further preclude an ability to determine "readiness return on net assets" or to relate resource investment levels to readiness outcomes;

(9) lack of central supply chain management and supporting analytical capacity results in multi-agency, consensus-driven, bureaucratic "solutions" hindered by lack of an Army supply chain management science and an enabling "analytical architecture" to guide Logistics Transformation; and

(10) lack of an "engine for innovation" to accelerate then sustain continual improvement for a learning organization.

The existing aviation logistics structure is indeed vulnerable to the supply chain "bullwhip". While endless remedies have been adopted over the years to address visibly apparent symptoms, the fundamental underlying disease has not been adequately diagnosed or treated, much less cured. Now, better understanding these underlying causes of failure, a new approach to logistics management is required for the US Army.

The analytical challenge is to conquer unpredictability: to better understand then attack the root causes of variability and uncertainty within each stage and their collective contributions to volatility across the system of stages – the "bullwhip effect". Analysis clearly reveals that inventory investment levels can be significantly reduced while maintaining or improving performance (e.g., readiness) simply by linking stock policies to the sources of uncertainty and inefficiency that require inventory in the first place. However, to reduce the impact of this variability, some of which is unpredictable but much *is predictable*, supply chain managers must understand their sources and the magnitude of their impact. By improving demand forecasting and reducing supply-side variability and inefficiencies within each of the stages, logistics system performance is moving toward an efficient frontier in the cost-availability trade space.

The first step in suppressing the bullwhip effect is to isolate, detect and quantify these inefficiencies within each stage and their respective contributions to AMC system-wide aggregate inventory requirement objectives (RO). The next step is to use this knowledge to drive inventory policy. Since Army inventories are managed to these computed ROs, reducing the value of the RO is critical to eliminating unnecessary inventory. As prescriptions for improved performance recommended by this project are implemented in each of the stages, their respective contributions to reducing RO - while sustaining or actually improving readiness performance - can be measured, compared and assessed within a rational cost-performance framework (figure 2).

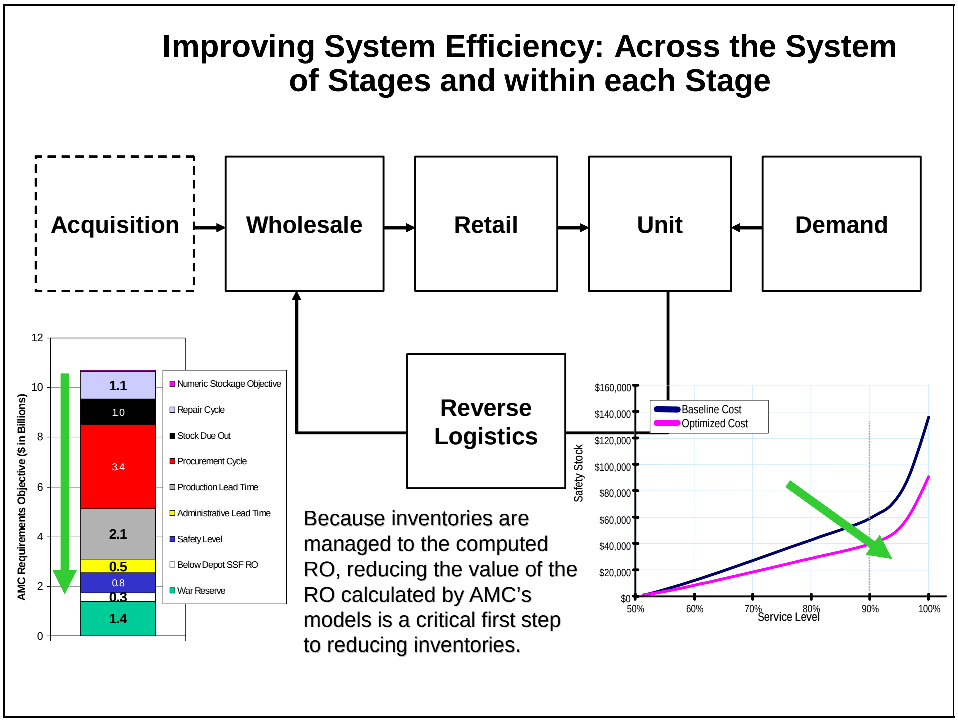


Figure 2

In general, these various contributions to aggregate system-wide RO - induced by the "bullwhip" effect - can be isolated, quantified, then systematically reduced by understanding and attacking root causes: reducing demand uncertainty by adopting empirically-derived, mission-based demand forecasting; reducing supply-side lead times (for all components that contribute to higher RO including administrative, procurement, retrograde and repair cycle times) and their associated variability; and improving order fulfillment while reducing backorders and requisition wait times by implementing RBS, inventory pooling, and ultimately, tactical-level demand driven supply networks.

An especially compelling and urgent need, and also one with lucrative potential benefits (so-called "low hanging fruit"), is the reverse pipeline: as retrograde operations become more responsive and contribute to a synchronized closed-loop supply chain, it becomes possible to reduce RO and safety stock for specific DLRs while simultaneously reducing backorders and *increasing readiness (Ao).* As these efforts are systematically pursued, the logistics system becomes more efficient: RO (safety stock, etc.) is reduced while performance (backorders and Ao) is increased, thereby moving toward the "efficient frontier" in the spares investment-readiness performance trade space (figure 3).

Achieving “Efficiency” in the Cost - Availability Trade Space

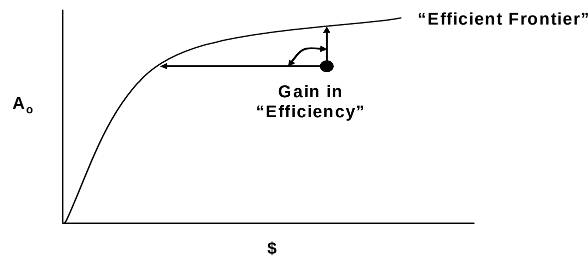


Figure 3

II. Multi-stage Integration for Efficiency, Resilience and Effectiveness

Although its recognition provides important insight into Army logistics, merely acknowledging that the aviation supply chain is vulnerable to the “bullwhip” does not, of course, automatically solve the problem. Simply recognizing that these conditions exist does not guarantee that needed changes will actually be made. However, these persistent effects can be avoided if long term organizational behavior and management processes are addressed.

In addition to reducing demand uncertainty, identifying the causes and reducing the effects of supply and demand variability within each of the logistics stages, the stages must also be “integrated” - linked together in meaningful ways – in order to enable credible cause and effect relationships to be identified among new initiatives, Department of the Army resource allocation investment levels, and readiness-oriented tactical outcomes.

Complex challenges typically require an analytical approach where the problem is systematically broken down into smaller, more manageable models based on process, function, organization, etc. This component-based modeling approach, in which the pieces of a complex problem are modeled as segments, must then be complemented with an integrating modeling effort – “synthesis” – where the segments are then incorporated into a parent model that represents the broader scope of the original challenge. Although component-based analysis provides great insight into sources of uncertainty and variability, we must guard against treating the entire logistics enterprise merely as an aggregation of its component parts that can be improved independent of one another. The historical record suggests that many of the “panaceas, fads, and quick fixes” that operate under the guise of innovative management approaches are likely to fail because they are fundamentally “anti-systemic”.

A. Achieving Efficiency: An Integrated Multi-Echelon Inventory Solution

One of AMC’s most challenging functions is the requirement to position and effectively manage a large, globally-distributed inventory with millions of parts in hundreds of locations. The challenge is further magnified since these geographic locations are situated in different tiers, or echelons, of the supply chain. One of the major difficulties in managing this enormous multi-echelon network is achieving an enterprise-wide inventory optimization solution. Multi-echelon inventory optimization is difficult for at least two reasons: replenishment policies are applied to a particular echelon without regard to the impact of that policy on other echelons ("sub-optimizing" within independent stages of the supply chain); and higher-echelon (in this case, wholesale stage) replenishment decisions tend to be based on specious, uncertain or unreliable demand forecasts.

Visualizing this complexity using a set of hierarchies is useful. A "geographic hierarchy" addresses the question of "where" spares and repair parts should be deployed across multi-echelon, global supply chains. A "product hierarchy" exploits the multi-indentured nature of major assemblies and subassemblies, such as aircraft turbine engines, addressing "which" specific parts should be placed within the various echelons of the geographic hierarchy. And a "planning horizon hierarchy" addresses the question of "when" parts will be needed since demand is triggered by events that are highly uncertain, yielding demand patterns that are both probabilistic, and dynamic – hence stochastic processes.

This demand uncertainty cannot be completely eliminated through forecasting, yet increasing inventory to buffer this uncertainty is costly. This phenomenon results in a classic risk management challenge. Failure to achieve an integrated solution results in several inefficiencies and degraded performance:

- the supply network carries excess inventory as redundant safety stock;
- customers face shortages even when inventory exists elsewhere in the network;
- shortfalls and backorders occur yet interface metrics between echelons (e.g., fill rates and safety level) appear to be acceptable;
- upstream suppliers receive distorted and delayed demand projections and cannot deliver reliable performance;
- and short-sided internal allocation decisions are made for parts with limited availability.

Commercial enterprises characterized as "multi-echelon" have typically used one of two approaches to address this inventory positioning challenge: a sequential application of the single echelon approach; or, more recently, distribution requirements planning (DRP), an extension of materials requirements planning (MRP) used in manufacturing. Both approaches (figure 4), however, result in excessive inventory without necessarily improving performance levels. This occurs because an optimal solution for the entire network has not been achieved: total inventory has not been minimized subject to an outcome-oriented result such as customer service performance objectives. Inefficiencies occur due to lack of visibility both up and down the supply chain: the retail stage has no visibility of the wholesale stage inventory balance, and wholesale lacks visibility into retail demand.

Independent demand forecasts among the stages result in greater demand variation between them - the "bullwhip" effect - leading to bloated but undifferentiated inventory levels, especially at wholesale. Furthermore, total network costs are difficult to assess, and the enterprise-wide implications of new initiatives or strategies cannot be accurately evaluated since this sequential approach can only focus on their impact one stage at a time. Similarly, DRP, which uses a deterministic approach, cannot rigorously compute safety stock for the wholesale stage since retail stage demand variability has not been incorporated. As with the sequential approach, there is no linkage between safety stocks in the two stages.

Multi-Stage Integration Options

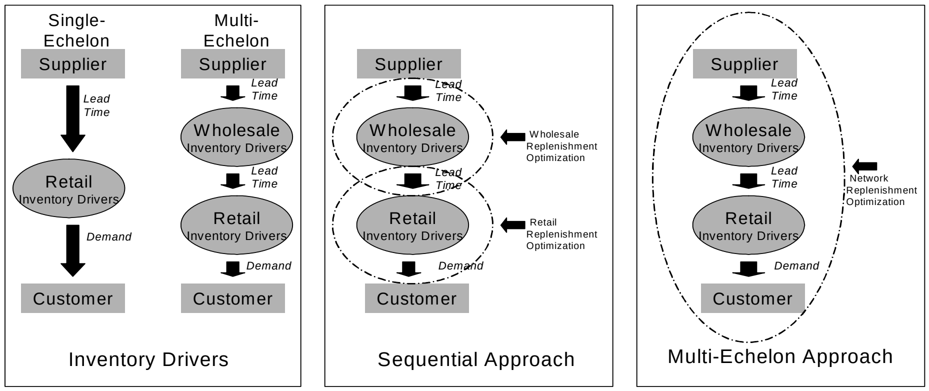


Figure 4

In complex supply chains, then, a recurring management challenge is determining where, and in what quantities, to hold safety stock in a network to protect against variability and to ensure that target customer service levels are met. In an effort to improve supply chain efficiency, an appreciation for the interdependencies of the various stages is required in order to fully understand how inventory management decisions in one particular stage or location impact other stages throughout the supply chain.

For military and aerospace logistics systems, optimizing these decisions requires a decision support system that captures multi-echelon, multi-item, multi-indenture interactions and also the dynamics of the reverse flows for reparable components. Such a decision support system must also be linked to the various supply information transaction, depot repair and overhaul, and long term planning systems that affect the overall responsiveness, support adequacy, and capacity of the fleet supply chain enterprise – the “readiness” of the entire, globally-dispersed logistics support system. These supporting management systems include maintenance, repair and overhaul scheduling, procurement and order fulfillment, asset visibility, and transportation support.

Consequently, an integrated, multi-echelon network, if achievable, offers several opportunities for supply chain efficiency:

- multiple, independent forecasts in each of the stages are avoided;
variability in both demand and lead time (supply) can be accounted for;
- the “bullwhip” effect can be observed, monitored, and managed;
- its various root causes can be identified and their effects measured, corrected and tracked;
- common visibility across the supply chain stages reduces uncertainty, improving demand forecasting and inventory requirements planning;
- order cycles can be synchronized (this has special significance for DLRs in the retrograde and depot repair stages);
- differentiated service levels (e.g., Ao targets for different units) can be accommodated;
- and action can be taken to reduce unnecessary inventory and operational costs while simultaneously improving readiness-oriented performance [1].

Although the calculations to incorporate key variables, their relationships, and associated costs are certainly not trivial, they can nonetheless be performed using advanced analytic methods, including RBS optimization methods mentioned previously and described in greater detail below. Improved results are then possible and the organization can have far greater confidence that it is operating closer to the efficient frontier within an investment-performance trade space (see figure 5 for a comparison of these approaches).

Multi-Stage Optimization Advantages

KEY AREAS	SEQUENTIAL APPROACH	DRP APPROACH	TRUE MULTI-ECHELON APPROACH
Optimization Objective	Meet immediate customer's (RDC or DC) service goals at minimum inventory; suboptimal for network	Not optimization; objective is to provide net requirements upstream to determine replenishment needs	Meet end-customer service goals at minimum inventory
Demand Forecasting	Independent forecasts in each echelon based on immediate customer's demands	Pass-up demands or projected orders with no measures of their variabilities	Forecasts based on lowest echelon's primary demand signals and other information; demand variations also are forecasted
Lead Times	Uses immediate suppliers' lead times and lead time variabilities	Uses immediate suppliers' lead times; ignores variabilities	Uses all lead times and lead time variations of upstream suppliers
Bullwhip Effects	Ignored	Ignored	Effects measured and accounted for in overall replenishment strategy
Network Visibility	*Immediate* downstream customers' demands and *immediate* upstream suppliers' lead times-*myopic* view of the network	Some downstream visibility; no upstream visibility	All echelons have complete visibility into other echelons; this visibility is exploited in the replenishment logic
Order Synchronization Between Echelons	Ignored	Maybe, probably not	Fully modeled to reduce unnecessary lags in network
Differentiated Customer Service	Not possible	Not possible	Achievable, as orders out of a higher echelon location to a lower echelon are fully controllable; allocation schemes using set-aside inventories can be used
Cost Implications Between Echelons	Not possible	Not possible	Fully modeled so true network optimization can be achieved

Figure 5

Within DoD and its supporting FFRDCs, the mathematical theory for multi-echelon, multi-indenture, multi-item optimization supporting military inventory systems has been developed and refined over recent decades. Much of this pioneering theoretical work, primarily focusing on ground-based land combat systems, was accomplished by scientists and mathematicians at the Army Inventory Research Office (IRO) in Philadelphia. However, IRO was abolished in the early 1990s as part of the post-Cold War drawdown and much of the original talent at IRO has retired or been reassigned to other organizations.

For military aircraft it has also been demonstrated that DLRs most directly relate to aircraft performance and, in general, minimizing the sum of DLR backorders is equivalent to maximizing aircraft availability [2]. Significant effort has also been placed on determining optimal stock levels and locations for reparable components in a multi-echelon system. While the subsequent extension of this theory has been widespread [3], the focus of practical implementation within DoD has been on fixed-wing aircraft in the Navy and the Air Force rather than rotary wing aircraft in the Army (figure 6).

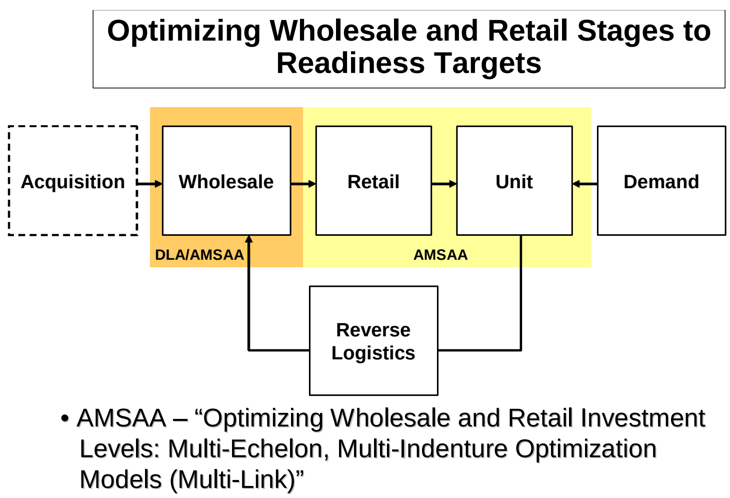
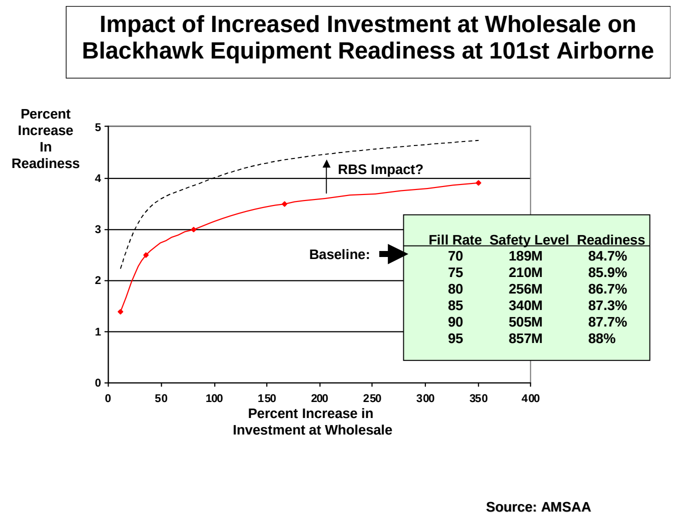


Figure 6

Another structural constraint which previously precluded an integrated multi-echelon approach for Army supply systems was the existence of separate stock funds used by the Army financial management system for retail and wholesale operations. In recent years, however, these separate funds have been combined into one "revolving fund", the "Single Stock Fund" (SSF) within the Army Working Capital Fund (AWCF). In theory, this should both facilitate and encourage adoption of an integrated multi-echelon approach. For example, in AMCOM's case, the wholesale stage now has both visibility into the retail stage and more control over stock policy in the wholesale *and* retail stages, which it previously did not have for aviation and missile Class IX. Upon achieving milestone III for the SSF program, it becomes possible for AMC to incorporate a multi-echelon optimization model and enable wholesale stock levels, *in addition to retail RBS solutions*, to be directly related to readiness (Ao) (figure 7).

However, in practice so far, although AMC "owns" these retail stocks under this new SSF policy, ASL and SSA stocks are still being "managed" by retail organizations as in the past.

Consequently, if the SSF policy implementation is not complemented with business process re-engineering, including multi-echelon, multi-item, multi-indenture optimization methods, then the full potential of SSF will not be realized.



Fill Rate	Safety Level	Readiness
70	189M	84.7%
75	210M	85.9%
80	256M	86.7%
85	340M	87.3%
90	505M	87.7%
95	857M	88%

Figure 7

It is not possible to truly “optimize” performance output from large scale, complex systems if they have not first been “integrated”. The key integrating enabler for improved efficiency in all Army weapon system supply chains – and the more complex the system, the more crucial the enabler - is multi-echelon readiness based sparing. Indeed, this is a *precondition* for Army Logistics Transformation.

B. Designing for Resilience: Adaptive Logistics Network Concepts

The intent is certainly *not* to blindly adopt the latest management “fad” inundating the corporate world but rather to consider adapting proven concepts to the unique needs and challenges the Army now faces. For example, the idea of “integration”, when achieved by reducing slack or “waste” in the system, does not necessarily enable greater flexibility. The opposite result could occur with “just-in-time” methods. Lean manufacturing concepts have certainly helped firms to become more competitive through the application of “just-in-time” principles which exchange “industrial age” mass for “information age” velocity. And many of the original lean manufacturing concepts, especially the focus on reducing “stagnant” work-in-progress inventory, have been successfully adapted for supply chain management (SCM) across the entire enterprise.

Nonetheless, “just-in-time” manufacturing concepts, although a powerful inventory reduction method, need stable, predictable supply chains for maximum efficiency. Even when enabled by IT, “lean” supply chains can be fragile, vulnerable to disruption, and unable to meet surge requirements needed to accommodate an immediate increase in demand. In fact, recent official documents describe exactly such a condition for Army logistics in recent years. Under greater duress and the compounding stress of ongoing wars, the military logistics system has indeed resulted in “a lean supply chain without the benefit of either an improved distribution system or an enhanced information system” [4].

A more appropriate analogy for Army logistics is a flexible, robust logistics "network"; not a serial "chain" or hierarchical arborescence (figure 8), but rather a network "web" - as in spider web - which is then enabled by a strong analytical foundation with supporting information technology to achieve an integrated, flexible, efficient and effective logistics capability.

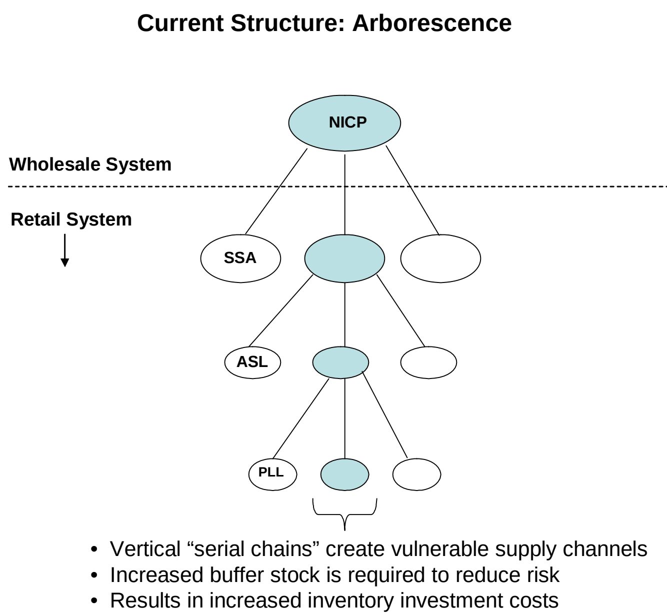


Figure 8

These adaptive network concepts are driven by an overarching DoD "Transformation" program coordinated by the OSD Office of Force Transformation (OFT). For logistics, which is one of six major battlespace functional area groupings (others are fire, maneuver, protection, C3 and ISR), this visionary adaptive enterprise capability is referred to as "Sense and Respond Logistics" (S&RL) [5]. The basic foundational theory for S&RL is derived from the autonomous nervous system in biological systems which, in conjunction with the sensory perceptions of sight, smell, taste, hearing and feeling, enable reactive and anticipatory protective responses to be taken.

This S&RL concept builds upon IBM's "autonomic computing initiative" in which machines use on-board diagnostic sensors to assess and monitor system "health", forecast and predict system and component level failure using prognostics, then employ automatic identification technologies to alert maintenance and logistics managers and engineers to developing problems even before they become visible. S&RL then further extends this "autonomic logistics" platform-level concept to the larger logistics support network thereby providing the capacity to predict, anticipate and coordinate logistics support wherever and whenever it is needed across the battlespace. Conceptual documents currently describe S&RL as a "network-centric, knowledge-driven, highly adaptive, self-synchronizing, dynamic and physical functional process [which] achieves 'effects-based' operations and provides a precise, highly agile, end-to-end, point-of-effect to source-of-support network of logistics resources and capabilities" [6].

Adaptive network concepts have evolved from pioneering work performed at the Santa Fe Institute [7]. Their research has focused on understanding how immensely complicated networks, made up of large numbers of interacting “agents” that cooperate and compete, regularly arrange themselves into complex organizations that are efficient, adaptive and resilient even though the various agents are pursuing their own respective self-interests. According to this “complexity theory”, efficient, self-organizing systems like this emerge only at the edge of “chaos”, somewhere between a prescribed rigid order that is unresponsive to new information (including threats) resulting in paralysis, and a system so overloaded with new information that it dissolves into chaos.

The research and subsequent understanding of emergence in self-organizing systems has been rapidly advancing in recent decades, extending originally from cybernetics to incorporate growing knowledge in cognitive science, evolutionary biology, dynamical systems, stochastic processes, computational theory, and culminating now in “complex adaptive systems”.

Complex adaptive systems become self-organizing by responding to external conditions while maintaining an internal integrity that keeps them together and cohesive. This results in a higher level of order that enables the system to adapt in ways that continually benefit its member “agents”. A byproduct of this concept is that it is not possible to accurately predict the future for such a complex adaptive system. Therefore the “best”, or “optimal” solution, cannot be engineered in advance. Research is showing that some of the greatest improvements occur when these self-organizing systems are forced to respond to random or unexpected events, and creative solutions are thereby discovered.

This ambitious vision endeavors to replicate, albeit in a highly accelerated fashion, evolutionary, nonlinear biological concepts characterized by terms such as “versatile”, “adaptive”, “elastic”, “agile”, “robust”, and “resilient”. This approach differs from linear, mechanical engineering system concepts which have been the traditional province of large-scale systems design. For military operations, this “network-centric” future force will be linked and synchronized in time and purpose, allowing dispersed forces to communicate and maneuver independently while sharing a common operating picture. Conceptually, the traditional mandate for overwhelming physical “mass”, in the form of a linear array of land combat forces converging at the decisive place and time, is replaced by attaining comparable “effects” derived from dispersed and disparate forces operating throughout a non-linear battlespace.

Demand Driven Supply Network (DDSN)

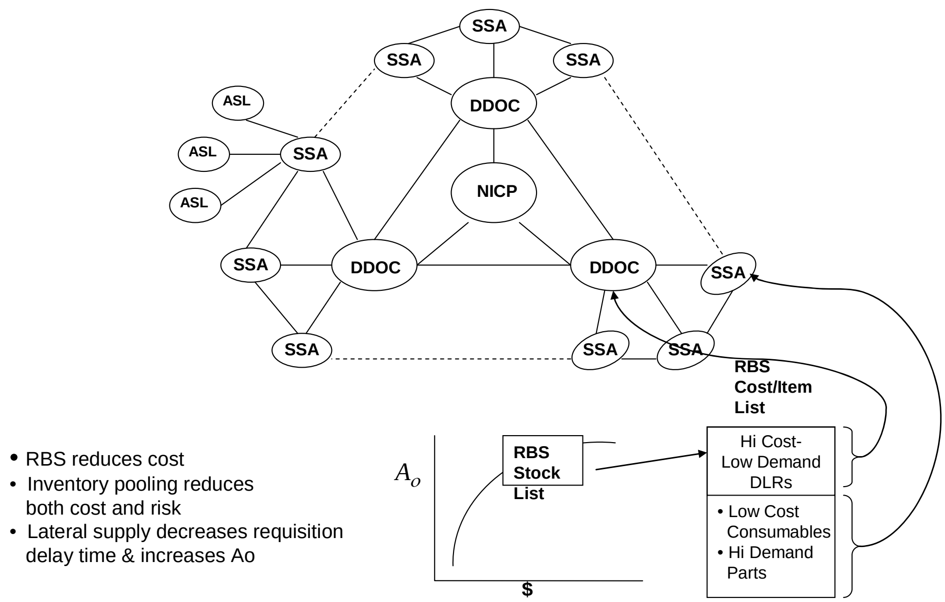


Figure 9

Our ability to logistically support at least some of these concepts, especially the notion of an agile supply network at the theater and tactical levels for Army and joint logistics distribution, may be much closer at hand now than previously recognized. At the tactical level for example, the demand driven supply network (DDSN) described previously, which includes mission-based forecasting on the demand side and RBS, lateral supply and risk-pooling (especially for DLRs) on the supply side, provides the foundational basis for a more agile and resilient network "web" (figure 9).

Through theoretical development corroborated by recent field tests, this DDSN concept has also been shown to attain *both* improved effectiveness (Ao) and, as total asset visibility (TAV) and in-transit visibility (ITV) IT-based technologies are incorporated, increasingly better efficiency [8]. Such a tactical-level DDSN is not only effective and efficient then, but also both resilient and adaptive, enabling a rapid transition away from the traditional hierarchical arborescence structure, which required "mountains of iron" necessary to buffer uncertainty, inefficiencies, and rigidity, toward an adaptive network design consistent with Sense and Respond Logistics.

An example at the theater level pertains to additional aviation repair capacity, currently provided by the ADMRU/AVCRADs concept, needed to sustain overseas operations. Although the conventional view, from an "efficient" supply chain perspective, would be that surplus capacity ("repair capacity" in this case) and inventory (DLR "safety level") are undesirable, the operational disposition of such additional capacity and inventory is clearly beneficial as a means for creating "agility" and "adaptability" for supply chains that must react quickly to sudden demand shifts due to operational mission requirements or to disruptions of various components within the supply chain.

By applying design principles for supply chain resilience [9], a supply chain operating a large-scale (global), demand-driven ("pull") system under stable and predictable demand can quickly adapt to support localized (e.g., theater scenario), forecast-driven requirements that may involve considerable uncertainty, but which must be "pushed" by the customer (combat units) to achieve maximum effectiveness (mission Ao in this case). Resilient design concepts include the identification of "push-pull" boundaries separating "base" from "surge" demand using decoupling points for the placement and use of strategic capacity and inventory.

These concepts suggest, first, creating pre-positioned mission-tailored support packages (e.g., ASLs) designed using RBS in conjunction with mission-based forecasting. Or, if not pre-positioned, the same effect could be achieved by "setting aside" small, similarly constructed packages that could be rapidly deployed along with the Army aviation unit similar to the US Marine Corps "fly away element" or the US Air Force "war reserve spares kit". These tailored mission support packages can then accommodate Class IX replacement needs at deployed locations where existing (e.g., host nation) sustainment is not immediately or readily available. This is an example of defining a "decoupling" point in the existing supply chain and creating additional slack inventory to accommodate a short term surge that the existing logistics supply network infrastructure cannot support.

Second, to accommodate sustained, rather than temporary, higher demand for extended operations (e.g., OIF today), resilient supply chain design principles would suggest creating additional capacity, or relocating existing capacity, closer to the demand source. This strategic supply chain concept shifts "decoupling" points and push-pull boundaries by dynamically changing the supply chain configuration. Hence, the logistics network responds quickly to initially accommodate a short-term need with built-in slack inventory, and then adapts, if and when necessary, by actually changing its configuration to sustain increased longer-term requirements by relocating production (repair) capacity closer to the source of demand. During OIF, AMCOM acted belatedly to achieve the latter by activating, deploying, and now rotating AVCRADs for in-theater repair. However, the former (pre-positioned stock) could not be accomplished since Army aviation assets currently are neither included in pre-positioned stocks or "set aside" as mission-tailored deployable support packages.

In summary, effort for attaining resilience must focus on strategically designing and structuring supply chains to respond to the changing dynamics of globally positioned and engaged forces, conducting different operational missions under a wide range of environmental conditions. Ultimately, this necessitates innovation in supply chain design, implementation, and management.

C. Improving Effectiveness: Pushing the Logistics Performance Envelope

So far, using supply chain concepts and the graphical Army multi-stage logistics model (figure 3), several challenges and opportunities have been isolated and identified both within these several stages and across them. However, "efficient" and "effective" solutions should be explicitly differentiated within the investment-performance, or cost-availability, tradespace. This section clarifies and illuminates these distinctions using the graphical tradespace construct that has been consistently used throughout the book. Then, using additional analytical methods and concepts, the next chapter further endeavors to develop and offer an "analytical architecture" to guide Logistics Transformation for the Army.

Economists commonly make a distinction between efficiency and productivity: efficiency refers to the output achieved from inputs using a given technology, while productivity also encompasses the results of changes in technology. By "efficient" we refer to those methods (whether policies, techniques, procedures, technologies) which, if adopted, reduce uncertainty and/or variability both within any particular stage as well as across the "system of stages" that comprise the multi-stage logistics enterprise. The results of these methods would have the effect of moving toward the "efficient frontier" in the cost-availability trade space (figure 10). Achieving an "efficient" solution results in operating on the existing efficient frontier and implies the best possible use of existing resources *within the constraints of the current system design and business practices* using existing technology.

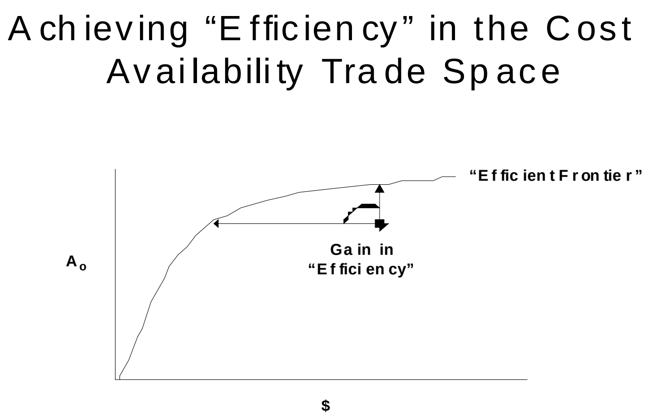


Figure 10

In contrast, a more "effective" ("productive") method is one which actually shifts the existing efficient frontier representing an improved "operating curve". This reflects the fact that current business practices have actually changed: new or different technologies are being exploited. Cost benefit analyses can be performed on various initiatives which yield improved, but different results (figure 11).The relative magnitude of each of these cost benefit alternatives, however, is dependent upon knowing the location on the current efficient frontier and, to some extent the expansion trace of the new, improved frontier that results when taking an existing "efficient" operation and, through organizational redesign, business process changes, or other forms of reengineering, creates a more "effective" operation characterized by an improved "operating curve".

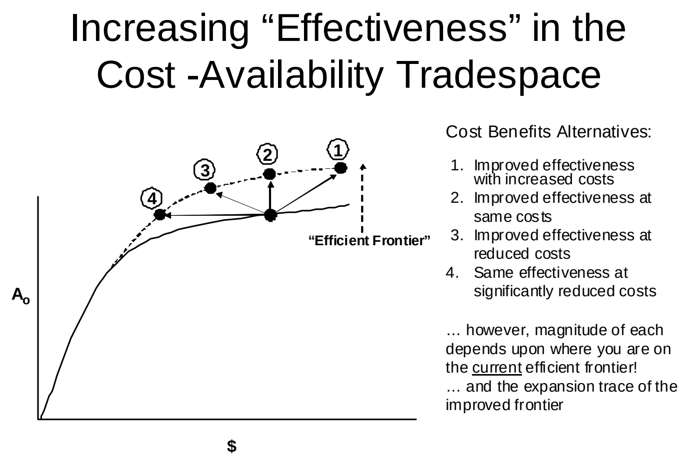


Figure 11

Finally, then, the obvious (graphical) goal to is sustain continual improvement and progress over time through "innovation" in all of its various forms. . . the notion of "pushing the envelope" (figure 12). This is the essence of "productivity gain" and differentiates, in competitive markets, those commercial firms that successfully compete, survive, and flourish over extended periods from those that do not.

For a "noncompetitive" governmental activity an "engine for innovation" is needed to compensate for the lack of competitive marketplace pressures typically driven by consumer demand and customer loyalty. The most obvious such engine for a military organization is imminent or evident failure on the battlefield. Failure in battle, especially if sufficient to cause the loss of a major war, clearly constitutes an "unmet military challenge" which is one of several key historical prerequisites for a "revolution in military affairs" (RMA) [10].

However, the US military, especially the Army, has been extraordinarily successful in recent battle, despite several acknowledged logistics shortcomings and inadequacies. The current issue then is whether or not these very real, persistent and serious logistics inadequacies are sufficiently compelling to warrant the necessary attention, resources, sustained intellectual support and extended commitment required for necessary change.

Indeed, a fundamental question is will, or even *can*, a so-called Logistics Transformation actually occur, especially with the Nation at war?

> "Every Army Chief of Staff, Chairman of the Joint Chiefs of Staff, and Secretary of Defense in the last 15 years has stated unequivocally that a true transformation of the US Army cannot occur without significantly changing the way we conduct logistics. The premise is that logistics is clearly the one area that absolutely must be transformed if the Army's vision of the future force is to be realized" [11].

So far, however, the actual experience of over a decade and a half of both Logistics Transformation and the Revolution in Military Logistics that preceded it offers a resounding "no" to this fundamental question. As with many large commercial firms, the Army appears to be paralyzed by an "innovation trap" common to such organizations. The consistent pattern has been one of internal cognitive capacity denying the need for change thus causing an inability within these organizations to commit to large-scale transformation efforts before it becomes too late [12].

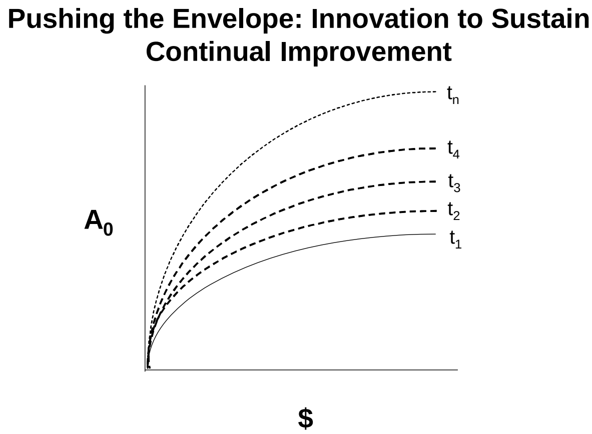


Figure 12

In the absence of imminent or evident failure resulting in battlefield losses which threaten the Nation's interests and/or values, an alternative "engine for innovation" is an extensive experimentation capacity providing an ability to "see" the impact of alternative concepts, policies and procedures, doctrine, tactics and organizational design - a "virtual" or "synthetic" environment that can realistically illuminate a better way thereby possibly preempting future failure.

This experimentation capacity must also have a "receptive organizational climate" including strong, sustained leadership support, mechanisms that actually enable discovery and "learning" to be derived from these experiments, and the institutional means to incorporate positive results into new or existing policies, doctrine and resource programs - in short, a bureaucratic capacity to both encourage and accommodate change. There are certainly illustrative examples of very successful "engines for innovation" within the Army that have had extremely influential, positive results, some with long term effects and others of short term impact.

One example with relatively long-term, sustained effects is the transition toward simulation-based training to capitalize upon the emerging power of live, virtual and constructive simulation technologies. This "opportunity" was initially forced upon the Army by both increasingly prohibitive training costs and decreasing availability of adequate real estate for live maneuver training areas, largely a consequence of the "environmental" movement. The resulting revolution in training and training technology has been ongoing for well over two decades now and has yielded a remarkable ability to provide a quasi-realistic, surrogate environment for the crucible of actual combat at nearly every organizational level. Training simulation is now ubiquitous, spanning individual soldier combat skill training, weapon system team training in crew simulators, highly stressful command and battle staff exercises up to and including multi-national corps exercises, simulation-driven theater and global wargames, and especially our combined training centers in CONUS and Europe. This transformation has produced the best-trained and arguably most dominant conventional Army in history.

A less conspicuous example within a much shorter timeframe, yet one with far more immediate consequences, is provided by the dramatic challenges to the Army's recruiting mission in the late 1990s. After nearly a decade of decline during the post-Cold War drawdown, the demand to stabilize Army end strength led to increasing recruiting requirements at a time when youth market conditions had become the most difficult and demanding in the history of the modern All Volunteer Force (AVF). The interaction of these and several other trends were not well understood at the time. As a consequence of several years of failed recruiting missions and retention challenges, Army combat organizations were struggling to meet personnel readiness objectives. Two of the Army's 10 active component divisions actually reported the lowest possible rating then. Indeed, recruiting forecasts at the time portended "imminent catastrophic failure" and, although not well known, the AVF was indeed in jeopardy as the military manpower system of choice for the US Army.

As a consequence of imminent failure, both Department of the Army and US Army Recruiting Command (USAREC) senior leadership focused attention on the creation and successful implementation of an "engine for innovation". Creative solutions which directly addressed the fundamental nature of the challenge were found and quickly implemented. This transformation was achieved through nation-wide testing, experimentation, modeling, market and recruiter surveys, extensive simulation and rigorous analysis, all conducted by newly-formed but very cohesive, multi-disciplinary teams of experienced recruiters, demographers, labor economists, statisticians, advertising experts, military psychologists and sociologists, market research and operations research analysts, and systems engineers. USAREC suffered its worst recruiting year, completely reengineered itself while transforming its approach to the youth market, then enjoyed its best year yet in its 30-year history, all within a span of less than 3 years from 1999 to 2001 [13].

These examples, though very different in form, duration and content, suggest the power, value and enormous contribution provided by a strong, comprehensive, analytically-based "engine for innovation" as a surrogate for failure to motivate needed organizational transformation. Indeed, the simulation revolution in training has now spawned an entire growth industry in Orlando, Florida, an area which has truly become a global training simulation center of excellence.

However, consensus-driven "demonstrations", adopted in recent years replacing analytically sound, empirically-based experiments and field testing for warfighting concept development, do not provide, and are not a substitute for, an adequate engine for innovation. The bad news is that such an approach clearly has not yet been adopted to support Logistics Transformation, much less accelerate it. The good news, however, is that the US Army, as these two examples illustrate, clearly has the experience and the potential capacity for doing so . . . if it chooses.

III. Design and Evaluation: An "Analytical Architecture" to Guide Logistics Transformation

Research to date has been largely "descriptive" in nature. An assessment of the current logistics structure was conducted using supply chain concepts to diagnose and better understand root causes of persistent challenges, their consequences and effects. Next, three "prescriptive" supply chain performance objectives - efficiency, resilience and effectiveness – were presented to focus various technology initiatives, policy reforms and management actions comprising Logistics Transformation.

A viable strategy is now needed to transition from the existing state of affairs toward a desired outcome defined by the characteristics presented previously. Inherent in developing such a strategy, or more simply a "plan", are needs to: (1) optimize the allocation of limited resources, and (2) understand and anticipate in advance the consequences, likely outcomes, and risks associated with an unlimited array of tasks that must be selected, sequenced, and synchronized for implementation.

These two analytical approaches - optimization modeling to efficiently allocate constrained resources toward desired objectives, and predictive modeling, including testing, experimentation and simulation, to anticipate likely outcomes and effects within a complex system - must be used together in a complementary manner to illuminate a viable plan for implementation. They provide an analytically-based strategy to link means (resources) with ways (concepts and plans) to achieve desired ends (objectives), or in other words, an "analytical architecture" to guide Logistics Transformation.

Furthermore, changing operational conditions, emerging test results, or outcomes from previously enacted policy changes may illuminate a clear and compelling need for adjusting the Logistics Transformation plan at a point in time (most likely doing so several times). These conditions may reveal certain project tasks that should be re-sequenced, possibly accelerated or conducted in parallel, or implemented in a more comprehensive, widespread and rapid manner. Further testing and evaluation may be needed to resolve key anomalies or concerns thus causing delays or completely eliminating altogether those initiatives which are not sufficiently mature for implementation or have been precluded by better methods. These options and resulting decisions should be grounded in thorough cost-benefit analyses conducted in a large-scale systems modeling environment representing the Army's logistics structure and processes. Today, however, our analytical capacity to evaluate new ideas and concepts is inadequate.

The modeling and simulation methodology outlined in these next sections would provide this much-needed analytical capacity and could constitute a "dynamic strategic planning" capability for Logistics Transformation. The intent is to avoid the typical project management "master plan" approach which prescribes a pre-defined, although detailed, set of tasks with tightly specified milestone schedules. Dogmatically following such rigid master plans admittedly may be mandated by various DoD regulations and federal contract laws. Yet these constraints discourage the possibilities of adjusting program initiatives and tasks when either necessity requires such adjustments or opportunities are presented through adaptation and experimentation. A more responsive, adaptive planning approach is needed to accommodate doctrinal changes driven by evolving mission needs and operational concepts, and to capitalize on emerging results from experimentation, field testing, and unanticipated breakthroughs yielded by a supporting engine for innovation.

This logistics analysis test bed could be patterned after any one, or a combination, of several organizational constructs, including the TRADOC "battle lab", US Government "reinvention center" provided for by the National Performance Review and Reinventing Government Act, or a think tank-based "center for innovation" design described at the end of this chapter. The purpose of this engine for innovation, regardless of the form it ultimately takes, is to provide large-scale systems simulation, analysis and experimentation capacity and expertise needed to serve as a credible test bed. This capability will generate the compelling analytical arguments needed to induce, organize, sequence, and synchronize the many changes needed to gain momentum then accelerate transformation for Army logistics, including those identified and described previously.

Furthermore, it would offer potential for quantum improvement - real substance - over the PowerPoint "analysis" that has become pervasive. Indeed, PowerPoint presentations have been elevated to an art form, yet they are as insidious as they are pervasive. Managers devote increasing time to packaging their ideas in media-friendly ways rather than to the rigor and resulting implications of their analyses. In contrast, rigorous analysis offers insight and alternative solutions to complex, seemingly intractable challenges that have persistently yielded to emotionalism and myth.

Finally, it is both practical and insightful to visualize overall “system efficiency” across all components of the multi-stage logistics model as the multiplicative *product*, rather than the additive *sum*, contributed by all parts of the supply chain process. In linear systems, changes in output are generally proportional to input; the sum of the inputs equals the output in a relatively predictable pattern. However, complex systems are inherently nonlinear, and outcomes cannot be predicted or understood by the simple act of adding up the parts and component relationships.

The purpose, function and relationships of key components of this enabling “analytical architecture” are described next

.

A. Multi-Stage Supply Chain Optimization

Evolutionary progress for an Army Logistics Transformation trajectory can be easily imagined along a spectrum transitioning from legacy-reactive to future-anticipatory concepts:

- reactive, cumbersome, World War II-era mass-based, order and ship concept where “days of supply” is the primary metric;
- modern supply chain management incorporating velocity-based, sense and respond concept where “flow time” is the metric;
- adaptive and dynamic, inference-based, autonomic logistics network concept to anticipate and lead, where the metrics are “speed and quality of effects”.

However, a clearly defined implementation scheme for “transformation” is certainly not self-evident. Analytical methodologies are needed to properly sequence the vast array of new initiatives, modern technologies, process changes, and innovative management policies in cost-effective ways: Which ones are dependent upon others as “enablers” for their success? How many can be done in parallel? For those that can be, will it be possible to identify and quantify the different effects of their respective contributions? Will the synergistic consequences of interactions among complementary initiatives be measurable? Which ones may be precluded by combinations of other, more cost effective options? And how can we be assured that these various initiatives are not inadvertently discarded because their potentially positive effects on readiness are “lost” in the existing “noise” of such a complex, massive supply chain? In short, how can cause and effect be “disentangled” as transformation proceeds?

The earlier use of a multi-stage conceptual model to analyze the Army’s logistic structure throughout Chapter III of this paper naturally lends itself to the use of dynamic programming (DP) or a comparable problem solving technique. DP is designed for complex, non-linear, mixed discrete/continuous problems that can be decomposed into smaller, more manageable parts for analysis, and then recombined in such a manner as to yield an overall system-wide optimal solution while avoiding the normal pitfalls and inadequacies of so many other methods which lead to suboptimal results. The basic concept which makes DP relatively unique in the field of mathematical programming optimization theory is referred to as the “principle of optimality”. DP works “backward” through the several stages of the problem to ultimately enable an optimal solution to be derived using a solution procedure, rather than a mathematical algorithm which is typically used for most other optimization methods [14].

Using figure 13 for reference, 4 of the 6 logistics model stages are aligned for illustrative purposes. Working backward from the point of consumption where readiness output occurs at the “unit” stage, the DP solution procedure moves from stage to stage - each time finding an optimal policy for each state (impacting Ao in this case) at that stage - until the optimal policy for the last stage (N) is found. A recursive relationship is used to relate the optimal policy at each successive stage (n) to the n-1 stages that follow. Once the final N-stage optimal policy has been determined, the N-component decision vector can be recovered by tracing back through all the stages. In this graphical example, the challenge is to determine the optimal allocation of a defined budget across a range of initiatives associated with these several logistics stages. Consideration must be given to various constraints that may be imposed within each of the stages as well. The overall goal is to maximize output from the "system of stages" - readiness (i.e., Ao).

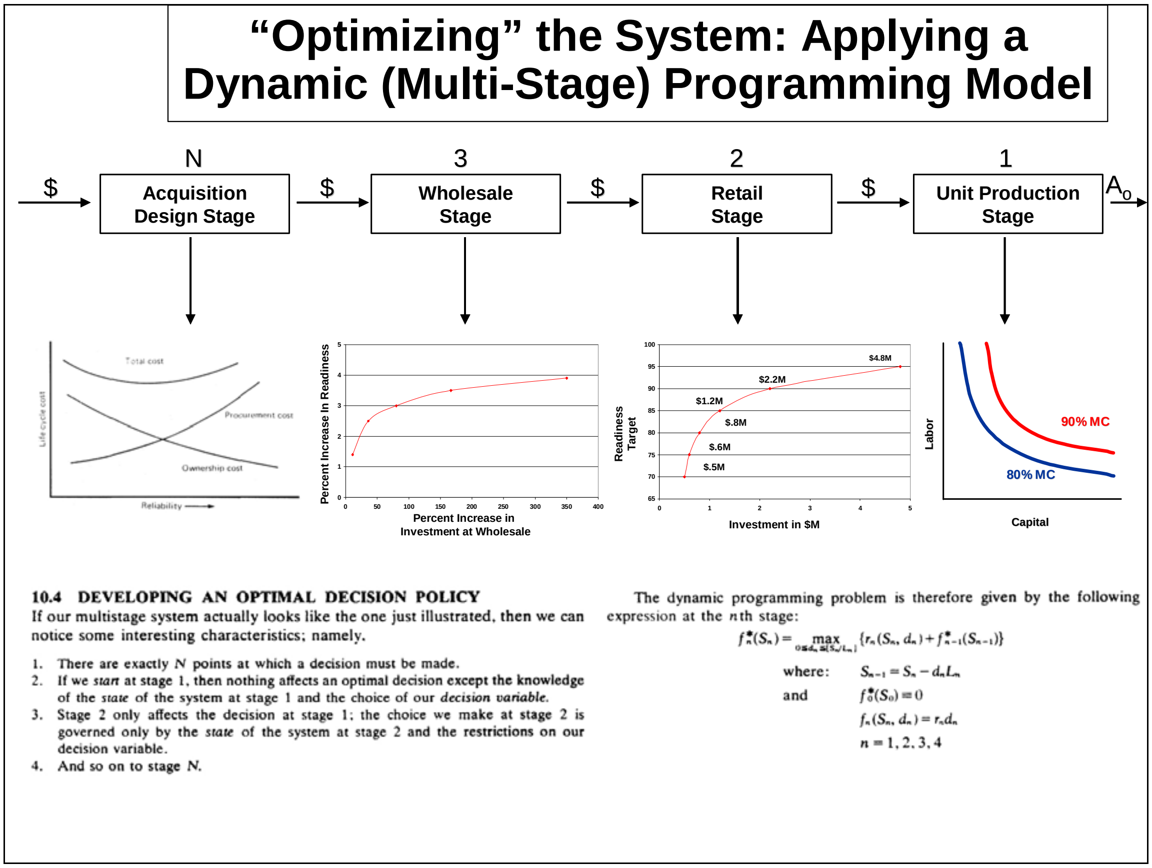


Figure 13

From a practical perspective, this illustrative example especially reinforces the crucial importance of developing a clearly-defined aviation readiness production function and adopting STA/RBS stock policies as enabling prerequisites to realize further cost-effective improvements to the system. For example, if the link between the unit stage (where readiness is produced for specific capabilities) and the retail stage management policy has not been optimized to desired readiness objectives (Ao) by adopting RBS, then the potential positive effects of a wide range of other improvements throughout the supply chain will not be clearly visible and fully realized. Additionally, potential investments should not be chosen on an individual basis but rather on how they interact with each other. Their real effects will simply be lost in the downstream "noise" of a very volatile, disconnected and inefficient supply chain.

B. System Dynamics Modeling and Dynamic Strategic Planning

Supply Chain Flows

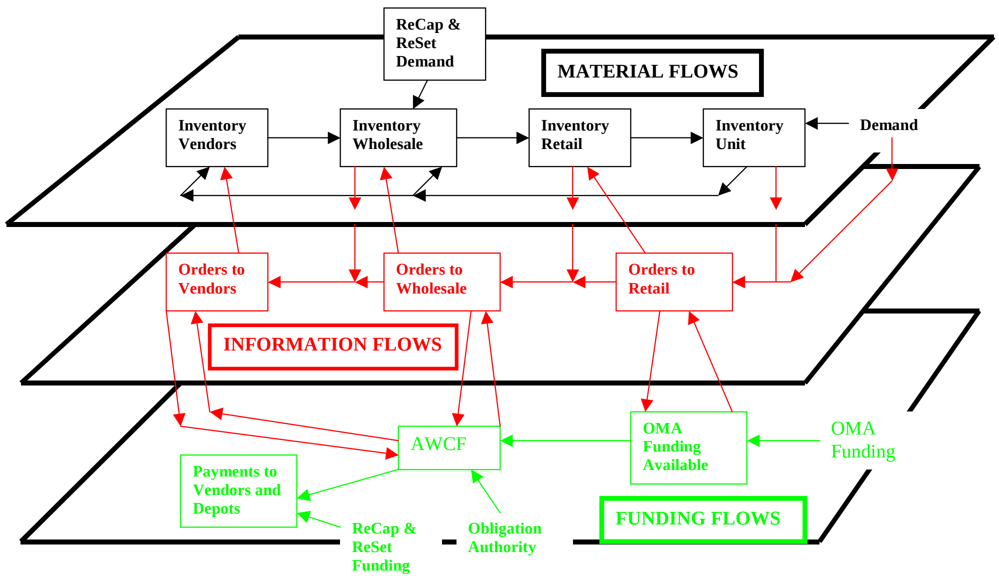


Figure 14

Second, use of a multi-*period* model must be incorporated into Logistics Transformation to accommodate both the extensive and extended nature of this enormous undertaking. As events occur and a transformation trajectory evolves, a mechanism is needed to routinely update the "optimal" solution which, inevitably, will change over time due to: (1) the inability to perfectly forecast future conditions; (2) consequences of past decisions which do not always reveal the results expected; and (3) the opportunities provided by adaptation and innovation as they materialize and offer improved solutions requiring new decisions.

This dynamic strategic planning (DSP) approach is, in essence, a multi-period decision analysis challenge which also encourages and assists in identifying, clarifying and quantifying risk to the transformation effort. Risk "assessment", a precursor to risk "management", is needed to reduce and mitigate the inevitably disruptive consequences of any major transformative effort with all the uncertainties surrounding significant change.

Most planning methods generate a precise, "optimized" design based upon a set of very specific conditions, assumptions, and forecasts. Optimization techniques which provided the foundation upon which DSP would subsequently evolve are primarily mathematical programming methods such as linear programming and its many derivatives, including integer programming, goal programming, and geometric programming. Although powerful and essential, a practical limitation of these techniques is that they require a specific set of conditions and explicit assumptions. While these conditions and assumptions may be appropriate in the short term for tactical operations, they are almost certainly never valid over longer planning horizons as strategic designs for technological systems [15].

In contrast, DSP instead presumes forecasts to be inherently inaccurate ("the forecast is always wrong") and therefore "builds in" flexibility as part of the design process. This engineering systems approach incorporates and extends earlier best practices including systems optimization and decision analysis. It has recently evolved by adapting "options analysis" now commonly associated with financial investment planning. DSP allows for the optimal solution - more precisely, 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 that evolve as various conditions unfold which, even when anticipated, cannot be predicted with certainty.

This planning method yields more robust and resilient system designs which can accommodate a wider range of scenarios and future outcomes than those more narrowly optimized to a set of specific conditions. Though perhaps easier to engineer and manage, traditional "optimal" designs can quickly degenerate toward instability when such conditions no longer exist [16].

The human mind also exhibits difficulty inferring accurately the behavior of "complex, dynamic systems" characterized by feedback loops and nonlinear relationships inherent in their large scale, scope and complexity. Advanced by Professor Herbert Simon (1978 Nobel Prize in economics), this "principle of bounded rationality" suggests even the best human judgment and mental analysis when applied to large, complex problems simply cannot account for all the interactions that will affect and determine outcomes[17]. Compelling evidence from theoretical investigation and the empirical record of actual experience clearly reveals that the behavior and performance of large-scale, global supply chains must indeed be characterized as "complex, dynamic systems".

These defining features - large-scale, complex, dynamic, tightly coupled, feedback, and nonlinear- are summarized in this paragraph to illustrate their relevance to supply chain behaviors, including oscillation, amplification and phase lag. *Large-scale* implies that the system is composed of a large number and variety of interdependent components. *Complexity* exists as a consequence of these interdependent components having cascading impacts on other aspects of a *tightly coupled* system which can yield counterintuitive effects. The system is d*ynamic* with the cumulative impact of market-based cycles, multiple delays, error corrections, and unexpected changes creating short run responses to perturbations which may be different than long run response. Interactions abound due to internal linkages with causal connections causing *feedback*, tight coupling and cascading effects. Cause and effect relationships do not have simple, proportional relationships and, for systems easily affected by outside conditions, result in high synergy, *nonlinear* behavior.

Unless these feedback mechanisms and their interactions can be anticipated, standard optimization methods will underestimate the impact of changes, often dramatically. Fortunately, an alternative approach which explicitly focuses on capturing the structural dynamics and complexity of such systems has been developed and refined.

System Dynamics, more than other formal modeling technique, stresses the importance of nonlinearities in model formulation while also possessing highly evolved guidelines for model construction, including proper representation, analysis, and explanation of the dynamics of complex technical and managerial systems. While traditional mathematical programming tools are useful when dealing with *combinatorial complexity* in projects that have multiple parallel and sequential activities, system dynamics better deals with the *dynamic complexity* created by the interdependencies, feedbacks, time delays, and nonlinearities typically found in large-scale projects [18]. A central feature of systems dynamics, especially when enabled with computer simulation, is its ability to illuminate and explain seemingly counterintuitive results and effects commonly found in complex organizational and social systems.

These observations suggest that large-scale, transformational endeavors are much more than conventional "construction" engineering efforts. They represent a major human enterprise where effective managerial decision-making requires a thorough understanding of the evolution and dynamics of the change undertaken. New software tools now make it possible for managers to actively participate in the development of these system dynamics models, so-called management "flight simulators", which have become the basis for learning laboratories in many organizations [19].

Army Logistics Transformation would benefit enormously from such an application. Within a supply chain management context, system dynamics modeling and analysis would explore how various policies interact; would they interfere or cause diminishing returns? Ideally, the aggregate sum of their effects and benefits would be greater than their individual policy impacts; but what are the sources of synergy to create such results? Since supply chain behavior often exhibits persistent and costly instability, a "stock management structure" (figure 15) is used to model and explain these effects. Since this structure involves multiple chains of materiel stocks, information and financial flows, with resulting time delays, and because decision rules often create important feedback loops among the interacting operations of the supply chain, system dynamics is well suited for modeling and policy design. As described previously, it is important to understand the "optimal sequencing" of a wide array of possible policy initiatives in order to fully capitalize on their collective potential benefits.

Stock Management Structure

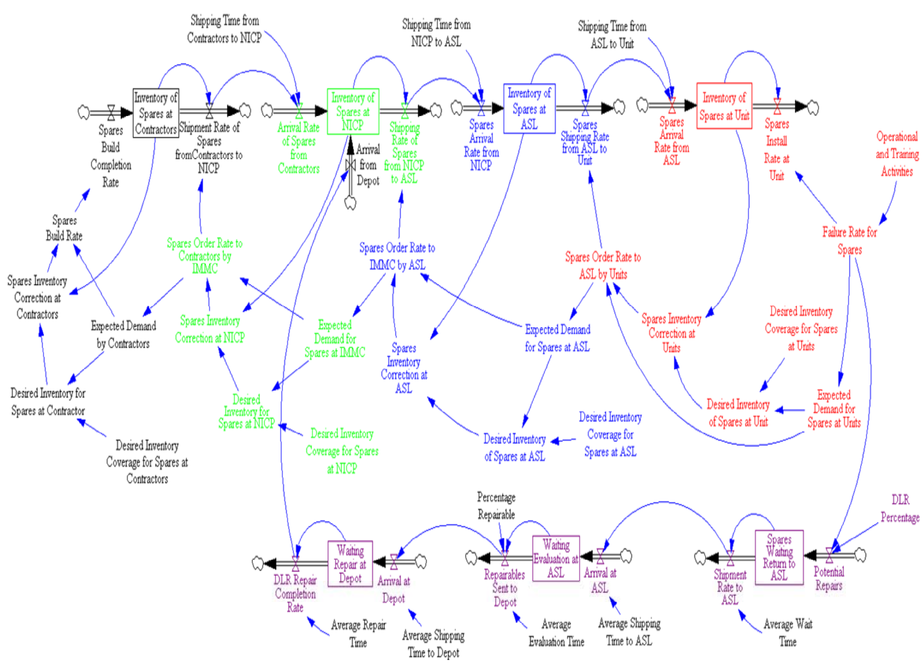


Figure 15

Much of the management literature in business process reengineering emphasizes focusing on finding, then relaxing, major bottlenecks in the existing manufacturing or operations process [20].

Focusing improvement effort on the current bottleneck immediately boosts throughput, while effort on non-bottleneck activities is wasted. However, relaxing one constraint simply enables another to develop as time progresses. Obviously, waiting for each successive bottleneck to occur would prolong and retard rather than accelerate continuous improvement. The value of system dynamics modeling is accelerating this understanding by exploring the implementation of different sequences in a synthetic (simulated) environment. By using the model to anticipate and accelerate this shifting sequence of bottlenecks, a *prioritization* scheme for these many initiatives can be developed.

This process redesign method, referred to as "sequential de-bottlenecking", enables potential chokepoints in the actual system to be anticipated, understood then eliminated, using the system dynamics model, before they become binding constraints on throughput. When applied to commercial supply chains, this approach has enabled faster growth, lower volatility, and greater value creation for organizations that have used it [21]. For the Army, a system dynamics model of the supply chain has the potential to guide and help accelerate Logistics Transformation by optimally sequencing and synchronizing the vast array of initiatives that have been suggested for implementation. Previously, we used a system dynamics model to demonstrate aviation supply chain vulnerability to the bullwhip effect.

Decisions Analysis, the second major analytical component in the evolution of DSP, enables structuring the combination of system dynamics-enabled design choices so they can be made in stages as a system evolves over time. Cost-effective options can be evaluated to determine the best pattern for system development depending on how uncertainties, both within the system and external to it, are resolved over time. Thus, DSP defines an optimal *strategy* or policy rather than a fixed plan; it is the designer's responsibility to determine this (resilient) strategy rather than merely pick a single (fragile), "optimal solution" from a menu of choices.

The most recent DSP improvements have focused on incorporating means to evaluate and build "flexibility" into designs. These include "real options" and "robust design" methods which enable calculation of the value of "flexibility" which was not previously considered. Consequently, "flexibility" as an attribute of engineering systems design was systematically neglected. "Real options", applied to "real", physical systems, is an adaptation of "options analysis" which was developed for and has been applied extensively in financial markets. Recent and ongoing applications of this newest aspect of DSP indicate the approach leads to substantial improvements in design. Also, embedding flexibility into diverse systems already "optimized" for performance under traditional deterministic concepts is leading to substantial savings in many cases [22]. An illustrative military application of DSP was development of an Army strategic resource planning capability to support the national defense strategy during the first Quadrennial Defense Review (QDR) in 1996-97, then guide Army resource planning in subsequent QDRs as defense strategy adapted to changing geopolitical trends [23].

C. Operational and Organizational Risk Evaluation

Third, in conjunction with DSP, a wide variety of analytical methods should be used to understand, evaluate and reduce "risk" during Logistics Transformation. "Risk" can take on different connotations depending upon the application. Accordingly, we address two concepts here: (1) operational risk faced by the logistics system responding to various shocks, supply chain disruptions, and mission requirements that may not have been anticipated, and (2) organizational risk to the Army logistics community, including the combination of investment, or programmatic, risk associated with new project undertakings and the larger impacts induced by transformation uncertainties associated with organizational change at a difficult and challenging time.

Operational risk, in this decision analysis context, consists of assessing both the likelihood of a particular adverse outcome as well as the consequences of that outcome. One of the most important steps in this risk assessment process is the quantification of risk. Yet the validity of the approach commonly used - expected value - is fundamentally flawed. Expected value metrics fail to represent the true risk of "safety-critical" systems for which the consequences may be catastrophic, even though the probability of such an event may be low. This occurs because the expected value approach essentially equates events of high consequence but very low probability of occurrence ("extreme events") with those of low consequence yet high probability, perhaps frequent occurrence. Thus, extreme events with low probability are given the same proportional importance regardless of their potential catastrophic and irreversible impact. Such systems should not be measured solely by the standard expected value metric, especially when the consequences are unacceptable.

Theoretical advances in modeling and assessment have addressed the risk associated with extreme events and the fallacy of the expected value approach. One particular technique, the partitioned multi-objective risk method (PMRM), explicitly captures the value of extreme events. Then, using a risk filtering, ranking, and management (RFRM) methodology, these risk elements are ranked based upon severity, then systematically addressed through a risk mitigation process. The mitigation process includes relevant scenario-based analyses in conjunction with risk reduction methods including redundancy (backup components to assume functions of those that have failed), robustness (insensitivity of system performance to external stresses), and resilience (system ability to recover following an emergency).

Another more recently refined technique which should also be considered includes an adaptation of the Leontief input-output model. This new technique provides for a comprehensive risk assessment and management framework designed to ensure the integrity and continued operation of complex critical infrastructures. The theoretical derivation and supporting application principles for these analytically-based risk management methods are presented in reference [24].

Practical management frameworks, incorporating the advances described above, have recently been developed to systematically identify supply chain vulnerabilities, assess risk, and then formulate strategies to reduce those vulnerabilities and mitigate risk. Various sources and potential causes of disruption are then bundled into associated risk categories [25]. Analytical "tool kits" can be applied to examine specific effects and larger consequences for these risk categories, then supply chain modeling and simulation is used to analyze, evaluate and compare alternative operational strategies and their respective costs [26].

Those strategies which reduce disruptive risk and enhance supply chain resilience, *while simultaneously improving both efficiency and effectiveness*, are ideal candidates for accelerated implementation. Two practical risk mitigation strategies which impact all three supply chain system performance objectives - efficiency, resilience, and effectiveness – are: (1) a demand-driven supply network (DDSN) which reduces buffer inventory, improves readiness, and provides tactical agility, and (2) theater-level "decoupling points" to enhance operational agility and flexibility by providing, respectively, "slack inventory" for short, specific mission surge needs (e.g., humanitarian NEO) and, when necessary, "slack capacity" for long-term increases in demand to sustain in-theater operations (e.g., AVCRAD for sustained combat operations).

To address organizational (rather than operational) risk for Army Logistics Transformation, a variety of virtual, constructive, and live simulation methods, especially analytical demonstrations, field testing and experimentation, can identify, early on, which technologies or new methods warrant further consideration. This process enables differentiating those appropriate or sufficiently mature for implementation from others that are not. In this context, organizational risk consists of the combined effects of both uncertainty of outcomes - simply not knowing the impacts of various alleged improvements on the logistics system - and also the uncertainty of future costs incurred as a consequence of either adopting, or failing to adopt, particular courses of action.

A recent example of this accelerating, "crawl-walk-run" approach is the sequence of experimentation and testing adopted by this project to first demonstrate, through rigorous analytical experimentation using the UH60 aircraft in the 101st Airborne Division, the potential value of adopting RBS as aviation retail stock policy; these insightful, positive results then provided impetus for and enabled further, more widespread field testing with several aircraft types in an operational training environment at Fort Rucker.

Confidence and credibility in a new, different method have been gained through experience while significantly reducing the uncertainty initially surrounding the new initiative. And return-on-investment results clearly reveal reduced investment costs while still meeting or exceeding aircraft training availability goals. A graphical display to conceptually portray these several analytical contributions to reducing organization risk is provided at figure 16.

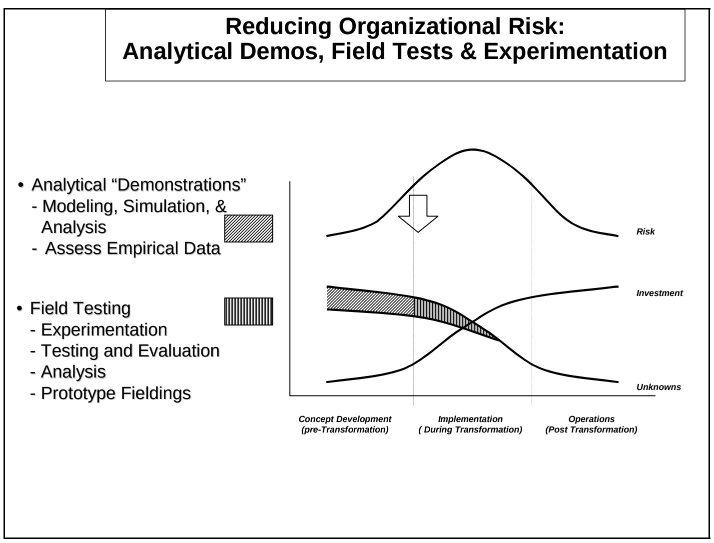


Figure 16

Finally, the Global War on Terrorism has illuminated a wide range of vulnerabilities in commercial global supply chain operations [27]. Among several research projects addressing these challenges is the "Supply Chain Response to Global Terrorism" project recently initiated by MIT's Center for Transportation and Logistics (CTL). This project is highlighting the "dependence of corporate supply chains on public infrastructure and systems coordinated or affected by the government [which] represents new vulnerabilities for businesses now more heavily dependent on the government than previously recognized" [28]. Using assessments from recent terrorism effects on supply chain disruption as well as other historical observations, both natural and man-made, several common failure modes have been identified. The current research focus is on developing cost-effective methods and classifying various responses for reducing vulnerabilities by improving both the internal security and organizational resilience of these global networks. The Army logistics community should actively participate in this project.

D. Logistics System Readiness and Program Development

The fourth and final enabling analytical component includes the development, refinement and use of econometric/transfer function models. This capability is needed so that OSD and HQDA-level budget planners and resource programmers can relate budget and program investment levels with associated performance effects, including future capability needs and desired readiness outcomes. New impetus for this long-recognized need is now provided by DoD Directive 7730.65 which requires developing and implementing a new "Defense Readiness Reporting System" (DRRS). This new DRRS:

> " . . . shall provide the means to manage and report the readiness of DoD and its subordinate Components to execute the National Military Strategy. . . the DRRS [will] establish a capabilities-based, near real-time readiness reporting system . . . to identify critical readiness deficiencies, develop strategies for rectifying those efficiencies, and ensure they are addressed in program/budget planning and other DoD management systems. . . The Secretaries of the Military Departments shall develop Service mission essential tasks in support of their responsibilities to Combatant Commanders and functions as prescribed in [Title 10, United States Code, as amended]" [29].

In general terms, these Title 10 "functions" include manning (e.g., recruiting), equipping (e.g., weapon system procurement), training (e.g., BCT and AIT, unit training, NCOES, etc), and sustaining (e.g., logistics) forces in each of the military departments. The Services, as "force providers", generate and maintain military capabilities which are then provided to the regional Combatant Commanders to accomplish specified missions. Each Title 10 "function" consists of significant institutional resources, organizations, and programs which collectively define "systems". Hence, a measure of each system's ability to achieve its respective goal can be defined as its "readiness" (e.g., logistics system readiness).

Application of this systems approach using supply chain management concepts will help to identify constraints and "weak links" that are inhibiting desired readiness output (e.g., Ao) thus reducing the overall strength of the logistics chain. Marginal investment resources should then be spent on strengthening these weak links. OSD and the Services are pursuing many logistics initiatives, but as the supply chain structure is improved and refined the logical next step is to understand and report the ability and capacity of the chain to generate output commensurate with its purpose [30].

New supply chain management concepts are incorporating geo-spatial sensors and automatic identification technologies (AIT) to enable "total asset visibility" (TAV) and the transition toward adaptive supply chains. In particular, radio frequency identification (RFID) is expected to significantly reduce transaction error rates while also providing near-real time, high volume data. Although these new technologies hold great potential, it is unlikely that legacy software and enterprise resource planning (ERP) systems will be able to provide improved decision support and fully extract all of the potentially useful information contained in these high volume data streams.

Traditional forecasting methods typically use conventional *linear* regression models (CLRM) which assume that unexplained variance is *homoskedastic* implying that the error term in the model is constant (and normally distributed). However, complex supply chains exhibit *nonlinear*, dynamic qualities due to the interactions, delays, and feedback effects across multiple stages of materiel, information, and financial flows - the bullwhip effect as previously described. Not only does CLRM fail to capture the volatility inherent in the process, but as data streams magnify in volume and accelerate in time due to RFID, the error term becomes increasingly *heteroskedastic* (the error term itself is stochastic and varies with time) rendering forecasts that are less, rather than more accurate.

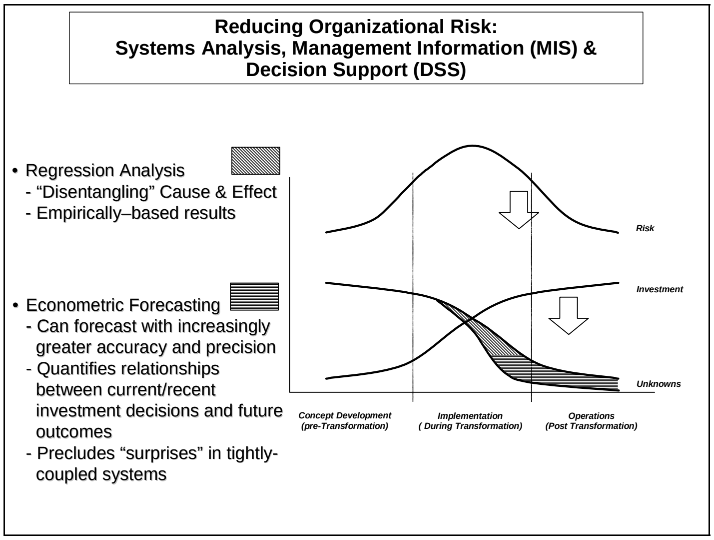


Figure 17

Recent forecasting advances for financial markets (including a Nobel Prize in economics), which exhibit similar volatility, have yielded improved, more accurate and precise results [31]. These models, described as *generalized autoregressive conditional heteroskedastic* (GARCH), are able to significantly reduce the error term by better quantifying interaction and lag effects among the explanatory variables and time series within the model. As the volume of data increases, the ability of GARCH techniques to better disentangle and explain cause and effect relationships *while reducing forecasting error* (unexplained model variance) improves. One project initiative involves examining the application of GARCH to RFID-generated supply demand data for units engaged in ongoing military operations in Iraq. Early results are promising, indicating that GARCH is yielding order of magnitude improvements for predictive performance compared to standard CLRM methods [32].

As these new, powerful forecasting tools are refined and improved to provide near real-time, enterprise-wide visibility into demand variability and volatility at the points of consumption, they can be combined with emerging agent based modeling (ABM) approaches which will replace existing equation based models (EBM) currently used in legacy and ERP systems [33]. These innovative technologies, when fully developed and implemented, will ultimately enable the transition to adaptive value networks in the commercial sector and, for DoD, a genuine capacity for autonomic Sense and Respond Logistics.

In the near term, however, driven by the new DRRS mandate and enabled by supply chain concepts, econometric modeling and dynamic forecasting to understand, measure and monitor Army logistics as a readiness-producing system, a conceptual framework has emerged for a "Logistics Readiness and Early Warning System". The purpose is not only to assess and monitor supply chain capacity to efficiently and effectively support current requirements, but also to anticipate its ability to responsively meet a range of future capabilities-based requirements as well. The objective is to overcome what has historically been a funding-induced cycle of instability manifested in periodic “boom and bust” cycles.

As figure 18 portrays, three elements would interact in a “feedback-alert-warning” cycle. “Automated Monitoring” continuously tracks and forecasts both tactical readiness (e.g., Ao) and supply chain parameters, then signals an alert if there is a decline in projected readiness or adverse trend in metrics. “Management Assessment” then validates an alert, quickly evaluates the potential problem, and assesses the impact of current and planned resource allocation as well as other technical initiatives which might mitigate or improve the logistics projection. After HQDA-level policy analysis and review, “Policy Response” acts to prevent a shortfall while minimizing recognition and resource response lags. This responsive link to program development is absolutely crucial to an adaptive demand network. Historically, however, this response has significantly lagged or been missing altogether causing “boom and bust” cycles in resource programming, thus precluding viable resource-to-readiness frameworks for management decisions.

Logistics Readiness and Early Warning System

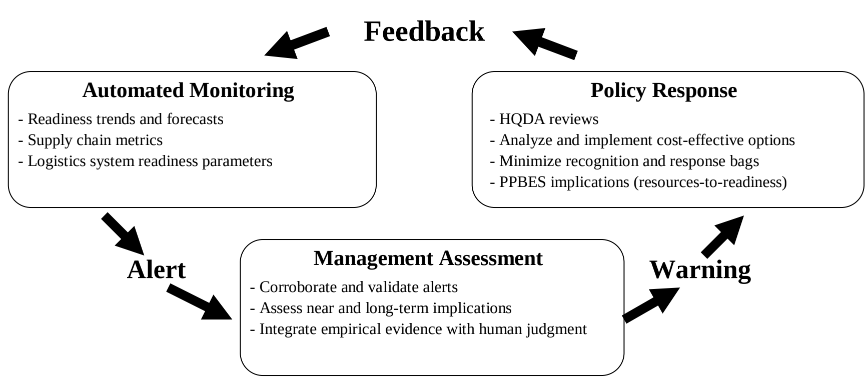


Figure 18

As cause-effect relationships are better understood, and as model parameters, decision variables and elasticities are refined to reduce forecasting error and improve model “calibration”, this capability will help to quantify high-impact investments and the differential effects of various logistics “drivers” on readiness outcomes. Our purpose is to both improve performance execution and refine requirements planning abilities using supply chain systems readiness leading indicators to anticipate, diagnose, and then pre-empt potential failures using analytically-based DSS. As part of this project, a modeling capability is being developed to support performance-focused strategic resource analysis and logistics program and budget development [34].

Further developed and refined over time, these forecasting models can increasingly be used for future capability forecasting, program requirements determination, and readiness prediction.

"Forward forecasting" is used to proactively anticipate and get ahead of the problem; "forward planning" to evaluate a range of alternative solutions, and then "forward budgeting" to lock in program (POM) resources in order to dampen, and ideally eliminate, future boom and bust cycles. These models should constitute part of a "Logistics Readiness and Early Warning System" contributing toward the DoD mandate for a larger Defense Readiness Reporting System by linking Army PPBES (resource planning system) to operational planning systems (readiness) [35]. The goal is to relate planning guidance, funding decisions, and execution performance in meaningful ways, all of which are informed by this supply chain "health monitoring and management" concept
.

E. Accelerating Transformation: An "Engine for Innovation"

Several agencies and organizations with logistics modeling and supply chain simulation capabilities could be pulled together, just as this new Army aviation-focused logistics readiness project has attempted to do [23]. They should now be integrated, even if loosely, into a more formal research consortium to better coordinate their efforts and reinforce their respective strengths. This synergistic effort will facilitate properly sequenced field tests, experiments and evaluation with supporting modeling, simulation and analysis. Furthermore, these organizations should form the nucleus of an "engine for innovation" for Logistics Transformation.

There are several commercial applications and academic sources of expertise that should also be included. One possibility is to create, as the Navy has done, a dedicated organization consisting of a partnership with both academia (for creative, cutting edge concepts) and the corporate world (for existing commercial applications) working in conjunction with a new Navy-led, Congressionally-funded logistics readiness research center. Another recently proposed partnership concept is creation of a "Center for Innovation in Logistics Systems" (CILS), summarized in the following paragraphs.

The CILS organizational construct consists of three components which essentially comprise the core competencies (mission essential tasks) for the center:

> (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 on large-scale logistics systems; and
> (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.

These three components serve to:

> (1) encourage and capture a wide variety of "inventions";
> (2) "incubate" those great ideas and concepts within virtual organizations to test, evaluate, refine and assess their potential costs, system effects and contributions in a non-intrusive manner; then
> (3) transition those most promising into actual commercial and/or governmental practice.

Hence the term "innovation" is deliberately in the center's title to express the notion of an "engine for innovation" to support major transformation endeavors in the government and private sectors driven by an increasingly recognized necessity for change. These organizational components and their relationships (figure 19) are defined below.

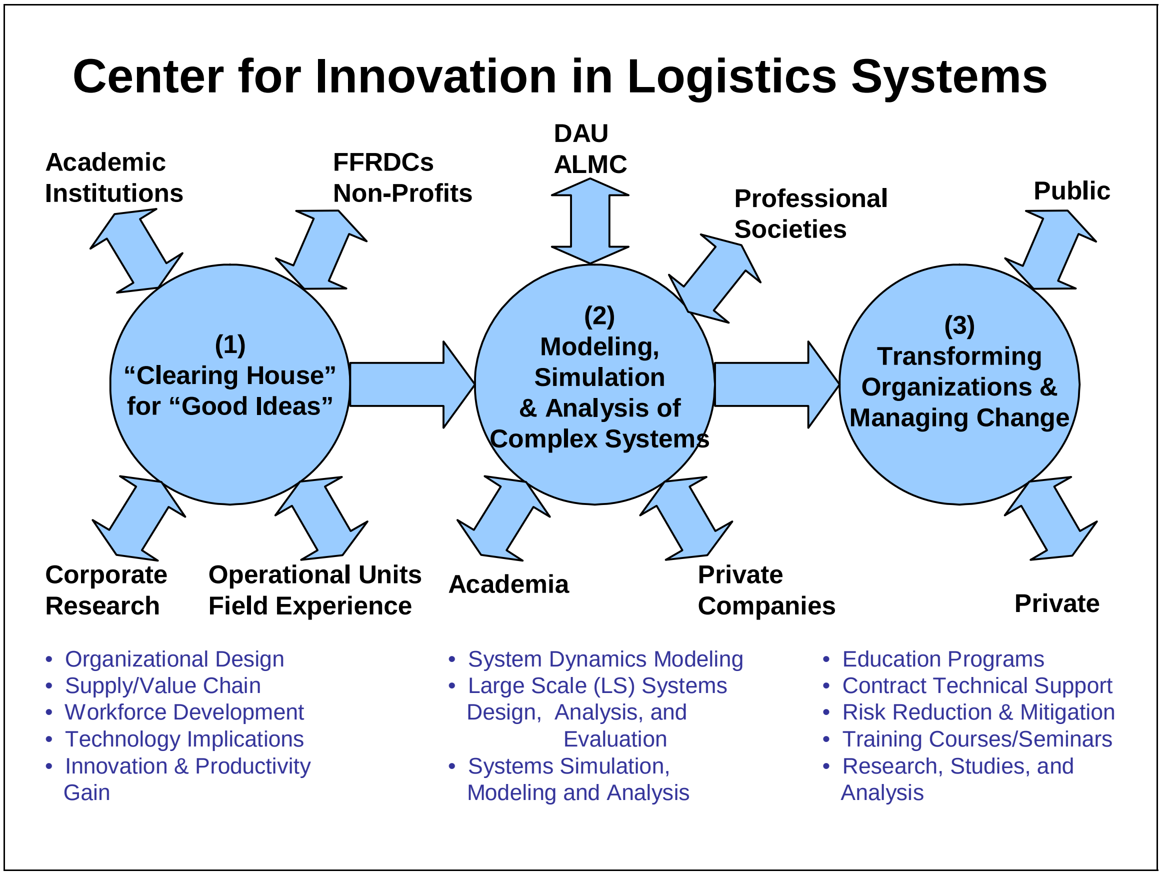


Figure 19

The "R&D Model and Framework" - (1) in figure 19 - provides a generalized structure for supply and value chains enabling the development of a research model. The model enables our current understanding of endogenous and exogenous factors influencing the performance of logistics organizations and also indicates where existing theory and research are inadequate. The logistics research model also yields an association between various subject matter expertise (organizations and individuals) and the manifold elements that comprise the research model. These organizations include academia, FFRDCs, research offices and companies in the corporate world, and both federal and state government agencies.

A consortium will be established, consisting of representatives of these research organizations, to share recent research information, define and clarify gaps and opportunities in current theory and research, partner on research development projects, refine and adjust the research model, and generally guide the advancement of the logistics research model thereby improving the collective understanding of supply chain behavior, management and design. This collaborative effort is intended to drive the "engine for innovation" with "good ideas" generated from a focused, solid research program and supporting research campaign plan. It could also further the interests of private sector companies wishing to offer their creative concepts to further scientific scrutiny and greater visibility. This enterprise constitutes the logistics research "strategic outreach" program to promote and encourage innovation thereby enabling a continual process of improvement in practical application.

The "Large-Scale SCM and Logistics Systems Analysis, Modeling, Testing and Experimentation" component - (2) in figure 19 - rigorously examines the implications of good ideas generated by the research consortium. Using comprehensive modeling, simulation, and testing capabilities, it provides a virtual, or synthetic, laboratory for innovation and transformation. The disciplines involved and methods applied should include:

- industrial and systems engineering;
- engineering management;
- market research and cost analysis;
- workforce implications of socio-demographic, psychographic and labor economic trends;
- organizational design and social psychology;
- high-performing systems theory;
- inventory theory, supply chain management and design;
- system dynamics and large-scale, high resolution systems simulation; and
- the integrating power of systems analysis, operations research, and management science.

The purpose of this extensive modeling and analysis effort is to thoroughly understand not only the likely immediate and isolated impact of adopting new and different concepts and initiatives, but their potentially broader implications for the larger value producing enterprise over time. Concepts warranting further evaluation from these analytical demonstrations, which use constructive and virtual simulation and modeling approaches, would then be assessed in a "live" environment using pilot tests, field testing, experimentation and evaluation.

The final CILS component, "Implementing Organizational Change" - (3) in figure 19, provides the means to accelerate the "transition to market" phase of the larger innovation process: commercializing good ideas and inventions into successful applications in both the public and private sectors. Effective training, education and technical support are indispensable to ensuring the success of leaders and organizations committed to and about to undertake major change in traditional practices, processes, procedures and especially their organizational culture.

The development of strategic planning and management frameworks are also essential to enable learning within organizations. The identification of organizational risk, including investment costs and anxiety-causing unknowns, can illuminate the need for and value of applying analytical methods to reduce and mitigate these various elements of risk for organizations embarking upon major transformations (figure 20). This component provides feedback loops to the other two components in the logistics innovation center. This feedback, central to a "learning" organization, provides the connection to real world challenges and results thus refining and guiding the research model by providing necessary adjustments and enhancements, grounded in empirical evidence, to improve the accuracy and predictive power of systems simulation models. These feedback loops provide for a repository of lessons learned as well.

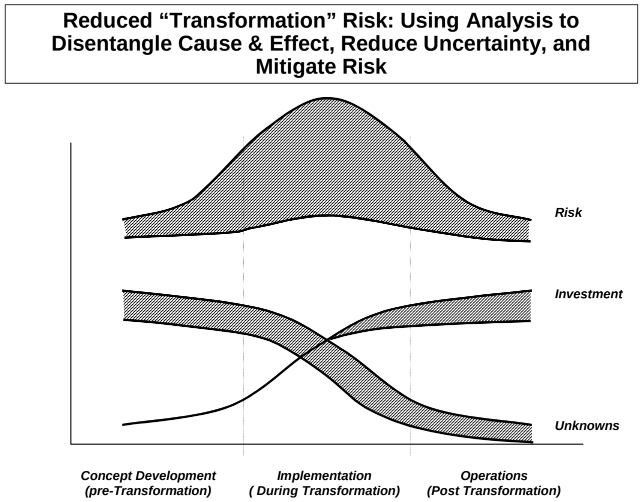


Figure 20

These four modeling approaches - multi-stage optimization, dynamic strategic planning, risk management, and program development - should be used in unified and complementary ways to constitute a "dynamic strategic logistics planning" (DSLP) capability. DSLP can take, as input, both the empirical evidence of ongoing operational evidence (real world results) and also the potential contribution of new opportunities derived from an "engine for innovation" (synthetic results), and then guide - as output - Logistics Transformation toward strategic goals and objectives: an efficient, increasingly effective, yet resilient global military supply network. Collectively, they constitute the "analytical architecture" needed to sustain continual improvement for Logistics Transformation (figure 21).

Collectively, CILS and DSLP have the potential to accelerate the process of management innovation by building a capacity for low-risk experimentation using a credible, synthetic environment. The purpose of this cyclical process is to sustain continuous improvement through a deliberative process of incremental innovation achieved through experimentation, prototyping, and field testing.

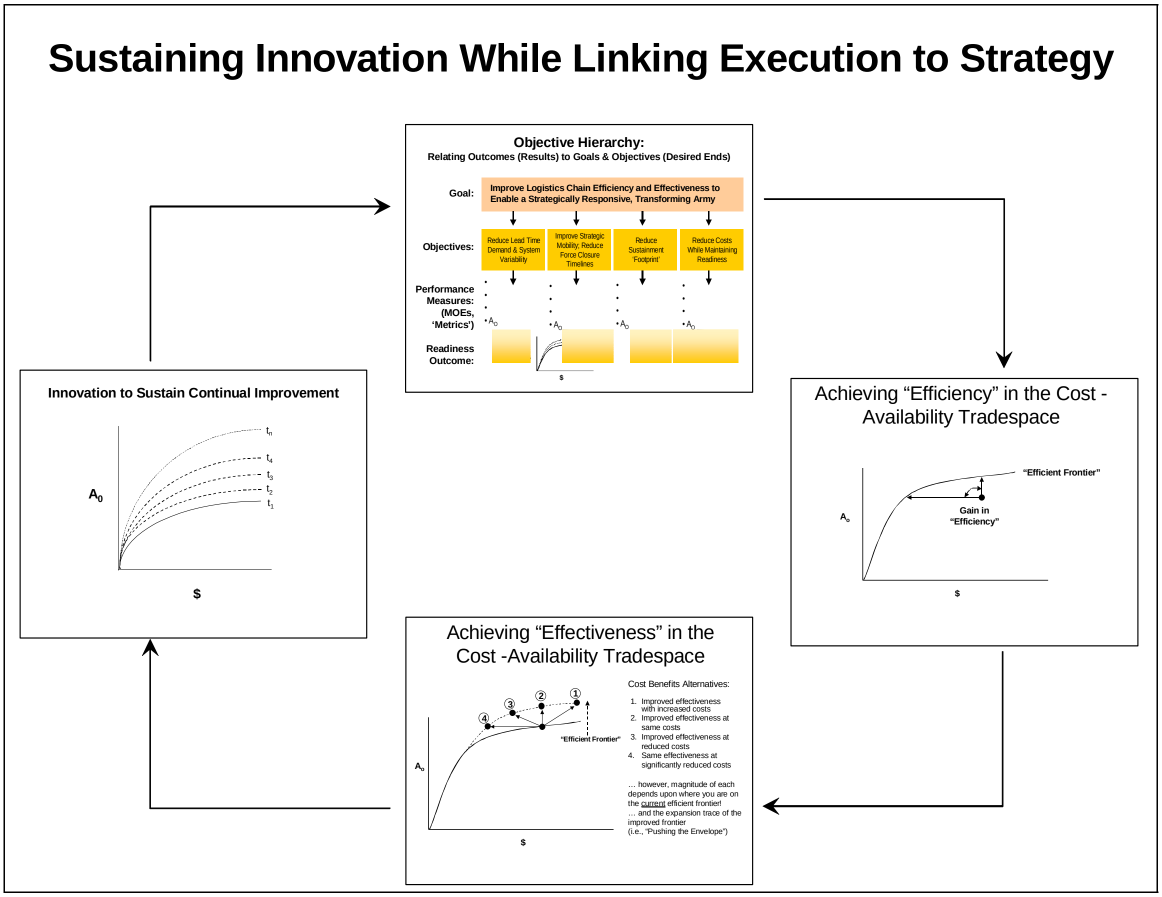


Figure 21

IV. Final Thoughts

Strategy is fundamentally about dealing with change - it represents the heart of management. Today, however, an honest appraisal suggests existing organizational structures, relationships, and logistics processes are, collectively, the product of decades of short-term workarounds, ad hoc solutions, and periodic management fads, but mostly inertia, rather than disciplined strategic thinking. This pattern has been accompanied by a persistent failure to challenge predisposed paradigms, management policies, and organizational procedures. Under increasing organizational pressure, the tendency toward reactive, ad hoc crises management has completely supplanted long-term strategy.

Tactical units in the US Army are renowned for pioneering and refining the After Action Review (AAR) concept as a continuous learning method to surface, diagnose, and correct deficiencies in order to improve and sustain operational excellence. Yet comparable diagnostic effort has not been prevalent at strategic levels within the institutional Army bureaucracy. Since analytically rigorous "autopsies" - "dissection" for root cause diagnosis, understanding, and response - on management issues are not routinely performed to uncover "ground truth" and learn from mistakes, reactive "firefighting" has been the standard response to visible symptoms. Army logistics management has become sclerotic.

As with any complex, large-scale systems challenge, key implementing concepts will be essential to ensure a successful Army Logistics Transformation endeavor. These organizational, analytical, information systems, technology, and management concepts should all be guided by a clear understanding of the ultimate purpose for which the enterprise exists, an organizational vision for the future, and a supporting strategy to realize the vision (figure 22).

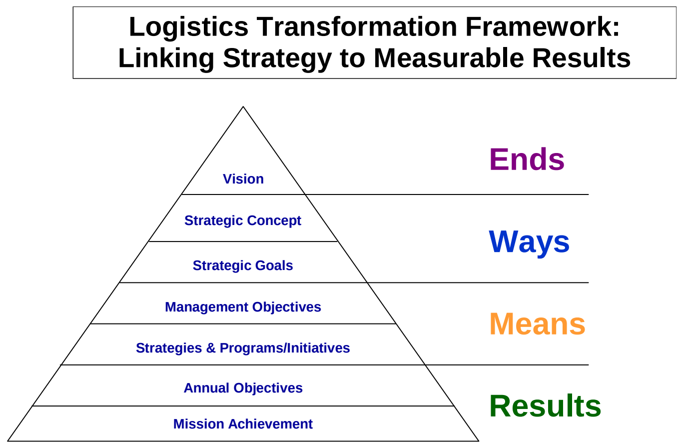


Figure 22

Ultimately, this strategy must focus the effects of transformative change upon capabilities-based, readiness-oriented outcomes. All too often for logistics, the "ends-ways-means" strategy paradigm has not been applied. Sporadic efforts have attempted to compensate for perceived inadequacies in "means" (resources) and "ways", instead yielding reactive, narrowly focused responses attempting to band aid yesterday's problems, rather than focusing on the "ends" – generating mission readiness - which is the purpose for which the entire enterprise exists.

"Transformation" will indeed require disturbing existing cultural paradigms, causing an inevitably disruptive period of significant change. And, despite the inexorable advance of technology, it will be improved management and decision support systems that ultimately enable innovation potential to be realized. Finally, this endeavor should embrace that of a Learning Organization. This will be a crucial enabler for sustaining continuous improvement.
The purpose of this project is to ensure Logistics Transformation for the US Army transitions toward a readiness-focused logistics organization which, averting Path D, ultimately follows a strategic trajectory along Path C (figure 50).

The future is properly the temporal focus of "transformation". However, a major precept of any "learning organization", even more fundamental than the five disciplines that characterize one, is the ability to actually learn from - not merely observe - the past [37]. Distilled to its essence, simply failing to repeat past mistakes represents the most basic form of human progress [38]. The study of history informs contemporary conceptual thought. Additionally, since people naturally tend to see their current problems as unique and overwhelming, historical analogies can be especially helpful. They stretch and broaden our thinking and allow contemporary challenges to come into better focus through the long lens of history. Emphasis on "out of the box" thinking today should also be tempered through understanding and appreciation by "looking into the box" of the past.

Accordingly, consider the following characterization:

> "... the system lacked a clear chain of command. Agencies all shared responsibility yet no one was responsible. . . it could not coordinate and standardize [data] to a common 'language'. Each bureau had raw data, analyzed for only its purposes, expressed in its terms, and responsive to its need. . . reorganizations [were] a response to crises and created the illusion of progress while merely producing confusion, inefficiency, and, most seriously, personnel demoralization. . .Because of continual reorganizations, the bureaus had new difficulty furnishing data . . . The situation became more complicated when records in one division differed from those in another . . .[he] found the independent, loosely related bureau financial practices a 'nearly insuperable barrier to consolidation' [and] varying interpretations of regulations caused confusion . . . He believed supply should conform to industrial and scientific principles yet lacked the authority . . . The Army was pushing an already strained supply system into a state of paralysis. . . an integrated supply system remained a myth . . by the end of the war he feared the supply system would collapse . . .[after the war, Congressional] hearings pinpointed the supply problem . . .Yet their Act did not unify the system. It institutionalized divided authority, providing enough checks and balances to paralyze action. . ." [39].

This extract is from Phyllis Zimmerman's historical biography of Major General George W. Goethals, the famous Army engineer who designed and managed construction of the Panama Canal [40]. Today, more than a century later, this achievement is still recognized as one of the greatest engineering and project management feats in modern history. At the beginning of America's entry into World War I Goethals was recalled from retirement to head the Army's supply organization. While his frustrations above, expressed in 1918, may also sound accurate in 2007, the long lens of history surely reveals one major advantage now compared to conditions nearly a century ago.

Turning to history then, rather than technology, to provide comparative insight into past and current conditions, one powerful observation becomes apparent: the "Power of Analysis" - operations research, systems analysis, and supply chain management science - did not exist then to help Goethals with the Army's enormous supply and logistics challenges. This truly incredible power is, however, at our disposal today. The contrast between the methods we have been using and what we could and should use could not be more stark. While significant organizational change has always provoked resistance and should naturally be expected, as one of our most distinguished historians, Barbara Tuchman, observed: pursuing flawed and failed policies *knowing* that plausible alternatives and better options are available is truly "the march of folly" [41].

We hope this endeavor will serve as a catalyst for an intellectual and professional resurgence in military logistics systems analysis. We are certainly encouraged by our empirical research results which continue to reinforce and corroborate many of the intuitive concepts and ideas presented in this paper. Nonetheless, the degree to which the significant changes proposed herein can impact institutional culture and practice remains to be seen. Consequently, we have engaged the larger military operations research and professional logistics communities and continue to encourage the participation of all those interested to collectively pursue this enormous challenge.

Finally, it is certainly appropriate and necessary to ask what the potential impacts and expected benefits of this undertaking may be. Figure 23 offers a series of direct responses to this question.

They are framed from various perspectives of several key professional positions involved in focusing logistics to better support and sustain the Army's most effective, flexible, and adaptable assets - America's Soldiers. Now at the dawn of the 21^{st} Century, just as they did during the 20^{th} Century, American Soldiers collectively constitute the single most powerful force for good in the history of the world – the next "Greatest Generation".

Specialist Four Dalton: AH-64 Attack Helicopter Mechanic, 82nd Airborne Division Combat Aviation Battalion - reduces his labor-intensive "workarounds"; he no longer is the routine "bill-payer" and go-to-guy who must compensate for inadequate supply support; a more satisfied customer - the one who matters most.

SFC Dalton: Maintenance Production NCO - gains much greater trust in a supply support system that is more responsive and better anticipates his needs; a more satisfied customer with renewed confidence.

CW2 Dalton: Aviation Company Maintenance Tech - no longer wastes so much time scrounging for parts, making "deals" and placing his integrity at risk to achieve readiness goals for his unit and commander; a more satisfied customer who believes the Army is now beginning to have a smoothly functioning supply system.

CW5 Dalton: AVCRAD Production Officer - for this "crusty" Vietnam vet, a long-recognized need without any previous attempts at an honest solution; the fundamental flaw has always been organizational design and OIF yielded a very predictable disaster; now, finally retiring, with an "honest solution" actually appearing on the horizon, he is no longer so cynical. . . but, true-to-form, still "crusty".

LTC Dalton: AH-64 Attack Battalion Commander - eliminates "distorted behavior" in his command; he no longer must "game" the readiness reporting, supply and financial management systems, resorting to twisted, convoluted, counterproductive actions needed to achieve ER goals that he alone has always been held responsible for. Now, working collaboratively with both his supporting Apache PM and contract logistics provider, he gradually believes that the supply "system" becomes at least partially accountable for ER his unit achieves.

Ms. Dalton: IMMC "Item" Manager - empowers her to become a weapon system "readiness" manager. Always hardworking and dedicated, she notices fewer episodes of "intense management" and ad hoc workarounds. She knows her decisions make a real difference now . . . and she can see the results.

COL Dalton: Program Manager - can now actually do his job and make sensible tradeoffs among cost, performance, schedule (RDA) - and, unlike before, reliability, maintainability, tactical Ao and sustainment costs (O&M) - empowering and enabling him to manage his program to readiness goals and LCC for the first time. He works smarter, not harder.

MG Dalton: (G-8, Director, PAE) - can now relate HQDA program investment inputs to future readiness (Ao) outcomes and recommend PPBS/PPBES-related PB decisions and tradeoffs across RDTE, PA, and OMA accounts with much greater clarity and confidence. He can now provide compelling programmatic arguments since he has the analytic foundation for determining a multi-year resource program which matches resources necessary to meet readiness demands for a "capabilities-based" force prescribed in the DPG.

LTG Dalton: CG, CJTF - is assured that he'll receive ops-based, mission-focused log support; neither "just-in-case" (too burdensome) nor "just-in-time" (too risky), he will have both the package appropriate for his mission and responsive resupply.

Dr. Dalton: ASA (ALT) - can now report to SecArmy that Army complies with DRRS for Title X logistics function; he is now empowered with insight from a new "Logistics Early Warning System".

GEN Dalton: CSA - has greater confidence that his HQDA investment decisions can now be related to readiness-oriented results; unlike his predecessor, he no longer feels compelled to ask in frustration "Why am I still throwing billions down this 'black hole' called 'spares'?"

Congressman Dalton: HASC - gains much greater confidence in credibility of both budget submissions and requirements presented for Army logistics. He supports full funding because he understands implications for national security. He concurs with his colleagues that GAO should now remove Army "inventory management" from its "high risk" list of government programs, where it has been for a decade and a half.

"Joe" (the American taxpayer) Dalton (SP4 Dalton's father): gets a better return on his tax dollar; feels assured that his young, 82nd paratrooper son will be OK - Airborne Hooah!!

Figure 23

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36. Project participants included: Logistics Management Institute (LMI); RAND's Arroyo Center; AMC's Army Materiel Systems Analysis Activity (AMSAA) and Logistics Support Activity (LOGSA); Institute for Defense Analysis (IDA); and MIT's Forum for Supply Chain Innovation (FSCI). Funding support was provided by AMCOM
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38. Using this definition of "human progress" as a guide - simply failing to repeat past mistakes - the recent public record of Army logistics as a "learning" organization suggests significant "observations" but, regrettably and inexplicably, few lessons "learned". See "Defense Logistics: Preliminary Observations on Logistics Effectiveness in OIF", GAO -04-305R, 18 Dec 2003, p. 4: "Failure to apply 'lessons learned' from prior operations"; and "Operation Desert Storm", GAO/NSIAD-92-258, 23 Sep 1992; "Conduct of the Persian Gulf War: Final Report to Congress", DoD, Apr 1992; "Kosovo/Operation Allied Force After Action Report: Final Report to Congress, DoD, 31 Jan 2000.
39. *The Neck of the Bottle: George W. Goethals and the Reorganization of the US Army Supply System, 1917-1918*, Phyllis A. Zimmerman, Texas A&M University Press, 1992.
40. I am indebted to Benson D. Adams, then-AMC Special Assistant to the Commanding General for Transformation Integration, for suggesting the relevance and timeliness of this biography.
41. *The March of Folly: From Troy to Vietnam*, Barbara Tuchman, Random House, 1984. Historian Arthur Schlesinger, Jr. has described the "enemies of progress" as gravity, custom, and fear: gravity and custom represent the inertia of tradition and known ways of doing things; and fear represents resistance to that which is new or different.