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## Effects-Based Logistics Operations: A Strategic Supply Chain Approach For the US Army

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   3. Scope
   4. Organization

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   3. Retail Stage
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   1. Organizational Redesign
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   4. Logistics Transformation and Disruptive Change

VI. Summary

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Endnotes
Additional References
Annexes
Initiative Summary
(Readiness Based Analysis / Supply Chain Management)

**UAH** - Analyze & Optimize Complete Aviation Supply Chain
**IDA** - Relating Resourcing to Readiness

**Acquisition** → **Wholesale** → **Retail** → **Unit Readiness** → **Demand**

**RAND** – Equipment Downtime Analyzer and an Aviation Readiness Equation

**AMSAA** – Optimizing Wholesale & Retail Investment Levels: RBS Analytical Demos & Field-Tests; Multi-Echelon, Multi-Indenture Optimization Models (Multi-Link)

**Reverse Logistics**
“Retrograde”

**LOGSA** - Provide Project Enabling Analytic Data Support
- Retrograde Analysis

**LMI** - Operations-Based Demand Forecasting
AWCF Hardware (Aviation)
Resource Trends

Source: AMCOM RMD
Assessment

- Investment is increasing, yet back orders are growing and UFRs are increasing
- “Workarounds” are increasing, readiness is slowly declining
- Readiness reporting appears suspicious, lacks credibility
- Systems are deadlined for relatively inexpensive parts
Improving System Effectiveness: Integration and Optimization

“Segmented” Logistics Support Operations
(Managing the interfaces)

vs

Logistics Chain Integration
(Optimizing the system)

An increase in service level (customer support) requires an increase in inventory and safety stock: increase “Safety Levels”

Service levels can actually be increased while simultaneously reducing inventory levels, safety stock and aggregate RO
Multi-stage Supply Chains

Consider a multi-stage supply chain:
- Stage $i$ places order $q^i$ to stage $i+1$.
- $L^i$ is lead time between stage $i$ and $i+1$.

Source: MIT
Multi-stage Systems: $\text{Var}(q^k)/\text{Var}(D)$
Demand Uncertainty

Low (Functional Products)  High (Innovative Products)

Low (Stable Process)  High (Evolving Process)

Supply Uncertainty

Demand Uncertainty Reduction Strategies

Supply Uncertainty Reduction Strategies
### Demand Uncertainty

<table>
<thead>
<tr>
<th>Supply Uncertainty</th>
<th>Low (Functional Products)</th>
<th>High (Innovative Products)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (Stable Process)</td>
<td>Efficient supply chains</td>
<td>Responsive supply chains</td>
</tr>
<tr>
<td>High (Evolving Process)</td>
<td>Risk-hedging supply chains</td>
<td>Agile supply chains</td>
</tr>
</tbody>
</table>
III. Multi-stage Approach - Analysis of Systemic Challenges

1. Readiness Production Stage
2. Operational Mission and Training Demand Stage
3. Retail Stage
4. Retrograde/Reverse Logistics Stage
5. Wholesale/Depot Stage
6. Acquisition Stage
Conceptual Model of Logistics Structure
The “Production Function” for “Readiness”:
Defining and Quantifying the Availability Equation

\[ A_0 = \frac{\text{Uptime}}{\text{Total Time}} = \frac{\text{MTBF} \times K}{(\text{MTBF} \times K) + \text{MTTR} + \text{MLDT}} \]

Where

- **MTBF** = Mean Time Between Failures (Reliability)
- **K** = Ratio of Calendar Time to Equipment Operating Time (Duty Factor)
- **MTTR** = Mean Time To Repair (Maintainability)
- **MLDT** = Mean Logistics Delay Time (Supportability)
“Production Function”: Components of Readiness

Supply Availability

- Weapon System Reliability
  - MTBF
    - NMCS
- Supply Support Capability
  - MLDT
    - NMCM
  - MTTR
- Personnel Manning and Skill Levels
- Training Resources (OPTEMPO $)

Demand Requirements

- Deployment Missions (DEPTEMPO)
  - Patterns of Operation
    - Duration
    - Profile
  - “K-factor” usage rates
  - Environmental Conditions and Locations
- Training Requirements (OPTEMPO)

Readiness – related Measures / Metrics
- [ER] – Equipment Readiness ($A_e$)
  - FMC
  - NMCS
- [MC (PMC)]
  - NMCM
- [AS] – Assigned Strength
- [TS] – Trained Strength
Conceptual Model of Logistics Structure
Enhanced Class IX Planning:
Linking Operational Patterns, Demand Forecasting, and Supply/Acquisition Planning (See Annex B)

- Reduce Demand Uncertainty and Variability by Improving Requirements Estimation and Spares Forecasting
- Reconfigure the Logistics Chain to Reduce the Costs of Demand Uncertainty
- Transition from “Supply Chain” Concept to a “Demand Network”

\[ \sigma^2 = L\sigma_D^2 + D^2\sigma_L^2 \]
STRATIFIED SAMPLING

POPULATION OF SIZE $N$ DIVIDED INTO $K$ STRATA

RANDOM SAMPLING:

$$\hat{P}_{RSM} = \frac{x}{n}$$

STRATIFIED SAMPLING:

$$P_k^1 = \frac{x_k}{n_k}$$

THEN:

$$\hat{P}_{STRAT} = \frac{\sum_{i=1}^{k} N_k P_k^1}{N}$$

USUALLY:

$$\text{Var}(\Theta_{STRAT}) \leq \text{Var}(\Theta_{POP}) \leq \text{Var}(\Theta_{RSM})$$
Conceptual Model of Logistics Structure
Readiness Based Sparing at 101st Airborne - Blackhawk Parts

Analytical Demo Results

Source: AMSAA
Conceptual Model of Logistics Structure

Acquisition ➔ Wholesale ➔ Retail ➔ Unit ➔ Demand

Reverse Logistics
Reverse Logistics Structure
Conceptual Model of Logistics Structure

Acquisition → Wholesale → Retail → Unit → Demand

Reverse Logistics
SIX SIGMA, LEAN AND THEORY OF CONSTRAINTS:
CONTRIBUTIONS IN THE COST-PERFORMANCE TRADESPACE

Six Sigma – improving product quality (fewer defects) by reducing process variation (variation reduction)
Lean – synchronizing process flow (“takt” time) by removing excess WIP (inventory reduction)
Theory of Constraints – improving cost effectiveness by strengthening weak links (constraint reduction)
MK-48 Engine

**Repair Cycle Time (Days)**

Data Source: Concerto Activity By Project Records

**Labor Hours**

Data Source: Essex Replacement Program (ERP)

**Output Per Month**

Data Source: Concerto Activity By Project Records
ICAAPS: Intelligent Collaborative Aging Aircraft Parts Support (LMI)

- Aircraft and AVDLR operational usage
- Depot-level maintenance
- ICAAPS planning horizon

Depot maintenance discrepancy data
Depot consumable part usage data
Field operations and maintenance data

- Actual part requirements
- Forecasted part requirements
- ICAAPS reduces forecasting lag

Years
DLA-managed consumable parts

Field-level maintenance labor hours
Aircraft BUNOs

Y = fitting was replaced during SDLM
N = fitting was not replaced during SDLM

Empirical replacement threshold
SPIRE ‘Themescape’ view of KC135 Maintenance Data
Improving System Efficiency: Across the System of Stages and within each Stage

Because inventories are managed to the computed RO, reducing the value of the RO calculated by AMC’s models is a critical first step to reducing inventories.

Source: RAND AB 185-A
Conceptual Model of Logistics Structure

Acquisition \rightarrow \text{Wholesale} \rightarrow \text{Retail} \rightarrow \text{Unit} \rightarrow \text{Demand}

Reverse Logistics
The “Production Function” for “Readiness”:
Defining and Quantifying the Availability Equation

\[ A_o = \frac{\text{Uptime}}{\text{Total Time}} \]

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**Where**

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- \( \text{MTTR} \) = Mean Time To Repair (Maintainability)
- \( \text{MLDT} \) = Mean Logistics Delay Time (Supportability)
System Life Cycle Failure Rate Pattern: The “Bathtub” Curve

Useful Life Region

\[ P(t > t_o) = 1 - F(t_o) \]
\[ = 1 - (1 - e^{-\lambda t_o}) \]
\[ = e^{-\lambda t_o} \]
\[ = R(t_o) \]

Wearout Region

\[ P(T > t_o) = P(t > t_w) \cap P(t > t_o) \]
\[ = P(t > t_w) \times P(T > t_o | t > t_w) \]
\[ = R(t_w) R(t_o) \]
\[ = e^{-\lambda t_w} \times P \left( Z > \frac{t_o - \mu_w}{\sigma_w} \right) \]
Components of Operational Availability

**Failure Density**

\[ R(t) = e^{-\lambda t} \]

\[ MTBF = \frac{1}{\lambda} \]

**Supply Support Density**

\[ F(t) = 1 - e^{-\alpha t} \]

\[ MLDT = \frac{1}{\alpha} \]

**Repair Density**

\[ F(t) = 1 - e^{-\rho t} \]

\[ MTTR = \frac{1}{\rho} \]
Availability Improvement Analyses

Aircraft Availability Improvement Analyses

Baseline: 74.4%

52 RECAP (MTBUR’s: 1500 / 2500 / 20% minimum)

91 Components (MTBUR’s: 1500 / 2500 / 20% minimum)

~0.9%

~2.6%
IV. Multi-stage Approach - Integration for Efficiency, Resilience, and Effectiveness

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Inventory Drivers

Single-Echelon Approach

- Supplier
  - Lead Time
  - Wholesale Inventory Drivers
  - Retail Inventory Drivers
  - Customer

Multi-Echelon Approach

- Supplier
  - Wholesale Inventory Drivers
  - Retail Inventory Drivers
  - Customer

Sequential Approach

- Supplier
  - Wholesale Inventory Drivers
  - Retail Inventory Drivers
  - Customer

- Wholesale Inventory Drivers
  - Retail Inventory Drivers
  - Customer

- Retail Inventory Drivers
  - Demand
  - Lead Time

Multi-Echelon Approach

- Supplier
  - Lead Time
  - Wholesale Inventory Drivers
  - Retail Inventory Drivers
  - Customer

- Wholesale Inventory Drivers
  - Retail Inventory Drivers
  - Customer

- Retail Inventory Drivers
  - Demand
  - Lead Time

Network Replenishment Optimization

Demand

Optimization
Optimizing the Wholesale Stage to Retail

- AMSAA – “Optimizing Wholesale and Retail Investment Levels: Multi-Echelon, Multi-Indenture Optimization Models (Multi-Link)”
Impact of Increased Investment at Wholesale on Blackhawk Equipment Readiness at 101st Airborne

Baseline:

<table>
<thead>
<tr>
<th>Fill Rate</th>
<th>Safety Level</th>
<th>Readiness</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>189M</td>
<td>84.7%</td>
</tr>
<tr>
<td>75</td>
<td>210M</td>
<td>85.9%</td>
</tr>
<tr>
<td>80</td>
<td>256M</td>
<td>86.7%</td>
</tr>
<tr>
<td>85</td>
<td>340M</td>
<td>87.3%</td>
</tr>
<tr>
<td>90</td>
<td>505M</td>
<td>87.7%</td>
</tr>
<tr>
<td>95</td>
<td>857M</td>
<td>88%</td>
</tr>
</tbody>
</table>

Source: AMSAA
Current Structure: Arborescence

- Vertical “serial chains” create vulnerable supply channels
- Increased buffer stock is required to reduce risk
- Results in increased inventory investment costs
Demand Driven Supply Network (DDSN)

- RBS reduces cost
- Inventory pooling reduces both cost and risk
- Lateral supply decreases requisition delay time

\[ A_o \]

- RBS Stock List

- Hi Cost
- Low Demand
- DLRs
  - Low Cost Consumables
  - Hi Demand Parts

Cost per Item
RBS List
Achieving “Efficiency” in the Cost-Availability Tradespace
Increasing “Effectiveness” in the Cost -Availability Tradespace

Cost Benefits Alternatives:

1. Improved effectiveness with increased costs
2. Improved effectiveness at same costs
3. Improved effectiveness at reduced costs
4. Same effectiveness at significantly reduced costs

… however, magnitude of each depends upon where you are on the current efficient frontier!
… and the expansion trace of the improved frontier
Pushing the Envelope: Innovation to Sustain Continual Improvement
Total Cost Function

Maximum difference between Total Revenue and Total Cost or Maximum Profit

Value of Cost or Output (Return)

Total Cost Function

Production Function \( (A_0 \times VPC) \)

Tangents of equal slope

Steep here means shallow here

Decision or Stopping Points (Iterations)
Profit

![Graph showing inventory value vs profit for different cost scenarios.]

- **Legend:**
  - Award Fee
  - Cost
  - Profit
  - Max Profit

- **X-axis:** Inventory Value ($000,000s)
- **Y-axis:** ($000,000s)

- The graph illustrates the profit trajectory under various cost scenarios, with distinct lines for different financial indicators.
An Important Disconnect

What the customer got vs. what the customer wanted.

Legend:
- Ao
- Fill Rate
- Avg. Delay
- Profit
- Score

Inventory Value* ($ 000,000s) vs. Avg. Delay

What the customer got
What the customer wanted
"Optimizing" the System: Applying a Dynamic (Multi-Stage) Programming Model

10.4 DEVELOPING AN OPTIMAL DECISION POLICY

If our multistage system actually looks like the one just illustrated, then we can notice some interesting characteristics; namely.

1. There are exactly \( N \) points at which a decision must be made.
2. If we start at stage 1, then nothing affects an optimal decision except the knowledge of the state of the system at stage 1 and the choice of our decision variable.
3. Stage 2 only affects the decision at stage 1: the choice we make at stage 2 is governed only by the state of the system at stage 2 and the restrictions on our decision variable.
4. And so on to stage \( N \).

The dynamic programming problem is therefore given by the following expression at the \( n \)th stage:

\[
f^*_n(S_n) = \max_{0 \leq d_n \leq (S_n/L_n)} \{ r_n(S_n, d_n) + f^*_{n-1}(S_{n-1}) \}
\]

where: \( S_{n-1} = S_n - d_n L_n \)

and

\[
f^*_0(S_0) = 0
\]

\[
f_n(S_n, d_n) = r_n d_n
\]

\( n = 1, 2, 3, 4 \)
V. Strategic Management Concepts
   1. Organizational Redesign
   2. Contributions of (Transactional) Information Systems Technology and (Analytical) Operations Research
   4. Logistics Transformation and Disruptive Change
Logistics Transformation Framework: Linking Strategy to Measurable Results

- **Ends**
  - Vision
  - Strategic Concept
  - Strategic Goals
  - Management Objectives
  - Strategies & Programs/Initiatives
  - Annual Objectives
  - Mission Achievement

- **Ways**

- **Means**

- **Results**
Linking processes and systems with operational and financial performance

- **A**: Single Site, Informal and Manual Planning Processes
  - Below average business performance

- **B**: Lack of System Support
  - Improved bottom line profitability
  - 27% improvement potential

- **C**: Planning Practices and Systems Aligned
  - Significant improvement on operational performance
  - 75% higher profitability for BIC

- **D**: Systems are not Complemented by Planning Practices
  - Significant Inefficiencies

**Legend**
- Mature Business Processes
- Immature Business Processes
- Mature IT Systems
- Immature IT Systems
The Evolution of Insight

- Understand the Past
- Respond to the Present
- Predict the Future

Enterprise Systems

Multisourced, Real-Time, Fine-Grained

ABILITY TO GATHER, STORE AND ACCESS DATA

SPECIALIZED TECHNICAL KNOWLEDGE

Example Applications:
- Production Control
- RFID-Enabled Supply Chain Telematics

Example Applications:
- Predictive Simulation and Optimization

Example Applications:
- ERP and Most Traditional Systems Integration Work

Example Applications:
- Data Management, Applied Business Analysis, Customer Insight

DEEP BUSINESS DOMAIN / ANALYTIC KNOWLEDGE

ABILITY TO USE DATA FOR INSIGHT
Objective Hierarchy:
Relating Outcomes (Results) to Goals & Objectives (Strategy)

Goal: Improve Logistics Chain Efficiency and Effectiveness to Enable a Strategically Responsive, Transforming Army

Objectives:
- Reduce Lead Time Demand & System Variability
- Improve Strategic Mobility; Reduce Force Closure Timelines
- Reduce Sustainment ‘Footprint’
- Reduce Costs While Maintaining Readiness

Performance Measures: (MOEs, ‘Metrics’)
- $A_0$
- $A_0$
- $A_0$
- $A_0$

Readiness Outcome:
- $A_0$
Aligning Execution and Strategy: Learning from Performance Variability

Act from Variability
- Define program
- Define structured tests
- Implement

Select Performance Indicators

Learn from Variability
- Hypothesize cause and effect
- Evaluate

Detect Variability
- Drill down to detailed segmentation
- Isolate variability

Explain Variability
- Identify performance drivers
- Correlate drivers with variability

Objective Hierarchy: Relating Outcomes (Metrics) to Goals & Objectives (Desired Ends)

Goal: Improve Logistics Chain Efficiency and Effectiveness to Enable a Strategically Responsive, Transforming Army

Objectives:
- Reduce Lead Time
- Demand & System Variability
- Improve Strategic Mobility; Reduce Force Closure Timelines
- Reduce Sustainment 'Footprint'
- Reduce Costs while Maintaining Readiness

Performance Measures:

Outcome:

\[ 54 \]
Common Expectations and the Reality of Change

Performance

Historical Performance

Anticipated Performance

Disruption

The Reality of Change

Time

A

B

C

D
VI. Summary
VII. Final Thoughts
“Center for Innovation in Logistics Systems”

(1) “Clearing House” for “Good Ideas”
- Organizational Design
- Supply/Value Chain
- Workforce Development
- Technology Implications
- Innovation & Productivity Gain

(2) Modeling, Simulation & Analysis of Complex Systems
- System Dynamics Modeling
- Large Scale (LS) System Design, Analysis, and Evaluation
- Systems Simulation, Modeling and Analysis

(3) Transforming Organizations & Managing Change
- Education & Training
- Technical Support
- Risk Reduction & Mitigation
- Consulting
- Research, Studies, and Analysis

Academia • FFRDC Non-Profits • AMSC • Professional Societies • Public

Corporate Research • Government Organizations • Academic Departments • Private Companies • Private
Objective Hierarchy: Purpose of Objectives

Goal: Improve Logistics Chain Efficiency and Effectiveness to Enable a Strategically Responsive, Transforming Army

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Objective Hierarchy: Sources and Basis for Objectives

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Basis:
- Classical Inventory Theory
- Recent Developments in Supply Chain Management Theory
- “Benchmarking” Against Corporate Sector Best Business Practices
- Army Transformation Campaign Plan
- Army Transformation Roadmap
- Army Modernization Plan, 2003
- G4/LTA “Army Logistics Transformation”, Jan 03
Objective Hierarchy: Performance Measures

Goal: Improve Logistics Chain Efficiency and Effectiveness to Enable a Strategically Responsive, Transforming Army

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Performance Measures: (MOEs, 'Metrics')
- $\sigma_L$
- $\sigma_D$
- $\text{Var}(q^k)/\text{Var}(D)$
- $L \times D$
- $A_0$
- Lift Requirements
- Time to Deploy
- Weight
- Cube/Volume
- System MTBF
- CSS Structure
- $A_0$
- Total Rqmts Objective
- Safety Stock
- Service Levels
- RL Delay Time
- $A_0$
Objective Hierarchy: Relating Outcomes (Results) to Goals & Objectives (Desired Ends)

Goal: Improve Logistics Chain Efficiency and Effectiveness to Enable a Strategically Responsive, Transforming Army

Objectives:
- Reduce Lead Time
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- Reduce Costs While Maintaining Readiness

Performance Measures (MOEs, ‘Metrics’):

Readiness Outcome:
Innovation to Sustain Continual Improvement

Objective Hierarchy:
Relating Outcomes (Results) to Goals & Objectives (Desired Ends)

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Performance Measures:
(MOEs, 'Metrics')

Readiness Outcome:

Achieving “Efficiency” in the Cost - Availability Tradespace

Achieving “Effectiveness” in the Cost - Availability Tradespace

Cost Benefits Alternatives:
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...however, magnitude of each depends upon where you are on the current efficient frontier...
...and the expansion trace of the improved frontier
(i.e., “Pushing the Envelope”)
Reducing Organizational Risk: Analytical Demos, Field Tests & Experimentation

• Analytical “Demonstrations”
  - Modeling, Simulation, & Analysis
  - Assess Empirical Data

• Field Testing
  - Experimentation
  - Testing and Evaluation
  - Analysis
  - Prototype Fieldings
Reducing Organizational Risk: Systems Analysis, Management Information (MIS) & Decision Support (DSS)

- Regression Analysis
  - “Disentangling” Cause & Effect
  - Empirically–based results

- Econometric Forecasting
  - Can forecast with increasingly greater accuracy and precision
  - Quantifies relationships between current/recent investment decisions and future outcomes
  - Precludes “surprises” in tightly-coupled systems
Reduced “Transformation” Risk: Using Analysis to Disentangle Cause & Effect, Reduce Uncertainty, and Mitigate Risk

- **Concept Development** (pre-Transformation)
- **Implementation** (During Transformation)
- **Operations** (Post Transformation)