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Original title on 712 A/B: Effects-Based Logistics Operations: A Strategic Supply Chain Approach For the US Army

Revised title:

Presented in (input and Bold one): (WG_19, CG__, Special Session __, Poster, Demo, or Tutorial):

This presentation is believed to be:
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Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18
Contents

I. Background
   1. Persistent Challenges
   2. Purpose
   3. Scope
   4. Organization

II. Project Overview
   1. Background - The Immediate Problem
   2. Conceptual Approach - Current Logistics Structure
   3. Application of Supply Chain Concepts - Analytical Foundations for Improving Logistics System Effectiveness

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

IV. Multi-stage Approach - Integration for Efficiency, Resilience, and Effectiveness
   1. Achieving an “Efficient”, Integrated Multi-Echelon Inventory Solution
   2. Designing a “Resilient”, Adaptive Logistics Network
   3. Improving Logistics “Effectiveness”: Pushing the Performance Envelope
   4. Enabling “Effects-Based Operations”: Performance Based Logistics
   5. An “Analytical Architecture” to Guide Logistics Transformation

V. Strategic Management Concepts
   1. Organizational Redesign
   2. Contributions of (Transactional) Information Systems Technology and (Analytical) Operations Research
   4. Logistics Transformation and Disruptive Change

VI. Summary
VII. Final Thoughts
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
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 $i+1$.
Multi-stage Systems: $\text{Var}(q^k)/\text{Var}(D)$

Source: Simchi-Levi
Demand Uncertainty

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Supply Uncertainty Reduction Strategies

Demand Uncertainty Reduction Strategies

Supply Uncertainty Reduction Strategies
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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

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

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

**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

- 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:  \[ \hat{P}_k = \frac{x_k}{n_k} \]

THEN:  \[ \hat{P}_{STRAT} = \frac{\sum_{i=1}^{k} N_k P_k}{N} \]

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

Analytical Demo Results

ASL Investment in $M

Source: AMSAA
Conceptual Model of Logistics Structure
Reverse Logistics Structure
Conceptual Model of Logistics Structure
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)

Labor Hours

Output Per Month

Data Source: Concerto Activity By Project Records

Data Source: Essex Replacement Program (ERP)

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

Depot maintenance discrepancy data

Depot consumable part usage data

Field operations and maintenance data

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

DLA-managed consumable parts

Actual part requirements
Forecasted part requirements
ICAAPS reduces forecasting lag

Years

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
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
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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- **K** = Ratio of Calendar Time to Equipment Operating Time (Duty Factor)
- **MTTR** = Mean Time To Repair (Maintainability)
- **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

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

Failure Density

\[ R(t) = e^{-\lambda t} \]
\[ MTBF = \frac{1}{\lambda} \]

\[ A_o = \frac{MTBF}{MTBF + MLDT + MTTR} = \frac{1}{1 + \frac{\lambda}{\alpha} + \frac{\lambda}{\rho}} \]

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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5. An “Analytical Architecture” to Guide Logistics Transformation
Single-Echelon Supplier

Retail Inventory Drivers

Customer

Multi-Echelon Supplier

Wholesale Inventory Drivers

Retail Inventory Drivers

Customer

Lead Time

Lead Time

Lead Time

Demand

Demand

Demand

Inventory Drivers

Sequential Approach

Supplier

Wholesale Inventory Drivers

Retail Inventory Drivers

Retail Replenishment Optimization

Customer

Multi-Echelon Approach

Supplier

Wholesale Inventory Drivers

Retail Inventory Drivers

Retail Replenishment Optimization

Network Replenishment Optimization

Customer

35
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

Percent Increase in Readiness

Baseline:

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%

Source: AMSAA

RBS Impact?
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

$O \rightarrow$ 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

Gain in “Efficiency”

“Efficient Frontier”
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 ($A_0 \times VPC$)

Decision or Stopping Points (Iterations)

Steep here means shallow here

Tangents of equal slope
Profit

($000,000s)

Legend
- Award Fee
- Cost
- Profit
- Max Profit

Inventory Value* ($000,000s)
An Important Disconnect

![Graph showing inventory value vs. average delay with labels for what the customer got and what the customer wanted.]
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:

$$f^*(S_n) = \max_{\nu \in \nu(S_n, L_n)} \{r_n(S_n, d_\nu) + f^*_{n-1}(S_{n-1})\}$$

where: \[S_{n-1} = S_n - d_\nu L_n\]
and \[f^*(S_0) = 0\]
\[f_n(S_n, d_\nu) = r_n d_\nu\]
\[n = 1, 2, 3, 4\]
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

Ways

Means

Results

- Vision
- Strategic Concept
- Strategic Goals
- Management Objectives
- Strategies & Programs/Initiatives
- Annual Objectives
- Mission Achievement
Civilian “ORSA” (1515) Strength in AMC

- 1990: 41.99%
- 1991: 44.10%
- 1992: 42.81%
- 1993: 41.00%
- 1994: 39.22%
- 1995: 40.41%
- 1996: 37.21%
- 1997: 37.75%
- 1998: 37.02%
- 1999: 37.42%
- 2000: 34.29%
- 2001: 33.68%
- 2002: 31.84%
Linking processes and systems with operational and financial performance

- **Lack of System Support**
  - Improved bottom line profitability
  - 27% improvement potential
  - Business Processes: Immature  IT Systems: Immature
  - **B**

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

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

- **Systems are not Complemented by Planning Practices**
  - Significant Inefficiencies
  - Business Processes: Immature  IT Systems: Mature
  - **D**
Understand the Past
Respond to the Present
Predict the Future

Enterprise Systems
ABILTY TO GATHER, STORE AND ACCESS DATA

Multisourced, Real-Time, Fine-Grained

SPECIALIZED TECHNICAL KNOWLEDGE

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

Example Applications:
- ERP and Most Traditional Systems Integration Work

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

Example Applications:
- Predictive Simulation and Optimization

DEEP BUSINESS DOMAIN / ANALYTIC KNOWLEDGE

ABILITY TO USE DATA FOR INSIGHT
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:
Aligning Execution and Strategy: Learning from Performance Variability

**Select Performance Indicators**

- **Objective Hierarchy:**
  - Goal: Improve Logistics Chain Efficiency and Effectiveness to Enable a Strategically Responsive, Transforming Army
  - Objectives:
    - Reduce Lead Time & System Variability
    - Improve Strategic Mobility; Reduce Force Closure Timelines
    - Reduce Sustainment 'Footprint'
    - Reduce Costs While Maintaining Readiness

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

**Detect Variability**
- Drill down to detailed segmentation
- Isolate variability

**Learn from Variability**
- Hypothesize cause and effect
- Evaluate

**Explain Variability**
- Identify performance drivers
- Correlate drivers with variability
Common Expectations and the Reality of Change

Historical Performance

Anticipated Performance

Disruption

The Reality of Change

Time

Performance

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
Corporate Research
Government Organizations
Academic Departments
Private Companies
Professional Societies
FFRDC Non-Profits
AMSC
Public
Objective Hierarchy: Purpose of Objectives

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

Objectives:
- Reduce Lead Time Demand & System Variability
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Efficiency Objectives

Effectiveness Objectives
Objective Hierarchy: Sources and Basis for Objectives

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

Objectives:
- Reduce Lead Time Demand & System Variability
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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

**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’)
- $\sigma_L$
- $\sigma_D$
- $\frac{\text{Var}(q^k)}{\text{Var}(D)}$
- $L \times D$
- $A_0$
- Lift Requirements
- Time to Deploy
- Weight
- Cube/Volume
- System MTBF
- CSS Structure
- 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 Demand & System Variability
- Improve Strategic Mobility; Reduce Force Closure Timelines
- Reduce Sustainment ‘Footprint’
- Reduce Costs While Maintaining Readiness

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

Readiness Outcome: \( A_0 \)
Innovation to Sustain Continual Improvement

Objective Hierarchy:
- Goal: Improve Logistics Chain Efficiency and Effectiveness to Enable a Strategically Responsive, Transforming Army
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Performance Measures: (MOEs, 'Metrics')

Achieving “Efficiency” in the Cost - Availability Tradespace

Achieving “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 (i.e., "Pushing the Envelope")

Sustaining Innovation While Linking Execution to Strategy
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)**