Sustainable and Resilient Radiology Supply Chains: A Comparative Evaluation of Supply Chain Management Frameworks

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Purpose

The efficiency and resilience of healthcare supply chains are vital for ensuring consistent access to medical supplies, equipment, and diagnostics during public health crises such as pandemics, natural disasters, or high tariff environments.
Radiological services depend on reliable delivery of complex equipment and high throughput consumables like iodinated contrast, which are vulnerable to global disruptions.
This study aims to:

- Identify established general healthcare supply chain management (ghSCM) frameworks with potential applications in radiology
- Evaluate their methodologies, core components, and intended use cases
- Analyze each framework's strengths, limitations, and adaptability to radiology supply chains (rSCM)
- Highlight how well these frameworks address five critical ghSCM process elements: Procurement, Storage, Distribution, Risk mitigation, Cost analysis

We provide a structured comparison that can guide future development of radiology-specific SCM tools and improve preparedness in radiology settings.

Methods

A scoping review was conducted to identify and assess prominent ghSCM frameworks. A search was performed using databases Pubmed and Google Scholar with the following relevant terms and keywords related to ghSCM/rSCM including supply chain management, radiocontrast, imaging, healthcare, radiology, logistics. Frameworks were included if:

- Addressed SCM in health care contexts
- Contained at least one of the following: procurement, storage, distribution, risk mitigation, or cost analysis
- Were applicable or adaptable to medical imaging or radiological contexts

Each framework was selected and analyzed for its purpose, key components, strengths/drawbacks, and specific applicability to rSCM, with a focus on the five common process elements: procurement, storage, distribution, risk mitigation, and cost analysis.

Results

We found eight ghSCM frameworks that could be applied to rSCM: Lean, Agile, Supply Chains Operations Reference (SCOR), Balanced Scorecard (BSC), Multi-Criteria Decision Analysis (MCDA), REA/REALISTIC, Six Sigma/DMAIC, and Resilience Maturity Models (RMM)(detailed in Table 1). For example, Lean supply chains prioritize efficient distribution and minimized storage but may be less flexible/resilient to disruptions. Additionally, Six Sigma/DMAIC can be used to define and measure key metrics to reduce the number of re-scans in a clinical practice. A conceptual overview of the inter-related web of these frameworks (Figure 1), shows that each has unique strengths and weaknesses in common ghSCM elements (procurement, storage, distribution, risk mitigation, and cost analysis).

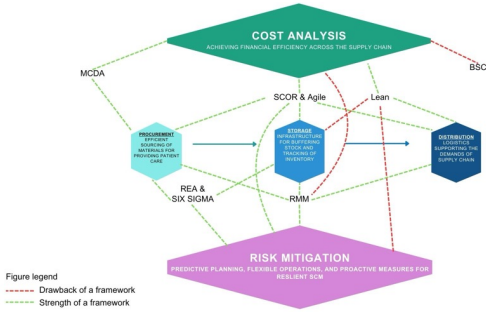


Figure 1. Conceptual overview of the inter-related frameworks' strengths and drawbacks in general healthcare supply chain management (ghSCM) . This diagram illustrates how various frameworks interact in five common ghSCM elements: cost analysis, procurement, storage, distribution, and risk mitigation. Green dashed lines indicate a framework's strength, while red dashed lines indicate a potential drawback. The upper node (cost analysis) and bottom node (risk mitigation) highlights their importance across several SC elements, of procurement, storage, and distribution, showing how these key processes are integrated across an overarching strategy for resilient and sustainable SCM.

Table 1. Comparison of general healthcare supply chain management (ghSCM) frameworks for potential application in radiology SCM (rSCM). This table summarizes eight widely-recognized ghSCM frameworks (first column: Lean, Agile, SCOR, Balanced Scorecard, MCDA, REA/REALISTIC, Six Sigma DMAIC, and Resilience Maturity Models), and highlights each framework's purpose, key features, typical radiology applications (first three columns in purple, yellow, pink); and also the strengths, neutral, and drawbacks (last three columns in green, blue, red).

FRAMEWORK	PURPOSE	KEY FEATURES	APPLICATION IN RADIOLOGY	STRENGTHS	NEUTRAL	DRAWBACKS
LEAN[1,2]	• Eliminates waste and improves process efficiency	• Streamlined processes, reduced inventory, improved communication	• "Just In Time" inventory can drive down the cost of storing contrast	• Efficient operations • Minimal inventory holding costs	• Procurement heavily supplier reliant • Trades broader analysis for waste reduction	• Vulnerable to disruptions • Limited flexibility
AGILE[2,3]	• Enhances flexibility and responsiveness	• Adapts to fluctuations, emphasizes real-time tracking, strengthens supplier relationships	• Increase in the usage of portable X-Rays during COVID-19 by 70%	• Quick response to changes • Customer satisfaction • Suitable for volatile markets	• Cost analysis	• High operational costs • Complex management
SCOR (SUPPLY CHAIN OPERATIONS REFERENCE)[4]	• Evaluates and improves supply chain performance end to end	• Plan, Order, Source, Transform, Fulfill, and Return	• Contrast manufacturing, storage, distribution, and vial recycling	• Standardized framework • Improves process visibility • Strong benchmarking capabilities	• One size fits all approach • Used across multiple industries	• Implementation effort • Complexity can quickly increase with supply chain size
BSC (BALANCED SCORE CARD)[5]	• Aligns supply chain activities with organizational strategy	• Financial, Customer, Internal Processes, Learning and Growth perspectives • Utilizes Key Performance Indicators (KPIs)	• Evaluation of a radiology department within a broader hospital or health system	• Aligns activities & strategy • Customizable for different goals	• Holistic view of performance • Requires robust data collection • Dependent on KPIs	• Implementation intricacy • May oversimplify complex issues
MCDA (MULTI-CRITERIA DECISION ANALYSIS)[6,7]	• Supports decision-making with conflicting criteria	• Identify objectives, assign weights to criteria, rank alternatives	• Evaluation of PACS vendors	• Incorporation of qualitative and quantitative factors • Customizable for different goals	• Subjective weighting • Heterogenous/numerous criteria	• Time-consuming • Limited actionable frameworks
REA/REALISTIC[3,8,9]	• Models and analyzes complex supply chains holistically, extends REA framework	• Resource, Events, Agents, Location, Information, Strategy, Time, Identity, Contracts	• Utilizing blockchain to track lifespan of radioactive materials in nuc med	• Real time tracking • Detailed visibility	• Usage of emerging technologies • Data intensive	• Limited adoption as of now
SIX SIGMA DMAIC[10]	• Reduces variability and errors in supply chain processes	• Define, Measure, Analyze, Improve, Control	• Evaluation and reduction of re-scans	• Improves quality and reduces defects • Strong data-driven methodology • Enhances risk mitigation	• Focused effort in efficiency over broader strategy • Data intensive	• Resource-intensive • Long implementation timeline
RESILIENCE MATURITY MODELS[11]	• Measures the maturity of healthcare supply chain practices	• Evaluates Scope & Service, Communication & Partnership, Infrastructure & Analytics • 4 levels that SCs can mature across	• Mature chains developing maintenance schedules on aging equipment to improve resilience and reduce down time	• Predictive model for long term improvement • Structured phases	• Benefits roll in with maturity • Can be reliant on partnerships	• Significant time/cost before utility

Conclusions

rSCM operates within complex, high-stakes environments that demand both precision and resilience. Our review demonstrates that rSCM can benefit significantly from the integration of selected components from multiple general ghSCM frameworks.
By applying a hybrid model that draws from the unique strengths of established frameworks such as Lean's efficiency, Agile's responsiveness, SCOR's standardization, and MCDA's structured decision-making.
Radiology departments can enhance both operational performance and supply chain responsiveness in routine and crisis conditions such as pandemics, natural disasters, and high tariff environments.
By providing a practical decision-support tool for radiology and healthcare system leaders. It empowers them to:

- Identify gaps in their current supply chain practices
- Tailor interventions based on contextual demands
- Support short- and long-term goals
- Build resilience into imaging-specific logistics strategies
- Advance cost transparency and sustainability in line with broader institutional goals

Ultimately, understanding and leveraging multiple ghSCM frameworks offers flexible paths for each operational context and rSCM development.

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