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Research Article

Engineering-Operations Collaboration for Stranded Inventory Reduction: A Framework for Cross-Functional Alignment

Venkata Naveen Kumar Manne*

Independent Researcher, USA

* **Corresponding Author Email:** naveenkmanne1@gmail.com - **ORCID:** 0000-0002-5247-0990

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Abstract:

Stranded inventory emerges as a critical challenge in manufacturing organizations where engineering design modifications proceed without adequate coordination with operational procurement and material management functions. Materials purchased under specific product specifications become obsolete when engineering changes implement without cross-functional visibility and planning alignment. The disconnect between engineering innovation imperatives and operational inventory optimization creates substantial financial losses through material write-offs, storage costs for unusable components, and expedited procurement expenses. Traditional manufacturing structures normally separate different functions, for instance, the engineering teams focus on the performance of the product, whereas operations teams manage material flows separately. However, nowadays, these problems have been aggravated due to various challenges faced by modern companies such as shortened product lifecycles, complicated global supply networks, and unstable material prices. Consequently, what used to be simply an operational inefficiency issue of stranded inventory has turned into a top-level strategic problem that calls for systematic management. Engineering-operations collaboration frameworks help to establish the ways in which synchronized decision-making can be carried out throughout product development and lifecycle changes. Closed-loop change management systems mandate operational impact assessment before design modifications receive approval. Design-to-value approaches that consider supply chain limitations naturally include procurement as a key stakeholder in product architecture decisions. Inventory health tracking and lifecycle management provide the necessary tools to localize the risks of obsolescence well in advance. Collaborative planning routines and supplier integration help to remove the boundaries of coordination that exist within the organization, thereby extending the coordination to the suppliers and partners in the supply networks. Joint use of well-structured change control, supply-chain-aware design principles, lifecycle-conscious inventory management, and supplier collaboration converts stranded inventory from unavoidably wasted resources to manageable risk while at the same time, retaining engineering agility which is crucial for competitive differentiation.

1. Introduction

On the one hand, manufacturing organizations are increasingly compelled to maintain the delicate balance between product innovation and operational efficiency. To this end, the engineering teams drive the wheel of continuous improvement through design modifications, component upgrades, and specification changes. The operations teams, on the other hand, take care of material procurement, production scheduling, and inventory optimization. However, the failure of these functions to integrate their operations results in the creation of stranded inventory due to the disconnect between them. Materials purchased under previous specifications become obsolete following engineering changes. Supply chain management encompasses the integration of key business processes across network members to deliver value to customers and stakeholders [1]. This integration becomes critical when engineering decisions affect material flows and inventory positions throughout the supply chain.The stranded inventory problem manifests across multiple scenarios. Engineering change orders issue without operational consultation. Bulk material purchases misalign with evolving product roadmaps. Component stockpiles become incompatible through design revisions. Surplus materials remain after product discontinuation. These situations generate direct financial losses through material write-offs. Storage costs for unusable inventory accumulate. Expedited procurement expenses for replacement components escalate. Chopra emphasizes that supply chain strategy must align with competitive strategy and accommodate uncertainty in demand and supply [1]. Engineering changes introduce supply uncertainty that disrupts material planning when coordination mechanisms fail.Traditional approaches treated stranded inventory as an unavoidable cost of innovation. Shortened product lifecycles have changed this perspective. Complex global supply networks amplify coordination challenges. Increased material costs elevate this issue from operational nuisance to strategic concern. The historical evolution of supply chain management reveals a progression from fragmented logistics functions toward integrated cross-functional processes [2]. Early supply chain thinking focused on physical distribution and transportation efficiency. Later developments recognized the need for coordination across purchasing, production, and distribution activities. Contemporary supply chain management requires strategic integration across organizational boundaries and functional silos [2].The fundamental challenge lies not in eliminating engineering changes. Design modifications remain essential for competitiveness. Creating collaborative frameworks where design evolution and operational reality converge becomes paramount. Lummus and Vokurka define supply chain management as the coordination of production, inventory, location, and transportation among supply chain participants to achieve optimal responsiveness and efficiency [2]. This coordination extends to engineering functions whose design decisions directly impact inventory requirements and material flows.Manufacturing organizations implement numerous engineering changes annually across product portfolios. Individual products experience discrete changes during commercial lifecycle phases. High-velocity development environments generate intensive engineering activity during development windows. This change velocity necessitates systematic coordination mechanisms rather than ad-hoc communication. Informal collaboration approaches fail to scale across the volume and complexity of concurrent engineering activities. Organizations without structured engineering-operations alignment exhibit elevated material write-off rates. Supply chain integration demands information sharing, process alignment, and collaborative decision-making across functional boundaries [1]. Engineering-operations collaboration for inventory management exemplifies this integration imperative.This article examines the technical and procedural foundations of engineering-operations collaboration for stranded inventory prevention. The discussion explores structured change management systems. Design methodologies that incorporate supply chain constraints receive examination. Lifecycle governance approaches that synchronize cross-functional decision-making throughout product development and transition phases form the analytical framework. The frameworks presented address both preventive strategies implemented during product conception and reactive coordination mechanisms deployed during engineering change execution.

2. Related Work and Methodology

Manufacturing literature has extensively documented the challenges of managing inventory in dynamic production environments. Conventional inventory management frameworks are mainly centered around demand variability and supply uncertainty, thus they do not provide sufficient measures against obsolescence risks resulting from changes in engineering design. Traditional economic order quantity models and reorder point systems are built on the premise of specification stability; hence they determine optimal order quantities and safety stocks basing on consumption patterns and lead timesThese models perform adequately in stable environments but fail when engineering modifications render materials obsolete before consumption through normal production channels.Recent scholarship has expanded understanding of engineering change management as a critical supply chain coordination mechanism. Early frameworks treated engineering changes as isolated technical decisions requiring approval workflows and documentation control. Contemporary perspectives recognize engineering modifications as supply chain events triggering material requirement adjustments, supplier coordination needs, and inventory risk management imperatives. Change management literature emphasizes structured review processes and impact assessment protocols. However, existing frameworks often address technical and quality implications while treating inventory consequences as secondary concerns managed reactively after change approval.Product lifecycle management research has advanced understanding of coordinated decision-making across product development, manufacturing, and service phases. Lifecycle perspectives recognize that design decisions during development phases create constraints and opportunities affecting downstream manufacturing and supply chain operations. Product architecture choices determine component commonality potential and modularization opportunities. Material selection decisions influence supplier flexibility and procurement agility. These realizations form the basis for preventive approaches which deeply root supply chain aspects into design processes rather than treating them as consequences to be handled after finishing the design. Supply chain collaboration research reveals that the key coordination mechanisms between buyers and suppliers are facilitated through communication, joint planning, and relationship governance. Collaborative frameworks mainly concentrate on the aspects of partnership such as agreement of the goals, trust-building, and establishment of the shared visibility, which in turn, allow for the coordination of the reaction to supply and demand disruptions. Engineering change management represents a specialized collaboration scenario where design modifications create supply disruptions requiring coordinated inventory adjustments across extended supply networks. Existing collaboration frameworks provide conceptual foundations but require adaptation addressing unique characteristics of engineering-driven supply uncertainty.The methodology presented integrates insights from engineering change management, product lifecycle management, and supply chain collaboration literatures into unified frameworks addressing stranded inventory prevention through cross-functional coordination. Four interconnected mechanism categories receive specification spanning change execution, design conception, lifecycle monitoring, and supplier integration phases.Closed-loop change management mechanisms address change execution through structured protocols mandating operational impact assessment before design approval. Impact assessment captures affected materials, current inventory positions, and procurement commitments. Change classification distinguishes urgent modifications requiring immediate implementation from planned improvements permitting coordinated transitions. Transition planning establishes phased approaches consuming existing materials while introducing new specifications.Design methodology mechanisms address design conception through supply-chain-conscious product development. Component standardization and modularization create inventory resilience enabling material reuse across products and generations. Multi-source material specifications provide procurement flexibility during component transitions. Lead time and minimum order quantity considerations prevent procurement inflexibility creating stranded inventory vulnerability.Lifecycle governance mechanisms address ongoing inventory monitoring through classification frameworks segmenting materials by lifecycle status. Active materials supporting current production receive standard management. Transitional materials supporting declining products require consumption acceleration. At-risk materials facing anticipated changes need proactive planning. End-of-life processes coordinate product discontinuation with material drawdown. Service parts planning balances availability commitments against obsolescence exposure.Supplier integration mechanisms extend coordination beyond organizational boundaries through collaborative planning and capability development. Joint forecasting incorporates engineering roadmaps into material plans. Flexible contracting accommodates design changes through modified deliveries and consignment arrangements. Supplier development cultivates responsive capabilities reducing lead times and order minimums enabling procurement agility during design transitions.Combined implementation across all mechanism categories creates comprehensive frameworks transforming stranded inventory from inevitable consequence of engineering innovation into manageable risk through systematic cross-functional coordination and extended enterprise collaboration.

3. Closed-Loop Engineering Change Management Systems

Effective stranded inventory prevention begins with structured engineering change management processes that mandate operational impact assessment before design modifications receive approval. Closed-loop systems establish cross-functional review mechanisms where engineering change orders undergo evaluation by representatives from operations, procurement, planning, and quality functions before implementation. Collaborative engineering requires integration of activities across organizational boundaries and functional disciplines [3]. Traditional sequential engineering processes create information barriers between design and manufacturing functions. Concurrent engineering approaches break down these barriers through parallel development activities and continuous information exchange.The technical architecture of closed-loop change management includes several critical components. Impact assessment protocols require engineering teams to document specific materials affected by proposed changes. Part numbers receive identification. Current inventory quantities undergo verification. Supplier lead times enter evaluation. Minimum order quantities factor into analysis. This documentation enables operations teams to evaluate consumption strategies for existing stock. Opportunities for material substitution or rework emerge through systematic assessment. Financial implications of potential obsolescence receive calculation. Willaert et al. emphasize that concurrent engineering success depends on organizational readiness and process maturity rather than technology alone [3]. Information systems enable change management workflows. Cross-functional collaboration cannot be achieved if there is no cultural alignment and the team does not have common performance objectives. Organizations which are not equipped with collaborative fundamentals, find it difficult to go through formal change processes even when the system they use is very advanced. Change classification frameworks distinguish between modifications requiring immediate implementation and discretionary improvements permitting phased transitions. Safety requirements drive immediate changes. Regulatory compliance issues demand rapid response. Discretionary improvements allow extended planning horizons. This classification enables operations teams to develop material consumption strategies aligned with change urgency. Immediate changes may necessitate accepting some stranded inventory. Planned improvements allow coordinated inventory drawdown synchronized with design cutover dates. Eckert et al. describe engineering changes as propagating through product structures with varying degrees of predictability [4]. Direct changes affect specific components with clear boundaries. Emergent changes trigger cascading modifications across multiple subsystems and assemblies. Change classification must account for propagation complexity beyond initial scope definition.Transition planning represents another essential element of closed-loop systems. Abrupt design changes create operational disruption. Transition strategies establish phased approaches where existing materials consume through normal production channels. New specifications gradually introduce during transition periods. This approach requires coordination between engineering release schedules and operations procurement cycles. Material ordering aligns with anticipated design implementation timelines. Complex engineering domains exhibit high interdependency between components and subsystems [4]. Changes in one area propagate to connected elements through functional relationships and interface specifications. Transition planning must map these interdependencies to identify affected inventory populations beyond directly modified components. Suppliers receive advance notification of pending changes. Manufacturing facilities adjust production schedules to consume transitioning materials. Quality systems validate new specifications before full-scale implementation. Organizations achieving effective transition management establish formal cutover criteria defining conditions for design release. Inventory thresholds trigger specification changes. Supplier readiness gates prevent premature implementation. Production validation confirms manufacturability before mass production commitment [3].

4. Design Methodologies Incorporating Supply Chain Constraints

Preventive measures, in addition to handling individual engineering changes, deeply integrate supply chain considerations into product design processes. Design-for-supply-chain and design-for-manufacturability practices intentionally include procurement constraints, material availability, and inventory aspects in engineering decisions from the very first concept to the production release. The integration of product design, process design, and supply chain design decisions is a strategic necessity for the competitiveness of the manufacturing sector [5]. Traditional organizational structures separate these design domains into distinct functional areas. Engineering departments focus on product functionality and performance. Manufacturing engineering concentrates on production processes and efficiency. Supply chain organizations address sourcing and logistics. This separation creates sequential decision-making where product specifications lock before process and supply chain implications receive full consideration.Component standardization and modularization constitute fundamental design strategies for stranded inventory prevention. Establishing libraries of approved, reusable components shared across product families reduces proliferation of unique part numbers. Isolated inventory pools vulnerable to obsolescence diminish through standardization. Standardized components maintain utility across multiple product generations. Material flexibility emerges when design changes affect specific products. Ulrich and Eppinger describe product architecture as the arrangement of functional elements into physical chunks and specification of interfaces among interacting chunks [6]. Architecture decisions determine component sharing potential across product variants. Modular architectures with well-defined interfaces enable component reuse. Integral architectures with tightly coupled elements limit standardization opportunities. Organizations face trade-offs between architectural simplicity favoring integral designs and component commonality favoring modular structures.Modular product architectures further enhance inventory resilience by isolating design volatility to specific subsystems or assemblies. Changes concentrate in defined modules while stable platforms persist across product variants. Organizations maintain useful inventory for unchanged sections while limiting stranded material to modified modules. This containment strategy proves particularly valuable in industries experiencing rapid technological evolution in specific subsystems. Core structures remain relatively stable across product generations. Rungtusanatham and Forza emphasize that product architecture decisions influence manufacturing flexibility and supply chain responsiveness [5]. Modular designs permit delayed differentiation where common platforms produce in advance of customer orders. Final configuration occurs near delivery through module selection and assembly. This postponement strategy reduces forecast dependency and inventory risk for differentiated components.Material selection processes incorporating supply chain factors represent another preventive mechanism. Engineering specifications accommodate multiple approved suppliers. Single-source components receive avoidance. Commercially available parts gain preference over custom designs. Procurement flexibility emerges reducing stranded inventory risk. Design changes necessitating component substitutions proceed smoothly with multi-source specifications. Existing supplier relationships and inventory positions avoid obsolescence. Product Design and Development emphasizes industrial design, mechanical design, and production design as interconnected activities requiring coordination [6]. Component selection decisions affect manufacturing process requirements. Custom components may require dedicated tooling and supplier relationships. Standard components leverage existing supply base and equipment. Material choices influence assembly methods and quality control procedures.Lead time and minimum order quantity considerations during design phases prevent misalignment between engineering requirements and procurement realities. Components requiring extended lead times demand careful lifecycle planning. Large order minimums create procurement inflexibility. Engineering changes occurring mid-procurement cycle generate incoming inventory already obsolete upon receipt. Supply chain design decisions include supplier selection, logistics network configuration, and inventory positioning [5]. Long lead times necessitate early commitment to component specifications. High minimum orders force bulk purchasing decisions. Design teams incorporating these constraints into component selection achieve better alignment between engineering and procurement. Short-lead components with flexible ordering enable design agility. Long-lead components with rigid minimums require design stability across extended planning horizons. Product development processes must synchronize design freeze points with procurement lead times to prevent specification changes after order placement.

5. Inventory Health Analysis and Lifecycle Governance

Operational systems for monitoring inventory health relative to engineering roadmaps provide essential visibility for proactive stranded inventory prevention. Inventory aging analysis tracks material dwell time, consumption velocity, and alignment with current product specifications. At-risk inventory requiring engineering attention receives identification before obsolescence occurs. Intermittent demand patterns characterize many inventory items in manufacturing environments [7]. Demand occurs sporadically with periods of zero consumption interspersed with occasional requirements. Traditional forecasting methods developed for regular demand patterns perform poorly with intermittent items. Forecasting errors compound obsolescence risk when engineering changes affect slow-moving materials with unpredictable consumption. Organizations must distinguish between materials experiencing temporary demand pauses and those facing permanent obsolescence due to specification changes.Classification frameworks categorize inventory based on lifecycle status. Active materials support current production. Transitional materials support products nearing end-of-life. At-risk materials face potential impact from anticipated engineering changes. This classification enables targeted collaboration where engineering and operations jointly develop consumption strategies. Opportunities for material reallocation across product lines emerge through systematic review. Redesign options to utilize existing inventory receive evaluation when consumption through normal channels appears unlikely. Babai et al. demonstrate that obsolescence risk increases significantly for items with intermittent demand and declining consumption trends [7]. Materials exhibiting lengthening intervals between demand occurrences signal potential obsolescence. Distinguishing between normal demand variability and fundamental consumption decline requires statistical analysis of demand patterns over extended periods. Engineering roadmap visibility enables operations teams to anticipate which materials face obsolescence from planned design changes versus those experiencing temporary demand fluctuations.End-of-life governance processes establish structured approaches for product discontinuation that minimize stranded material formation. Last-buy planning coordinates final material procurements with production cessation timelines. Sufficient materials for committed customer orders require securing. Excess purchases necessitate avoiding. Engineering teams support these transitions by evaluating opportunities to extend existing material utility. Alternative products may accommodate legacy materials through design flexibility. Material substitution possibilities receive identification enabling inventory consumption beyond original product lifecycles. Product lifecycle management encompasses processes, methods, and tools supporting product evolution from conception through disposal [8]. Lifecycle governance is a necessity of the coordination of product planning, development, manufacturing, and service phases. The decisions taken at the end of life will have an impact on a multitude of stakeholder groups, such as customers who need continued support, suppliers who manage the production of components, and internal functions that balance service commitments against inventory optimization. Service parts planning represents a specialized aspect of lifecycle governance where engineering and operations collaborate to balance long-term spare parts availability against stranded inventory risk. Maintaining service support for discontinued products requires addressing. Excessive component purchases that may ultimately become obsolete demand avoiding. Equipment populations decline over time through retirements and replacements. Service demand forecasting extends across multi-year horizons beyond production cessation. Corallo et al. describe product lifecycle management as integrating people, processes, business systems, and information throughout product lifecycles [8]. Service parts management exemplifies this integration requirement. Engineering provides technical specifications and failure mode analysis. Operations manages inventory positioning and replenishment. Sales maintains customer relationships and service commitments. Finance evaluates inventory investment returns against service revenue streams. Collaboration becomes essential when determining last-time-buy quantities for service components. Overestimation creates stranded inventory as installed base populations decline. Underestimation forces expensive alternative sourcing or service level compromises. Engineering analysis combines installed base projections with component reliability data to estimate remaining lifetime requirements. Operations incorporates demand uncertainty and supplier constraints into procurement decisions. Joint planning processes reconcile technical assessments with operational realities to optimize service inventory investments while minimizing obsolescence exposure across extended service horizons.

6. Collaborative Planning and Supplier Integration

Synchronized forecasting and planning cycles between engineering and operations establish shared visibility into future material requirements influenced by anticipated design changes, new product introductions, and existing product phase-outs. Joint planning forums facilitate discussion of engineering roadmaps, material ramp-up strategies, and inventory transition plans. Operations teams adjust procurement patterns in anticipation of design evolution. Sales and operations planning represents a cross-functional process balancing demand and supply through integrated planning and decision-making [9]. The process involves demand planning, supply planning, and executive review phases conducted on monthly cycles. Demand planning collects sales forecasts, marketing initiatives, and customer commitments to build consolidated demand views. Supply planning examines capacity constraints, material availability, and production capabilities to see if they are enough to fulfill demand requirements. Executive review sessions resolve conflicts between demand aspirations and supply realities through resource allocation decisions and priority setting.Material requirement planning systems incorporating engineering change visibility allow procurement teams to modulate ordering patterns based on anticipated specification changes. Standard reorder points and safety stocks receive maintenance for stable materials. Materials facing potential obsolescence require different treatment. Planning logic adjusts inventory targets downward during transition periods. Accumulation of soon-to-be-obsolete components receives reduction through modified planning parameters. Lapide describes the importance of reconciling operational plans with strategic objectives and financial targets [9]. Engineering changes affect both operational execution and financial performance through inventory write-offs and expediting costs. Integrated planning processes must surface these impacts during planning cycles rather than discovering consequences after implementation. Engineering roadmaps feed into planning systems as inputs alongside demand forecasts and capacity plans. Planning teams evaluate material exposure to anticipated changes. Procurement strategies adjust based on design transition timelines. Orders for transitioning materials receive modification to align quantities with consumption windows before specification changes take effect.Supplier engagement extends collaborative inventory management beyond organizational boundaries. Flexible contracting approaches establish agreements where suppliers accommodate engineering changes through modified delivery schedules. Returnable inventory provisions create mechanisms for material return. Consignment arrangements transfer obsolescence risk from buyer to supplier. Engineering change notifications to suppliers enable coordinated inventory drawdown across the extended supply network. Critical or high-value components require particularly close supplier coordination. Collaborative relationships develop through sustained interaction, mutual adaptation, and relationship-specific investments creating joint value unavailable through market transactions [10]. Buyer-supplier relationships are characterized by a range of different types of interactions, from arms-length transactions to deep partnerships. Transactional relationships emphasize price competition and the use of standard specifications. On the other hand, collaborative relationships involve communication of information, joint problem-solving, and coordinated planning. Engineering change management can gain from collaborative approaches in situations where changes are frequent or have an impact on complex supply networks. Supplier development programs cultivate capabilities for rapid response to engineering changes. Quick-turn prototyping enables rapid design validation. Small-lot production reduces minimum order quantities. Flexible manufacturing arrangements accommodate specification variations without extensive changeovers. These supplier capabilities provide operational flexibility during design transitions. Organizations maintain engineering agility without accumulating stranded inventory through large batch purchases. Fischer and Reynolds identify trust, communication, and mutual benefit as foundations of sustainable collaborative relationships [10]. Supplier development requires investment in relationship building beyond transactional exchanges. Technical assistance helps suppliers improve process capabilities. Training programs enhance workforce skills. Joint improvement initiatives address capability gaps limiting responsiveness. As supplier capabilities improve, supply chains become more adaptable to engineering evolution. Lead times shorten. Order quantities decrease. Specification changes implement smoothly. The collaborative basis makes it possible to keep changing requirements without relationship strain or inventory losses.

Table 1. *Engineering Change Management Framework [3, 4].*

Change Type	Review Process	Transition Strategy
Emergency Changes	Cross-functional impact assessment with condensed review cycles	Immediate implementation with potential inventory acceptance
Standard Changes	Comprehensive operational evaluation with normal approval timelines	Phased transition with dual-sourcing periods
Enhancement Changes	Extended evaluation with coordinated implementation planning	Inventory drawdown synchronized with design cutover

Table 2. *Design Strategies for Inventory Resilience [5, 6].*

Design Approach	Key Features	Inventory Benefit
Component Standardization	Reusable parts across product families	Reduced unique part numbers and isolation
Modular Architecture	Isolated design volatility in specific modules	Preserved stable component inventory
Multi-Source Specifications	Multiple approved suppliers per component	Flexible supplier transitions during changes
Lead Time Integration	Procurement constraints in component selection	Aligned ordering with design stability windows

Table 3. *Inventory Lifecycle Classification [7, 8].*

Material Category	Consumption Pattern	Management Focus
Active Materials	Predictable consumption supporting current production	Standard inventory control and reordering
Transitional Materials	Declining consumption for end-of-life products	Accelerated consumption before discontinuation
At-Risk Materials	Potential obsolescence from anticipated changes	Proactive planning before specification changes
Service Parts	Long-term spare parts for discontinued products	Lifetime demand balancing against obsolescence

Table 4. *Supplier Collaboration Mechanisms [9, 10].*

Collaboration Type	Integration Method	Flexibility Outcome
Joint Planning	Shared engineering roadmaps and material strategies	Adjusted procurement anticipating changes
Flexible Contracting	Modified deliveries and consignment arrangements	Transferred obsolescence risk to suppliers
MRP Enhancement	Engineering change visibility in planning systems	Reduced ordering for transitioning materials
Supplier Development	Quick-turn prototyping and small-lot production	Reduced lead times and minimum quantities

7. Conclusions

The competitiveness of manufacturing is more and more dependent on the organization's capabilities to balance the speed of innovation with the operational efficiency. Engineering agility becomes a source of product differentiation and market responsiveness through continuous design evolution. Operational excellence requires inventory optimization minimizing capital tied in materials while maintaining production continuity. Traditional functional separation between engineering and operations creates inherent tension where design changes generate inventory obsolescence. Resolution demands systematic collaboration frameworks establishing shared visibility, synchronized planning, and coordinated decision-making across organizational boundaries. Closed-loop engineering change management transforms design modifications from unilateral engineering decisions into cross-functional transitions. Impact assessment protocols surface material implications before implementation. Change classification enables urgency-appropriate transition strategies. Phased cutover planning coordinates specification releases with procurement cycles. Engineering change processes incorporating operational perspectives prevent stranded inventory formation at source through disciplined evaluation and planning. Design methodologies embedding supply chain constraints provide preventive approaches reducing obsolescence vulnerability. Component standardization creates inventory pools resilient to individual product changes. Modular architectures isolate design volatility to specific subsystems preserving stable platform investments. Multi-source material specifications enable smooth supplier transitions during component substitutions. Lead time and minimum order quantity considerations during design prevent procurement inflexibility. Engineering decisions incorporating operational constraints achieve innovation without inventory penalties. Inventory health monitoring and lifecycle governance enable proactive obsolescence management. Classification frameworks segment materials by lifecycle status directing attention toward transitional and at-risk populations. End-of-life processes coordinate product discontinuation with material consumption. Service parts planning balances long-term availability commitments against inventory exposure. Systematic tracking transforms reactive obsolescence discovery into anticipatory risk management. Collaborative planning and supplier integration extend coordination into supply networks. Joint forecasting cycles incorporate engineering roadmaps into material plans. Material requirement systems adjust ordering patterns based on anticipated changes. Flexible supplier contracts accommodate design evolution through modified deliveries and consignment arrangements. Supplier development programs cultivate responsive capabilities reducing lead times and order minimums. Extended enterprise collaboration distributes inventory optimization across supply chain participants. Successful implementation requires sustained organizational commitment beyond process documentation. Information systems must enable real-time visibility across engineering and operations. Governance structures must mandate collaborative decision-making over functional autonomy. Performance metrics must reward collective optimization rather than departmental objectives. Cultural transformation supporting cross-functional collaboration proves as essential as technical frameworks. Organizations implementing comprehensive engineering-operations alignment achieve dual objectives previously considered contradictory. Engineering maintains innovation velocity through frequent design iterations. Operations optimizes inventory investment through reduced obsolescence and improved turnover. The frameworks establish practical foundations for balanced achievement of competing objectives essential for sustained competitive advantage in dynamic manufacturing environments.

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