Procurement for supply chain integration: responding to complexity in engineer-to-order defence projects

International Journal of Operations & Production Management

305

Received 5 March 2025
Revised 28 June 2025
29 August 2025
7 October 2025
Accepted 10 October 2025

Joakim Aspeteg and Jakob Rehme
Division of Industrial Management, Centre for Business Model Innovation, Linköping University, Linköping, Sweden
Jonathan Gosling
Logistics and Operations Section, Logistics Systems Dynamics Group, Cardiff Business School, Cardiff University, Cardiff, UK, and
Johan Holtström
Division of Industrial Management, Centre for Business Model Innovation, Linköping University, Linköping, Sweden

Abstract

Purpose – This case study explores a high-tech defence company, focusing on procurement's mediating role in enabling supply chain integration (SCI) within complex engineer-to-order (ETO) projects. The study aims to examine how procurement strategically responds to varying complexities to facilitate internal and external integration.

Design/methodology/approach – An exploratory cross-case study examined procurement's role in ETO SCI. Semi-structured interviews with procurement professionals and key stakeholders, including project managers, design engineers and other central project members, provided a multifaceted perspective. These interviews provided insights into high-tech ETO-projects' structural and dynamic complexities.

Findings – This study shows how procurement mediates SCI dimensions in response to varying structural and dynamic complexities. It develops a framework that links SCI responses to complexity types, offering a more nuanced understanding of procurement's integrative role in ETO-defence projects.

Originality/value – Addressing research gaps in the way in which procurement can respond to structural and dynamic complexity to facilitate SCI in ETO defence projects, the paper introduces a supply chain and technical complexity matrix, a framework tailored to high technology defence ETO-projects, by contributing to the SCI, ETO and procurement literature streams. Specifically, it positions procurement at the nexus of SCI dimensions and conceptualises its role in mediating structural and dynamic complexities. The framework offers both theoretical insight into procurement's integrative function and practical guidance for managing integration challenges in complex project-based environments.

Keywords Engineer-to-order supply chain, Supply chain integration, Procurement, Complexity

Paper type Case report

Introduction

European defence supply chains, weakened by decades of budget reductions, have become increasingly fragile. The sector's rapid capacity expansion has now been exacerbated by the war in Europe and Geopolitical instability. Ambitious proposed defence investments in complex technological equipment are exposing the vulnerabilities of globalised supply chains (The Economist, 2023). To manage these challenges, governments are pursuing public

International Journal of Operations & Production Management
Vol. 45 No. 13, 2025
pp. 305-331
Emerald Publishing Limited
e-ISSN: 1758-6593
p-ISSN: 0144-3577
DOI 10.1108/IJOPM-02-2025-0155

procurement reforms to tackle cost overruns and delays through closer industry ties and improved integration (Pfeifer and Fisher, 2024). For the defence industry, traditional procurement regimes, designed for stable schedules and long-term supplier relationships, are increasingly misaligned with today's compressed timelines, increasing defence demand and complex global supply chains. This misalignment foregrounds the central issue of how procurement, at the project level (cf. Moretto *et al.*, 2022), shapes responses through integration practices, both internally and externally, when faced with complexity.

SCI is the degree to which a manufacturer strategically collaborates with supply chain partners and manages processes within and across organisations (Flynn *et al.*, 2010). Prior work links SCI to resilience, efficiency and financial outcomes through improved information sharing, coordinated decision making, adaptability and process optimisation (Agyei-Owusu *et al.*, 2022; Ataseven and Nair, 2017; Flynn *et al.*, 2016; Frohlich and Westbrook, 2001), while emphasising that effects are contingent on operations strategy and competitive priorities (Leuschner *et al.*, 2013). For this study, we characterise defence projects as engineer-to-order (ETO) situations, where ETO denotes project-based development and delivery of customised products to specific customer requirements, often with limited standardisation and late design freeze (Alfnes *et al.*, 2021; Cannas and Gosling, 2021). Such projects require significant efforts to manage complexity and its different forms (Maylor and Turner, 2017). Studies show that ETO supply chains typically combine high levels of "structural complexity", including multi-tier networks and bespoke components, with "dynamic complexity", including shifting customer requirements and uncertain timelines (Birkie and Trucco, 2016; Bozarth *et al.*, 2009). Established integration approaches from repetitive manufacturing, therefore, translate only partially to ETO conditions, and evidence on SCI remains skewed toward high-volume contexts (Khanuja and Jain, 2019).

A key premise for this work is that procurement is strategically positioned to address these contextual issues, as well as the theoretical misalignment of SCI in ETO. Procurement sits at the intersection of SCI dimensions and mediates across technical, organisational and market domains (Laari *et al.*, 2023; Picaud-Bello *et al.*, 2022; Scherer and Biemans, 2025). In addition, key procurement activities such as supplier relationship management, early supplier involvement, sourcing choices, timing of component deliveries, and coordination routines directly shape lead times and system integration in ETO projects (Gosling and Naim, 2009; Hicks *et al.*, 2000; Mello and Strandhagen, 2011; Reitsma *et al.*, 2024). Governance choices that balance contractual and relational mechanisms, including moves toward procuring complex performance, are likewise enacted through procurement to tackle systemic complexity (cf. Roehrich and Lewis, 2014). Defence projects heighten these issues: large, technologically advanced systems are managed over long-life cycles and often orchestrated by prime contractors within oligopolistic structures (Caldwell and Howard, 2014; Howard *et al.*, 2016; Johnsen *et al.*, 2009). What remains underexplored is the way in which procurement can respond to structural and dynamic complexity to facilitate SCI in ETO defence projects. Therefore, the overarching purpose is to explore procurement responses to varying levels of complexity.

The research is guided by the following research question: "How can procurement respond to the integration of ETO supply chains across different types and levels of complexity?" The study is based on a qualitative embedded case design, incorporating interviews with procurement employees, project leaders, engineers and a customer representative. The design allows us to identify SCI factors salient to ETO defence supply chains and to examine procurement responses under different combinations of structural and dynamic complexity, culminating in a framework that links complexity profiles to integration approaches.

This study addresses a timely misalignment of resources, capacity and practices in the context of ambitious expansion of investment in the defence industry. We observe a mismatch where SCI literature is mostly skewed towards high-volume make-to-stock type industries, and there is not enough clarity on procurement's mediating strategic role. We contribute theoretically by showing how procurement addresses varying complexities through the integration of complexity theory and procurement literature. By distinguishing structural and dynamic dimensions of complexity, it develops a framework for tailoring procurement responses to balance integration efforts. The findings emphasise procurement's ongoing mediating role by underscoring procurement's strategic influence on SCI in ETO.

Theoretical background

Integration in ETO supply chains

Cannas *et al.* (2020) define ETO as an order fulfilment strategy where engineering and production flows are driven almost entirely by the end customer. The order-fulfilment strategy refers to the way a supply chain responds to a customer order, encompassing the flow of activities from sales inquiry to product delivery (Cannas *et al.*, 2020). Key structural activities to manage ETO order fulfilment flow include quotations, technical and commercial development, design, production, delivery, commissioning and after-sales (Adrodegari *et al.*, 2015). An important distinction for this work is that many, if not all, of these activities will require procurement teams to procure goods and services for customer-specific needs across the order fulfilment flow. Several typologies have been developed for ETO-type firms, which help convey their key characteristics. Hicks *et al.* (2001) emphasize complexity of product depth and Job Shop environment, while Willner *et al.* (2016) focus on low volumes and high number of engineering hours needed per order, when compared with non-ETO type firms.

Transferring supply chain practices from high-volume manufacturing to engineering-intensive ETO sectors is problematic due to irregular order patterns, low procurement volumes, and unique customer specifications that require frequent supplier adaptation (cf. Gosling *et al.*, 2020). Unlike manufacturers with consistent, high-volume procurement, ETO firms purchase components in low volumes and at irregular intervals, which limits their influence over suppliers (Cannas and Gosling, 2021; Hicks *et al.*, 2000). Despite these challenges, SCI is critical across tendering, product development, and production stages to ensure ETO products meet unique customer specifications efficiently (Cannas *et al.*, 2019; Gosling and Naim, 2009). Indeed, integration facilitates the fulfilment of customer expectations while minimising costly errors and delays (Mello *et al.*, 2015b).

In ETO projects, volatile specifications and exposure to engineering changes drive redesign and rework, which increase costs and lead-times (Hicks *et al.*, 2001; Iakymenko *et al.*, 2022; Shurrab *et al.*, 2022). Overlapping phases of design, procurement and manufacturing, combined with early commitment to delivery dates (Bhalla *et al.*, 2022; Hicks *et al.*, 2001; McGovern *et al.*, 1999), create challenges for design specifications, production planning, and capacity control (Fortes *et al.*, 2023; Mello *et al.*, 2015a). Low and irregular purchasing volumes limit supplier leverage (Cannas and Gosling, 2021; Hicks *et al.*, 2000), and intermittent supplier involvement causes information gaps (Bäckstrand and Fredriksson, 2022; Cohee *et al.*, 2018). For long-life systems and products, lifecycle and obsolescence risks need early attention (Howard and Miemczyk, 2010; Romero Rojo *et al.*, 2010). Design reuse and component standardisation reduce costs and lead time, reinforcing procurement-led supply chain integration across tendering, development and execution (Hicks *et al.*, 2001; Strandhagen *et al.*, 2018).

Integration in ETO-supply chains involves managing issues such as complex supplier relationships, negotiating with limited bargaining power due to low-volume orders, and balancing design specifications between functionality, additional features and cost (Hicks *et al.*, 2000). ETO-companies with limited leverage can address these constraints by establishing strong supplier relationships, communicating the value of long-term collaboration, embracing flexibility, and aligning procurement strategies with business goals (Christiansen and Maltz, 2002). However, poor information sharing can undermine coordination, particularly when suppliers are not continuously involved in the process (Bäckstrand and Fredriksson, 2022; Kjersem and Giskeødegård, 2020). Additionally, early customer engagement improves specification accuracy and execution, whereas late-stage involvement and changes increase project risk (Dixit *et al.*, 2019). Customer-specific requirements, order changes, and varied product knowledge contribute to supply chain uncertainty (Shurrab *et al.*, 2022), heightening the need for strategic procurement practices. Collectively, these issues stem from the inherent complexity of ETO environments.

Particularly, procurement integration is crucial, as up to 80% of materials and components originate from suppliers (Cigolini *et al.*, 2022). Moretto *et al.* (2022) highlight the importance of aligning procurement with both internal (time pressures, resource dedication) and external (customer involvement, project uniqueness) factors. They identify two procurement archetypes: procurement-focused (centralised, efficiency-driven) and project-focused (decentralised, project-specific), with a hybrid model in between. Reitsma *et al.* (2023) underline the importance of integrating procurement with R&D early in the design phase, assigning appropriate representatives, and clarifying roles.

Procurement and ETO complexity

Recent studies frame procurement as a strategic mediator, acting as a knowledge broker that translates customer needs, supplier capabilities, and internal objectives to facilitate integration across boundaries. Procurement supports this through coordinating evolving requirements, resolving demand-supply imbalances (Laari *et al.*, 2023), and leveraging supplier knowledge in product development (Picaud-Bello *et al.*, 2022). In ETO, procurement orchestrates integration from early development stages by aligning technical designs with supplier inputs (Eriksson, 2015; Reitsma *et al.*, 2024). This study outlines procurement as a strategic, mediating mechanism that enables alignment across internal functions and external partners under conditions of uncertainty.

In ETO-projects, design and procurement often begin before contract finalisation, demanding early and sustained integration in tendering, development, and supplier engagement (Bhalla *et al.*, 2022). Procuring long-lead-time items ahead of design finalisation can shorten timelines, but it also exposes projects to the risk of late-stage changes (McGovern *et al.*, 1999). Strategic sourcing choices, especially between standard and custom components, hinge on timing and design certainty (Strandhagen *et al.*, 2018). During tendering, procurement estimates costs and lead times while selecting suppliers who influence project outcomes (Buzzetto *et al.*, 2020). To perform effectively, procurement must maintain tight coordination across design, R&D, and operations, informed by supplier and market insights (Guy and Dale, 1993; Reitsma *et al.*, 2023).

Clear, technically robust specifications are essential, especially when developed collaboratively between design and procurement teams (Dowlatshahi, 1992). Functional flexibility is valuable (Hicks *et al.*, 2001), but technical clarity ensures manufacturability and facilitates supplier contributions. Early supplier involvement improves performance and reduces complexity when supported by formal agreements and shared objectives (Cohee *et al.*, 2018). Nonetheless, poor internal alignment can strain supplier relationships and reduce responsiveness (Ellegaard and Koch, 2014; Foerstl *et al.*, 2013), underlining the importance of procurement-led integration across functions.

Procurement also navigates trade-offs between cost, availability, and technical quality, often in collaboration with design teams (Dowlatshahi, 1992). Early awareness of engineering changes minimises rework and post-implementation inefficiencies (Iakymenko *et al.*, 2022), indicating the importance of early customer engagement (Dixit *et al.*, 2019). Long operational lifespans in defence systems introduce further complexity, particularly in sustaining in-use performance amid evolving threats and shifting technical landscapes (Howard and Miemczyk, 2010). Addressing obsolescence proactively from the design phase is critical, especially where ageing mechanical or electronic components may be unavailable in later stages (Romero Rojo *et al.*, 2010). Procurement thus supports lifecycle adaptability, ensuring systems remain operable and supportable over time. Thus, procurement is not only a transactional function but a strategic enabler of integration in complex ETO environments.

Complexity in ETO. Complexity, characterised by uncertainty, structural interdependencies, and dynamic changes, is central to ETO-projects due to their high customisation and novelty (Maylor and Turner, 2017). Complexity, we define as the variety of elements, i.e., products, systems, and organisational entities, and their interactions within a system (Choi and Krause, 2006). Influenced by Bozarth *et al.* (2009), we classify complexity into structural and dynamic dimensions, each stemming from internal (within the firm) or external (across the supply/value chain) sources (Baccarini, 1996; Williams, 1999). Baccarini (1996) conceptualises project complexity in terms of structural differentiation, meaning the number of elements and components, and the interdependency between them. This approach captures ETO's advanced technical architectures and supplier and customer network links (Choi and Krause, 2006). Dynamic complexity reflects uncertainty in project goals and methods, evolving from specifications and frequent changes typical in ETO settings (Tatikonda and Rosenthal, 2000; Williams, 1999). Together, these two dimensions cover internal and external complexity (see Table 1), aligning with ETO-projects' unique products, evolving requirements, and demands for integration in the supply chain (Baccarini, 1996; Choi and Krause, 2006; Tatikonda and Rosenthal, 2000; Williams, 1999).

Table 1. Structural and dynamic complexities in ETO supply chains

Complexity types	Structural	Dynamic
Internal	The number, variety and interdependence of components, subsystems, departments and interfaces that must be designed and assembled, driving dense dependency networks and high integration effort (Baccarini, 1996; Brehmer and Rehme, 2009; Browning and Heath, 2009; Duncan, 1972)	Novel or highly customised technologies plus evolving design specifications that trigger iterative design loops, rework and unpredictable technical changes (Azadegan *et al.*, 2013; Birkie and Trucco, 2016; Bozarth *et al.*, 2009; Brehmer and Rehme, 2009; Choi and Krause, 2006)
External	The count, heterogeneity and geographic spread of suppliers and/or customers, creating multiple tiers and hand-off points in the supply network (Birkie and Trucco, 2016; Tatikonda and Rosenthal, 2000; Williams, 1999)	Fluctuating material needs, customer-driven design changes, supplier/customer interdependencies and volatile order volumes that ripple through—and destabilise—the supply chain (Tatikonda and Rosenthal, 2000; Williams, 1999; Wong *et al.*, 2011)

Procurement and SCI in responding to ETO complexity. Complexity in ETO environments is inevitable and requires active management. As Maylor and Turner (2017) argue, it may be reduced but never fully eliminated, necessitating proactive rather than reactive approaches. In line with their "understand–reduce–respond" framework, we suggest that procurement has a role to play in managing contingency responses to complexity. SCI involves internal, supplier, and customer dimensions. Internal integration is increasingly seen as a prerequisite for effective external integration (Ataseven and Nair, 2017; Flynn *et al.*, 2010; Munir *et al.*, 2020). Yet, despite the acknowledged importance of internal integration, procurement's role in orchestrating internal–external linkages remains underdeveloped in SCI theorising.

Despite growing interest in procurement's role in SCI within ETO contexts, essential aspects of its theoretical foundations remain underexplored. First, most SCI frameworks are developed for stable high-volume manufacturing and do not account for the complexity and uncertainty inherent in ETO environments. Second, while procurement is acknowledged as important, its role as a strategic mediator in the nexus of internal, supplier, and customer integration under ETO complexity remains undertheorized. Third, there is a limited understanding of how different types of complexity, structural and dynamic, shape procurement responses that enable SCI.

Methodology

This study emerges from a research program examining procurement in defence ETO-projects, a critical sector innovating products amid contemporary military conflicts (Dixit *et al.*, 2019). Employing a multiple-case approach to investigate complex phenomena in real-world settings (Eisenhardt, 1989), the study uses *a priori* constructs, including SCI dimensions, to illuminate how procurement activities shape downstream supply chain decisions from both upstream and internal perspectives. Established theories introduced into a less-explored context (DuHadway *et al.*, 2022) uncover unique dynamics and extend existing frameworks. Drawing on case research principles in operations management (Voss *et al.*, 2002), the methodology integrates multiple literature streams: ETO SCM, SCI, and procurement with empirical data from interviews, secondary sources, triangulation, and case descriptions.

Research design and case selection

The findings focus on DefCo (pseudonym), a large Swedish multinational company engaged in complex ETO-projects. Exploratory research, valuable for uncovering unexpected phenomena to inform theory-building (Eisenhardt, 1989), was chosen to address the limited studies on procurement integration in ETO. This approach provides academic insights and managerial implications. While the findings are grounded in a specific industry context, they may apply to related ETO contexts. The study's focus enables an in-depth exploration of unique aspects while addressing the dynamics and challenges faced by ETO-companies.

The Defence Procurement Agency (DPA) procures, develops, and delivers equipment and services to the armed forces and military units (Ekström *et al.*, 2021). In the simplified supply chain illustrated in Figure 1, DefCo acts as a systems integrator, sourcing components and technology from suppliers to assemble final products ordered by the DPA. These products are delivered directly or through the DPA to the armed forces and end-users. DefCo's complex and lengthy development projects require close collaboration with suppliers to gather price estimates and technical information, as well as with the DPA to align product requirements. This process enables DefCo to estimate project costs and provide accurate quotations.

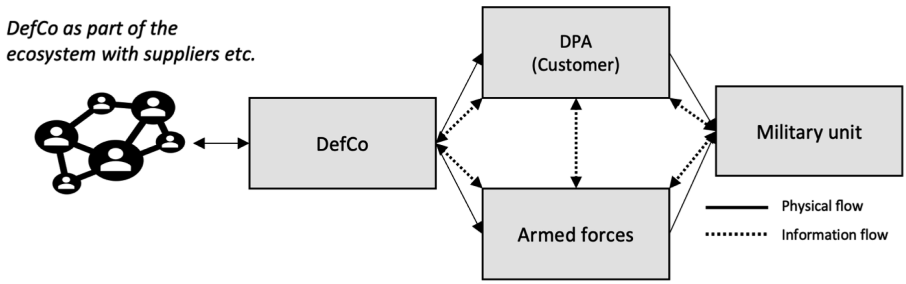

Figure 1. Research design and practice (a simplified generic defence industry supply chain, based on Ekström *et al.* (2021))

The projects were selected based on the following: (1) each had to be an ETO-project with at least a hybrid-focused procurement organisation (Moretto *et al.*, 2022); (2) a project-team needed to be available for interviews focusing on procurement issues; (3) preference was given to projects spanning several years; and (4) the projects should exhibit varied complexity, including the number of suppliers, supplier site development, customer involvement, concurrent development, and project lead times.

Data collection and analysis

The sample includes 26 interviews from three projects (1,538 min total) covering different roles (Table 2); primarily of procurement professionals, complemented by project leaders who provided a holistic view of the projects and explained how procurement is integrated internally and externally. Respondents from the design department were included to capture internal integration insights. Initial interviews with the head of procurement highlighted that collaboration with the design department was crucial for fostering long-term, proactive integration within and across projects. Additional interviews with operational excellence professionals, who acted as a bridge between engineering and procurement, shed light on managing costs and enhancing collaboration. A customer interview enriched the findings by providing insights into downstream integration. The selection criteria emphasised respondents' qualifications and experience, ensuring a comprehensive understanding of the projects and integration processes. This allowed respondents to relate their integration practices to past experiences in various industries and projects. This contributed to validity, as their insights helped ensure that the study accurately captured the studied phenomenon (cf. Golafshani, 2003; Voss *et al.*, 2002). Several interviews were conducted by multiple authors, promoting diverse perspectives and strengthening confidence in the findings through consistent observations (Eisenhardt, 1989). We triangulated our findings using confidential internal documents (process and role descriptions, project presentations) alongside interview data. Respondents and a designated manager reviewed all transcripts for clarity, accuracy, and confidentiality. Follow-up interviews then resolved any discrepancies and clarified outstanding issues.

Table 2. Cases and interviews

Project	Description	Role	#	Duration (min)
Alpha	Design, product development and integration of highly technical, innovative, complex and modular systems	Head of Procurement	1	64
		Head of Procurement Project Office	2	82
		Project manager (PM) design, system 1	3	57
		PM design, system 2	4	41
		PM Construction	5	43
		Contract Responsible	6	58
		Head PM	7	60
		Customer project leader	8	65
Beta	Design, product development and production of flexible and cutting-edge systems for real-time control and early warning	Head of programme	9	61
		Head PM	10	66
		Head of Procurement	11	40
		Head of Procurement	12	52
		PM production	13	54
		Point of Contact (POC) Procurement	14	96
		POC Procurement	15	96
		PM design system	16	57
		PM design system	17	57
		Product Manager	18	52
		PM, cost	19	69
		PM, operational excellence (OPEX)	20	68
Gamma	Design, product development and production of highly specialised systems for different platforms	Head of Procurement, interview 1	21	31
		Head of Procurement, interview 2	22	30
		Head PM, interview 1	23	72
		Head PM, interview 2	24	25
		POC Procurement	25	79
		PM design system	26	63
		Total	*26*	*1,538*

Online interviews were conducted, recorded, and transcribed verbatim. The transcripts were coded using Scrivener software, following a structured scheme that moved iteratively from first-order concepts (informant accounts) to second-order themes (integration dimensions) and then to aggregate SCI dimensions. Our analysis followed an abductive approach (Dubois and Gadde, 2002), moving iteratively between empirical data and existing SCI constructs. Specifically, while coding began at the level of informant accounts, we used the SCI dimensions as a sensitizing framework to guide how concepts were grouped and interpreted. In this sense, our approach reflects an adaptation of the Gioia methodology (Gioia *et al.*, 2013): we preserved the progression from informant terms to higher-order categories but did so within a theory-informed structure, allowing inductive insights to refine and extend the SCI-based coding frame. To evaluate internal and external structural and dynamic complexity (outlined in Table 4), procurement responses were coded on a high/medium/low scale based on interview data (bracketed in the table). The results were then compared across the three cases (Alpha, Beta, Gamma), enabling us to identify recurring patterns in procurement's mediating roles. Coding consensus was achieved through peer debriefing (e.g., Tables 3 and 4), consistent with O'Connor and Joffe (2020), who emphasise negotiated agreement as a reflexive means to ensure coding reliability and transparency. This negotiated consensus formed the basis for mapping the cases onto the complexity integration framework (Figure 2), illustrating how procurement's responses vary across different combinations of structural and dynamic complexity. Throughout the process, we remained reflexive, drawing on both insider and outsider perspectives to balance contextual depth and critical distance.

Results

This section presents within-case findings for Projects Alpha, Beta and Gamma. Then it turns to cross-case themes organised around the SCI-dimensions, maps them to the integration dimensions (2nd-order-themes) and responses to structural and dynamic complexity (1st-order-concepts), as reflected in Table 3.

Within-case findings

Project alpha. Project Alpha originated in early studies decades ago, with development and production starting about ten years ago [1]. It exhibits overlapping design, development and production phases, creating high dynamic complexity. Initially, knowledge gaps were addressed through intensive early integration with the customer. Because no comparable product had been built for decades, a near-complete restart of the supply chain was required, which comprised hundreds of sub-systems, making the technical scope structurally complex. The upstream supply chain mixes COTS-components with systems produced to DefCo drawings across a range of TRLs (from basic research to proven technology), and supplier systems undergo factory acceptance tests before delivery. The supplier base comprises approximately 1,000 suppliers, with several single-source items that limit leverage and increase risk.

Internal integration has become more formalised over time. Alpha embeds a procurement representative in cross-functional teams [2] and uses a group of procurement coordination managers to handle work coordination, supplier management, material planning, subcontracting and budget follow-up. Cross-functional sourcing is used to support prototype sourcing and make-or-buy choices, with coordinated reviews of early design options to inform cost and technology selection. Alpha applied design-to-cost. Later, some low-price selections increased total cost because new suppliers struggled to interpret demanding requirements. Alpha combines high structural and high dynamic complexity due to many interdependent systems and evolving requirements.

Supplier integration emphasises early involvement of ETO-experienced partners and balancing mature TRLs with areas needing lower-TRL development. Flexibility is key, as

Alpha must align multiple interdependent systems progressing at different speeds. As one respondent noted:

> Some suppliers are used to our flexible design process . . . while others, [accustomed] to off-the-shelf products, struggle with our strict validation and broad requirements. (3)

Integration is early and intensive for long-lead-time and selected major systems. Strong relationships and close follow-up are prioritised to ensure quality and lead times, despite the resource burden:

> Suppliers build specialized, expensive systems over several years . . . [yet] the value of close monitoring and continuous alignment is hard to quantify, though [being proactive] helps avoid future problems. (1)

Customer integration is exceptionally close. A mirrored organisation for system engineers and daily on-site customer personnel enabled joint decision-making on evolving technologies. Procurement and the customer collaborated weekly at the sub-system level. This iterative involvement helped manage obsolescence and technology change over long timelines.

Post-delivery, Alpha highlights operational readiness via proactive planning. Although current contracts omit maintenance, older products are covered by framework agreements for configuration management and annual service. Obsolescence management adds dynamic complexity: suppliers are expected to signal EOL, but notifications can be inconsistent.

Project beta. Project Beta started around the same time as Alpha and was developed for two customers who required slightly different end products. The project draws on roughly 100 COTS suppliers plus 20 drawing-based suppliers, combining proven items with developed solutions. Procurement was involved later in the process, indicating potential benefits from earlier cross-functional coordination with design. As one procurement manager noted:

> When we finally teamed up with engineering and challenged suppliers together, we achieved strong results, but doing so earlier would have saved costly redesigns. (11)

Internally, one coordinator mediates between the project and procurement [3]. Beta used design-to-cost; a product manager taught new design engineers, using the Kraljic matrix, how early decisions influence costs and sourcing flexibility [4]; aiming to avoid single-source components. As costs later rose, the procurement team challenged existing suppliers to meet new targets, illustrating the need to embed cost thinking from the concept phase to mitigate dynamic complexity.

Supplier integration is staged. Beta sought high-TRL solutions to reduce risk but sometimes adopted lower-TRL technologies to meet specific customer demands. Where cost pressures intensified, supplier strategies were revisited, including developing alternatives or switching suppliers (a response to structural complexity). Procurement prioritised lead time over price, with intensive follow-up to protect quality and delivery.

Customer integration followed a milestone-based pattern. In some systems, customers pre-defined certain suppliers; otherwise, procurement received customer needs via internal channels after contract award. The customers engaged in reviews, validation and trade-off decisions throughout development.

Project gamma. Gamma has been in development for nearly a decade [5], with ongoing component acquisition and an upcoming verification phase to meet standards before production. Production will be outsourced to a partner due to previous export requirements for local manufacturing, as some parts are manufactured in Sweden, and final assembly is conducted by the partner, adding to the structural complexity. Deliveries will be ongoing and in greater volumes than Alpha. The supplier base is small, around 20 suppliers, but it includes single-source items. In one instance, a single-source supplier prioritised a higher-volume customer, delaying Gamma and highlighting the dynamic complexity in capacity allocation.

Internally, Gamma uses a single mediator to link project and procurement:

> Procurement is divided into operational, strategic, and quality roles, with a Point of Contact (PoC) representing procurement in projects. The PoC . . . [tracks] material supply, [communicates] delays, [aligns] with programme management, and [coordinates] with commodity groups. (21)

Rather than design-to-cost, the programme prioritised time and functionality, and production teams were given stronger authority over cost-related decisions to align design and manufacturability better. Although a procurement manager noted that an improvement would be to have a checkpoint already during the design phase.

Early supplier involvement was crucial for managing long lead-time items, and procurement coordinated closely with engineering to secure components ahead of verification. Although the customer had no direct role in sourcing decisions, they influenced component selection for safety-critical systems. Procurement navigated these inputs while maintaining supplier alignment and flexibility. Given the small scale and custom nature of the project, securing supplier commitment required proactive relationship management and an understanding of ETO-specific demands. The procurement team focused less on cost and more on lead time, quality, and adaptability, key elements in managing dynamic complexity in Gamma.

> In delayed projects, technical completion takes priority over cost . . . [we] seek suppliers who deliver on time and [ensure] nothing less than perfect is accepted. (25)

Customer integration is managed through integrated project teams that keep the customer informed of progress. The customer did not participate directly in sourcing decisions, although they influenced component choices where safety implications were significant. Deliveries will be ongoing, with Gamma produced in greater volumes than Alpha.

Cross-case themes: procurement responses across SCI dimensions

All three projects adapted to complex procurement environments in different ways. Alpha managed extensive structural complexity, requiring intensive integration with customers and suppliers. Beta balanced dual-customer needs with cost control. Gamma prioritised time and functionality over cost, relying on selective customer input and a smaller supplier base. These differences shaped distinct procurement logics across the SCI dimensions. The analysis below is organised around the integration dimensions in Table 3.

Internal integration. Procurement mediation roles differ slightly. Alpha employs multiple project mediators to coordinate sub-projects, align material flows, and link with engineering and supplier quality – a routine-driven model. Beta and Gamma instead use a single point-of-contact connecting buyers to commodity and programme leads – broader but lighter. All three emphasize hybrid profiles and rotation to embed engineering and project skills in procurement. Cross-functional collaboration is central: Alpha promotes integration through procurement teams and tollgate governance; Beta via category teams aligning technology roadmaps; and Gamma through joint meetings and shared plans following early fragmentation. *Cost-consciousness design* takes distinct forms. Alpha's design-to-cost approach highlights that the cheapest option can raise total costs through supplier and internal inefficiencies. Beta embeds cost thinking in design reviews and uses Kraljic logic to prevent single-sourcing. Gamma prioritizes functionality and speed. In managing *obsolescence*, Alpha is most process-oriented, front-loading visibility on long-lead items and mediating between integrated logistics, procurement, and engineering to handle lifecycle guarantees. Beta addresses obsolescence episodically through last-time buys during delays.

Supplier integration. Early supplier involvement is central but context-specific. Alpha engages suppliers on critical or immature technologies and long-lead systems, sometimes sole-source, to co-define requirements and risks before standard procurement. Beta typically involves supplier's post-customer award, focusing on prototypes and lead-time compression, while Gamma engages them in bids and early development to assess capabilities and requirement impacts, vital for low-volume custom work. *Supplier capabilities alignment* diverge: Alpha matches high-TRL predictability with ETO-experienced partners, Beta

Table 3. Summary of procurement's mediating role in SCI

SCI dimensions (aggregate dimensions)	Integration dimensions (2nd order themes)	Responses to structural: (S) and dynamic (D) complexity identified in the data (1st order concepts) Alpha	Beta	Gamma
Internal integration	Procurement mediation roles	*S:* Procurement project leaders act as the hub between purchasing, engineering and production, participating in sub-projects, monitoring quality and material needs, and aligning flows of hundreds of thousands of components (2) Job rotation brings engineering/project experience into procurement (2; 8). How to optimise procurement coordination roles requiring broad supplier/market/product knowledge despite difficulties in recruiting experienced individuals (1; 2) *D:* N/A	*S:* The project/product sourcing manager oversees sourcing activities for a product or project, ensuring contracts, compliance, costing, and strategy, while acting as a link between engineering and strategic procurement, without direct supplier ownership (14). Close procurement–engineering collaboration, including role rotation, aligns performance goals with sourcing choices for better decisions (9) *D:* N/A	*S:* The procurement Point of Contact lead offset buys, evaluate tenders and supply chain risks, drive make-or-buy decisions, and ensure customer requirements are incorporated into supplier contracts (25). It requires broad supplier/market/product knowledge, and it is hard to recruit experienced individuals (25)
	Cross-functional orientation	*S:* Promote cross-functional mindsets (1; 2); break down functional silos and create forums to align strategies and roadmaps (1, 2, 6); Enhance supplier interfaces to reduce functional silos and foster holistic engagement (4); The procurement team includes a systems engineer, a buyer, and a Supplier Quality Manager (SQM). The engineer defines specs, procurement manages commercial terms, and the SQM ensures quality (2) *D:* N/A	*S:* Promote cross-functional mindsets (11); Align technology roadmaps across functions to ensure shared direction/priorities (12); Procurement should lead cross-functional category work, aligning sourcing and engineering on future technologies outside projects (11). Enhance supplier interfaces to reduce functional silos and foster holistic engagement (11; 12) *D:* N/A	*S:* Break down functional silos and create forums to align strategies and roadmaps (21); enhance supplier interfaces to reduce functional silos and foster holistic engagement (25) *D:* N/A
	Cost-conscious design	*S:* *D:* Attempt design to cost with cross-functional sourcing; initial low-price picks raised total cost later (3)	*S:* Improve manufacturing cost efficiency through cross-functional integration (18; 19) *D:* Freeze/change designs or educate engineers to expand sourcing options. (12, 18, 19)	*S:* N/A *D:* N/A
	Organisational routines	*S:* N/A *D:* Early visibility of long-lead-time items (3, 5). Sourcing long-lead-time items before final specifications are released (2; 3; 5); align with engineering on "first-time right" to avoid engineering changes (2)	*S:* N/A *D:* N/A	*S:* N/A *D:* N/A
	Obsolescence management	*S:* Mediate between ILS, procurement, and engineering to ensure a clear internal interface (5) *D:* Coordinate component support until implementation or delivery (8) and communicate contractual requirements for functionality and guarantees during development and production (8)	*S:* N/A *D:* During product development and production: communicating contractual requirements on components and systems for functionality maintenance and guarantees (8; 14). When contracts lapse due to delays, last-time buys or extensions are required (14)	*S:* N/A *D:* N/A

(*continued*)

Table 3. Continued

SCI dimensions (aggregate dimensions)	Integration dimensions (2nd order themes)	Responses to structural: (S) and dynamic (D) complexity identified in the data (1st order concepts) Alpha	Beta	Gamma
External (supplier integration)	Early supplier involvement	*S:* With immature technologies (3; 6), standard procurement fails; mitigate by forming selected sole-source partnerships on critical systems and co-develop requirements, align capabilities, and reduce risk (1) *D:* Involve suppliers early in requirements definition and offer phases to manage long lead-time items changes and secure cost inputs before award (1; 2)	*S:* Post-award supplier integration focused on prototypes and lead-time compression; involvement is early in the execute phase, not pre-award (11) *D:* Engage with suppliers using a sales-oriented procurement mindset to secure commitment, prepare for change and align expectations (11). Important that the suppliers are transparent about design changes (11)	*S:* Improve manufacturability and time-to-market (22, 25); secure supplier commitment for complex, low-volume custom orders (25); lock long-term sole-source contracts to lift margins (25) *D:* Involve suppliers early in market and bid phases to assess capabilities, analyse evolving customer requirement impacts, coordinate quotations, and evaluate supply chain risks (25)
	Supplier capabilities alignment	*S:* Favouring high-TRL suppliers for predictability and low-TRL ones for ETO adaptability (6). Partner with ETO-experienced suppliers for custom needs (3) *D:* N/A	*S:* When suppliers can't meet our performance expectations, we work with engineering to redesign them out, though doing this from the start would avoid costly redesigns. (11) *D:* N/A	*S:* Source from suppliers who design to functional specs and clearly disclose solution and system impacts (26) *D:* N/A
	Supplier lock-in	*S:* N/A *D:* Short system lifespans make end-of-life challenging (8); early notification compliance is inconsistent, especially for low-volume suppliers where influence is limited (15). Establish EOL management and supplier agreements to manage long-lead times and strengthen long-term commitment (4, 6)	*S:* Design for manufacturing and assembly without overly complex parts that can result in supplier lock-in; focus on components that allow for a variety of sourcing/supplier options (15) *D:* N/A	*S* Single-source exposure in low-volume custom parts (25) *D:* Capacity re-allocation delays; build buffers/second sources (23)
	Supplier relationship management	*S:* Supplier Follow up Benefits: embed cross-functional teams at supplier sites to clarify expectations, catch quality issues early and *avoid costly late-stage* (3); balance resources for on-site visits to boost quality and shorten lead times (3) *D:* Maintain robust partnerships through delivery, commissioning, verification, and training to sustain engagement (3). Bundle volume and adopt a long-term focus to drive mutual gains (2). Manage unexpected supplier issues (6)	*S:* Supplier Follow up Benefits (13; 16): embed cross-functional teams at supplier sites to clarify expectations and improve suppliers' visibility into how their parts are used – leading to higher motivation and efficiency gains (13); balance resources for on-site visits to boost quality and shorten lead times (16) *D:* Maintain robust partnerships for change (11, 16), Manage unexpected supplier issues (15)	*S:* Continuous monitoring of major suppliers and periodic checks on smaller ones (25) *D:* Maintain robust partnerships (25). Expecting suppliers to be transparent about their development maturity and any emerging issues, enabling early intervention and keep the development on track (26)

(*continued*)

Table 3. Continued

SCI dimensions (aggregate dimensions)	Integration dimensions (2nd order themes)	Responses to structural: (S) and dynamic (D) complexity identified in the data (1st order concepts)		
		Alpha	Beta	Gamma
External (customer integration)	Customer influence on sourcing	*S:* Procurement balances customer interests with best practices (1; 2; 8), allows client choice, and stays transparent on options (1), while considering strong historical supplier relationships (1) *D:* Weekly subsystem reviews; iterative joint trade-offs	*S:* Certain system suppliers were pre-defined (14) *D:* N/A	*S:* N/A *D:* N/A
	Organisational learning	*S:* Success depends on optimising knowledge transfer with customers (3). Customer-mirroring organisations facilitate technology transfer and improve alignment and communication (3; 4; 5) *D:* Technical alignment via milestones, and formal checkpoints, ensures consistency in technical decision changes (8)	*S:* N/A *D:* Technical alignment via milestones, and formal checkpoints, ensures consistency in technical decision changes (17)	*S:* N/A *D:* Integrated project teams monthly with the customer that are involved in discussions on components and system security changes (23)
	Requirement-driven system adaptation	*S:* N/A *D:* Integrating customer choices into existing systems, so technical solutions evolve throughout the development process (5). Overall, it's essential to align and adapt to customer needs and shifting market conditions (3; 5; 8)	*S:* N/A *D:* Manage scope creep through structured processes to prevent delays, cost overruns, and contractual issues, balancing trade-offs between original requirements, timelines, and system capabilities (9)	*S:* N/A *D:* Manage changing customer requirements and evolving supply chain risks during market and bid phases (25)
	Lifecycle continuity	*S:* Establish a formal obsolescence data process, approaching suppliers with structured inquiries (1–8). *D:* Use an obsolescence plan and include lifecycle obligations in contracts. Align with customers on trade-offs to maintain continuity across long product lifecycles (7; 8) *D:* N/A	*S:* N/A *D:* N/A	*S:* N/A *D:* N/A

redesigns out and replaces underperformers, and Gamma favours partners designing to functional specs with transparent system impact. *Supplier lock-in* risks exist across cases: Alpha faces it when only one supplier can deliver required parts, mitigating through EOL agreements and obsolescence management; Beta's design specified a patented component, which restricted supplier choice even though functional alternatives existed; Gamma relied on single source-suppliers, making strong contracts vital as switching at critical stages proved slow and costly. *Supplier relationship management* varied: Alpha stays very close with proactive follow-up. Beta ensures visibility into use contexts to motivate performance, and Gamma monitors suppliers continuously for transparency and early interventions.

Customer integration. Customer influence on sourcing ranges from continuous to selective. In Alpha's case, the customer was deeply involved in projects and participated in sourcing decisions. Beta's customers participate at milestones and sometimes pre-define suppliers. Gamma keeps customers informed via integrated project teams but typically not in supplier choice, except where system safety is affected. Across cases, procurement mediates capability demands with cost, risk, and supply options. *Organisational learning* and requirement adaptation also differ. Alpha's mirrored structure aids technology transfer and iterative requirement refinement across long developments; Beta uses formal checkpoints to manage scope change; Gamma's monthly integrated teams surface risks and safety-critical component choices. *Lifecycle continuity* was evident in Alpha's processes (obsolescence management, advocacy for lifecycle obligations).

Discussion

Internal complexity and integration (structural and dynamic-internal debates)

Prior research establishes internal integration as a precursor to external integration, enhancing knowledge sharing, process alignment, and production flexibility (Ataseven and Nair, 2017; Flynn *et al.*, 2010). This study reveals a more complex bidirectional relationship in project-based environments. Our findings demonstrate that external customer and supplier integration can actively drive internal alignment, a dynamic that is less emphasised in existing literature. The Alpha case exemplifies how customer involvement shapes internal integration mechanisms and supply chain alignment, enabling procurement and production planning to respond to project-specific needs. Literature has primarily examined the role of procurement from an organisational structure perspective, emphasising formal roles, defined processes, and contractual mechanisms (cf. Pagell, 2004; Wynstra *et al.*, 2003). This study, however, underscores the need to reconceptualise procurement as a dynamic actor within long-term, complex development projects. Rather than operating within predefined boundaries, procurement mediators must continuously navigate shifting project goals, evolving design choices, and emerging technology landscapes. This mediating role requires, for example, proactive engagement in cross-functional forums for technology road mapping (cf. Bhalla *et al.*, 2022; Romero Rojo *et al.*, 2010), adaptive coordination beyond initial project constraints, and strategic anticipation of supplier relationships (Hicks *et al.*, 2000).

Supplier complexity and integration

The analysis of procurement responses to external complexity, both dynamic and structural, indicates that it is important to consider adaptations and changes over time to support ETO-project completion, while also addressing cost concerns associated with structural factors. This raises several debates. Early sourcing of long-lead-time items, including customised parts, was crucial due to extended supplier development times. Consistent with Strandhagen *et al.* (2018), findings confirm that early ordering often occurs during the sales and preliminary specification process. However, this study adds nuance: such orders were often placed on a risk basis even before design was finalised, reflecting dynamic complexity. While procurement is typically associated with cost savings (cf. Murfield *et al.*, 2021), the findings align with those of Leuschner *et al.* (2013), who observed no direct relationship between integration and cost savings, as higher integration often leads to increased coordination costs. This suggests that quality, lead-time, and specification fulfilment precede cost considerations (de Araújo *et al.*, 2017; Kjersem and Giskeødegård, 2020), a dynamic complexity concern. Therefore, flexible, project-centric procurement structures are critical for ETO success, prioritising capability over cost (Gosling *et al.*, 2020; Moretto *et al.*, 2022).

ESI enhances ETO success by managing both dynamic and structural complexity through technical alignment, risk mitigation, and strategic sourcing. ESI provides early feedback and cost visibility, helping align expectations with feasibility (Cohee *et al.*, 2018). Procurement-design collaboration ensures suppliers meet evolving cost and quality demands (Hicks *et al.*, 2000; Reitsma *et al.*, 2023). Dynamic complexity emerges in obsolescence management, requiring choices between last-time buys and switching suppliers (Romero Rojo *et al.*, 2010). Single sourcing can reduce structural complexity but also limit the flexibility, especially under defence-related restrictions (Petersen *et al.*, 2005).

Customer complexity and integration

Unlike Dixit *et al.* (2019), who emphasised early customer involvement, this study highlights the importance of continuous customer engagement. This approach enabled frequent trade-offs between lead-time and functionality, ensuring prioritisation aligned with evolving customer requirements. As shown in the findings, continuous customer integration contrasts with milestone-based approaches in other projects by allowing real-time adjustments to functionalities while managing shifts in lead-time. This highlights the importance of treating the customer as a co-creator of value (Dixit *et al.*, 2019), particularly in high-dynamic complexity environments. This emphasises the case for expanding the traditional perceived boundaries of procurement beyond initial tendering and contracting, and for close and continual engagement with the customer.

Customer integration in Alpha extended beyond planning and into procurement and sub-projects. Customers provided knowledge that DefCo lacked, participated in supplier visits, and influenced sourcing decisions. This involvement helped manage complexity while presenting trade-offs between meeting customer preferences and leveraging industry expertise (Shurrab *et al*., 2022). The mirrored organisational structure for central engineering systems further facilitated knowledge transfer. This nuances the findings of Shurrab *et al.* (2022), showing that customer involvement in procurement can itself serve as a mechanism for managing complexity, albeit with new trade-offs.

Our research also highlights the challenges of setting accurate delivery dates in ETO environments due to long and variable lead-times, overlapping phases, product complexity, and uncertain capacity requirements, which is a central theme in ETO research (Cannas and Gosling, 2021; Gosling and Naim, 2009). The empirical findings show the dynamic and structural complexity factors that contribute to this, but also potential integration responses.

Responses to ETO complexity. Table 4 outlines a comparison between the cases and reveals differences in complexity. Alpha faces the highest structural and dynamic complexity, characterized by strong early supplier and customer involvement, proactive obsolescence management, high organisational learning, and deeply embedded routines that handle complexity through integration and ownership. Beta shows medium complexity, relying on structured processes, staged supplier involvement, checkpoint-based management, and scope control to balance flexibility with control. Gamma, by contrast, experiences lower structural complexity due to limited customer influence but faces higher dynamic complexity, as it depends more on suppliers, milestone-based integration, and continuous adaptation, which introduces greater risks of change and reallocation delays.

Table 4. Case evaluation

Procurement responses	Alpha	Beta	Gamma
Structural complexity			
Internal			
Procurement mediation roles	High (several mediators)	Medium (single mediator)	Medium (single mediator)
Cross-functional orientation	High (defined forums and roles)	Medium (lighter forums)	Medium (lighter forums)
Cost-conscious design	N/A	High (education/ checkpoints)	N/A
Obsolescence management	High (proactive ownership)	N/A	N/A
External supplier			

(*continued*)

Table 4. Continued

Procurement responses	Alpha	Beta	Gamma
Early supplier involvement	High (early long lead)	Medium (procurement joins later)	High (early verification)
Supplier capabilities alignment	High (various TRL-levels)	High (re-design to fit alternative suppliers)	Medium (fit to specifications)
Supplier lock-in	Medium (single source exposure)	Medium (limited options)	High (single source delay)
Supplier relationship management	High (embedded follow up)	Medium (issue follow up)	Medium (monitor and share)
External customer			
Customer influence on sourcing	High (sourcing trade-offs)	Medium (some predefined suppliers)	Low (indirect input via safety critical component choices)
Organisational learning	High (education and participation in sub-projects)	Medium (teaching new engineers Kraljic's matrix)	N/A
Lifecycle continuity	High (obsolescence plan)	N/A	N/A
Dynamic complexity			
Internal			
Cost-conscious design	Medium (applied yet limited)	High (steer change and educate)	N/A
Organisational routines	High (first time-right)	N/A	N/A
Obsolescence management	High (support and guarantees)	Medium (contract clarity)	N/A
External supplier			
Early supplier involvement	High (early for selected major systems)	Medium (staged involvement)	High (early key systems)
Supplier relationship management	High (on site follow up and continuous alignment)	Medium (follow up to protect quality and delivery)	Medium (continuous alignment during development)
Supplier lock-in	Medium (EOL exposure)	N/A	High (capacity reallocation delay)
Lifecycle continuity	High (active EOL coordination)	N/A	N/A
External customer			
Customer influence on sourcing	High (customer influence sourcing decisions)	N/A	N/A
Organisational learning	High (continuous alignment)	Medium (milestone based)	Medium (milestone based)
Requirement driven system adaptation	High (tech integration)	Medium (scope control)	Medium (manage change and risk)

The findings suggest that procurement in ETO environments requires not only effective integration but also an ability to tailor responses based on the type of complexity encountered. Overall, in structural complexity settings, the focus is on coordination, alignment, cost, supplier relationships, capabilities and life cycle management. Further, in dynamic complexity settings, the focus is on sourcing flexibility, adaptability, strategic partnerships and ongoing learning across supplier and customer interfaces. Table 5 summarises procurement activities in the integration dimensions and the two types of complexity – structural and dynamic.

Table 5. Procurement response activities to structural and dynamic complexities

Complexity types	Structural	Dynamic
Internal integration	*Procurement Mediation Roles* Optimize coordination roles (1; 2; 25); job rotation forums (2; 8; 9). Project/product sourcing manager dedicated to specific projects (11; 14) *Cross-Functional Orientation* Promote cross-functional mindsets and forums to align roadmaps and reduce silos across procurement, engineering, and suppliers (1; 2; 4; 6; 11; 12; 21; 25) *Cost-Conscious Design* Cost checkpoints (14); early cost alignment (18; 19; 20) *Obsolescence Management* Internal interface mediation (5)	*Organisational Routines* Early long lead-time visibility (2; 3; 5); first-time-right alignment (2) *Cost-Conscious Design* Educate for sourcing flexibility (18) *Obsolescence Management* Ensure component support through implementation and enforce lifecycle guarantees (8, 14)
External integration	*Early Supplier Involvement* Secures materials; 21 – aligns with needs; 22; 25) also: seamless integration (9; 13); overcoming reluctance (11; 23; 24; 25); single-source contracts (25) *Supplier Capabilities Alignment* Co-develop with low-TRL suppliers; evaluate capability fit early (1; 3; 6; 9; 14) *Supplier Lock-in* Design for manufacturability without overly complex parts, to allow multiple sourcing options (15) *Supplier Relationship Management* On site follow up (3; 13; 16); monitor key suppliers regularly (25) *Customer Influence on Sourcing* Balance customer requirements vs best practice (1; 2; 8) *Organisational Learning* Customer mirroring organisation to support knowledge flow and alignment (3; 4; 5) *Lifecycle Continuity* Establish a formal obsolescence-data process; constrain last time-buy alternatives (1–8, 15)	*Early Supplier Involvement* Partner ETO-experienced (3); sales-oriented mindset (11); mitigate late specs (12); secure pricing early to offset delay risks (25) *Supplier Relationship Management* Sourcing strategy and planning (3; 13; 16; 25), robust partnerships (3; 11; 16) *Requirement-Driven System Adaptation* Evolving tech integration (5); managing scope-creep (3; 5; 8; 9) *Organisational Learning* Technical alignment via review milestones (8, 17) and integrated project teams (23) *Lifecycle Continuity* Include lifecycle obligations in initial customer contracts and align on trade-offs (7, 8)

Across internal integration and structural dynamics settings, procurement supports integration through procurement mediation roles embedded in projects, as well as cross-functional alignment mechanisms to manage technical interdependencies and ensure integration. Further, procurement supports integration through cost control and cost alignment early in the project, as well as acting as an internal interface mediator. Across internal integration and dynamic complexity settings, procurement enables responsiveness through cost-conscious design practices, early visibility of long lead-time items, obsolescence management through lifecycle guarantees and iterative coordination routines. External integration and structural dynamics rely on early supplier involvement, supplier capability alignment, and formal lifecycle continuity processes to handle long lead-times and complex supplier interfaces. Also, including customer mirroring the organization to support the flow of knowledge and enhance alignment. In external integration and dynamic complexity contexts, procurement adopts adaptive relationship management, requirement-driven system adaptation, and joint end-of-life planning to address evolving specifications. For example, Alpha, facing high structural and dynamic complexity with ∼1,000 suppliers and evolving requirements, embedded procurement mediators, on site customer participation, and formalised obsolescence management; Beta, with moderate complexity (≈120 suppliers), relied on a single procurement sourcing manager and milestone-based integration with design to cost controls; and Gamma, characterized by low structural but higher dynamic complexity, prioritised functionality and schedule over cost through stockpiling and contractual end-of-life protections.

In Figure 2, we position the studied projects within the structural and dynamic complexity framework. This framework distinguishes between four internal and four external integration logics based on inherent complexity. Each of these complexity configurations demand a tailored procurement response. The core characteristics of complexity and descriptors of procurement responses are included in the framework. Alpha indicates high structural and dynamic complexity, internally and externally, whereas Beta, exhibits moderate complexity on both dimensions, and Gamma lies toward the low–low end internally, while exhibiting intermediate complexity externally. Thus, procurement's integration role depends on the combination of structural and dynamic complexity, internally and externally. This aligns with prior conceptualisations that structural complexity is caused by the scope and interdependence of system elements, e.g. numerous components, large supply network, dense interfaces, whereas dynamic complexity is a result of uncertainty and frequent changes in requirements (Baccarini, 1996; Choi and Krause, 2006; Tatikonda and Rosenthal, 2000).

Internal complexity. Across different internal-structural complexities, based on the number of interdependent parts and processes (Baccarini, 1996; Bozarth *et al.*, 2009), the ETO-project reinforces stability by clarifying roles, instituting cross-functional coordination forums, and establishing cost-control and obsolescence management routines. To address internal structural complexity, Alpha embedded procurement into engineering early and clearly defined its role within project teams (Dowlatshahi, 1992; Reitsma *et al.*, 2023). Beta used a lighter model with a single procurement coordinator mediating across functions, while Gamma relied on minimal internal integration, locking the scope early and reducing the need for heavy procurement involvement (cf. Moretto *et al.*, 2022). Under internal-dynamic complexity, where requirements and designs are changing, procurement's role becomes more agile and adaptive (Azadegan *et al.*, 2013; Maylor and Turner, 2017).

The emphasis is on rapid learning and flexibility: providing early visibility of long lead-time items (Guy and Dale, 1993; Petersen *et al.*, 2005), safeguarding schedules through change-management (Iakymenko *et al.*, 2022) and giving design teams leeway to adjust without losing control. Alpha illustrates this logic with frequent adjustments to evolving requirements, while Beta combined agility with cost management (design-to-cost) to maintain alignment under moderate uncertainty. Gamma, facing relatively fewer internal changes, only selectively engaged in adaptive practices, keeping internal processes lean. This dynamic internal integration logic reflects the need to manage uncertainty through responsiveness (Choi and Krause, 2006; Tatikonda and Rosenthal, 2000), ensuring that procurement can accommodate evolving project needs internally.

External complexity. Under external–structural complexity, with a broad supplier base and technically complex system deliveries (Birkie and Trucco, 2016; Williams, 1999); procurement prioritizes formal and long-term integration measures. Key responses include securing early-supplier-involvement to lock-in critical components (Strandhagen *et al.*, 2018), aligning supplier capabilities with technical requirements (Hicks *et al.*, 2000; Reitsma *et al.*, 2023), and implementing lifecycle continuity planning to mitigate risks like supplier lock-in or component obsolescence (Howard and Miemczyk, 2010; Romero Rojo *et al.*, 2010). Alpha again represents the high–high case, anchoring supplier relationships early and proactively managing obsolescence. Beta applied similar measures but in a moderated form, balancing capability alignment and staged supplier involvement (Cannas and Gosling, 2021). Gamma, although smaller in scale, still had to secure continuity from a handful of single-source

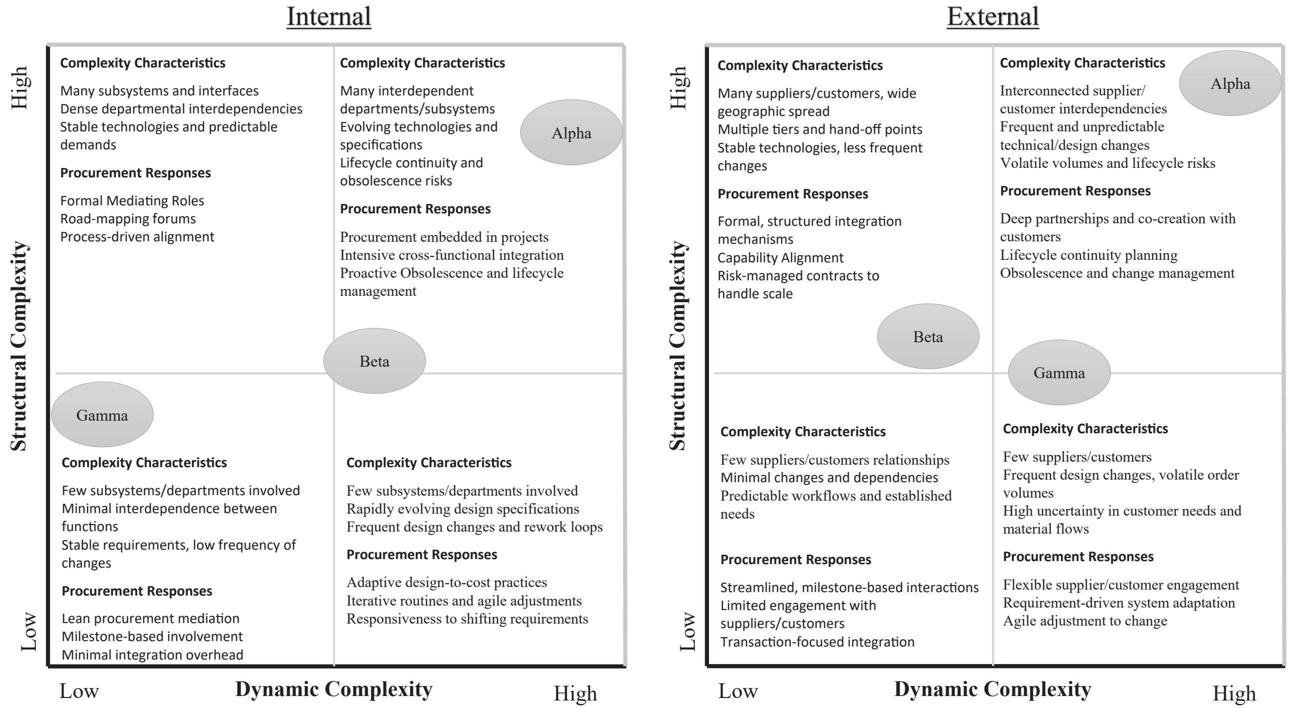

Figure 2. Structural and dynamic complexity framework

suppliers, illustrating how even low-structural-complexity projects require formal measures to avoid supply risk (Petersen *et al.*, 2005).

On the other hand, external–dynamic complexity calls for more fluid integration. When external conditions are volatile, e.g. changing customer requirements or supply uncertainties, procurement leans on adaptive relationship management (cf. Laari *et al.*, 2023; Picaud-Bello *et al.*, 2022). In these contexts, integration is maintained through frequent supplier–customer communication, staged and intensive involvement at key milestones (Bhalla *et al.*, 2022), and flexible contracting arrangements to accommodate shifting requirements. Alpha managed such volatility by embedding procurement closely with both suppliers and customers, enabling frequent interaction (Dixit *et al.*, 2019). Beta used milestone-based reviews and stage-gated supplier involvement to balance structure and adaptability (Munir *et al.*, 2020). Gamma, positioned closer to the intersection on the external side, relied heavily on adaptive relationships: frequent dialogue with suppliers, flexible contracts, and iterative adjustments to delivery schedules and specifications.

Procurement responses to complexities in ETO. Crucially, these cases demonstrate that procurement must balance trade-offs and sequence integration responses as complexity unfolds (Maylor and Turner, 2017; Moretto *et al.*, 2022). With finite time and resources, firms cannot maximally integrate on all fronts at once; procurement therefore assesses where integration efforts will have the greatest payoff given the project's dominant complexity at each phase (Baccarini, 1996). For example, Gamma's strategy of deferring intensive internal integration until after scope freeze and then ramping up external collaboration is a deliberate sequencing to match its complexity profile. Beta's concurrent but moderate internal/external integration reflects a trade-off to avoid over-commitment in either domain (Cannas and Gosling, 2021).

In practice, procurement should therefore play a continual mediating role sensing shifts in complexity and re-calibrating the integration approach accordingly (Laari *et al.*, 2023). As requirements evolve or uncertainties are resolved, a project may transition between quadrants of the framework (e.g. from moderate toward higher complexity), prompting procurement to adjust its tactics and re-evaluate over time. This dynamic capability to reposition integration focus is pivotal in ETO environments (Tatikonda and Rosenthal, 2000), ensuring that procurement's efforts remain focused without overextending into unnecessary integration. Overall, the framework highlights procurement as a central mediator that enables hybrid integration configurations tailored to each project's complexity demands; reinforcing internal stability where needed, fostering external agility where possible, and balancing both to navigate the structural and dynamic challenges at hand.

Conclusion

The purpose was to examine procurement responses to varying complexities in ETO defence, asking: *How can procurement respond to the integration of ETO supply chains across different types and levels of complexity?* Complexity was conceptualised through definitions of dynamic, structural, internal, and external complexity, combined with a synthesis of SCI factors relevant to ETO defence. Procurement responses under different complexity combinations were proposed within a final framework to analyse their interplay.

This study provides insights into procurement's role in defence ETO-projects by integrating ETO complexity, SCI, and procurement literature. Bridging these areas advances understanding of procurement's mediating role in ETO defence. While prior research has acknowledged procurement's importance (Moretto *et al.*, 2022), few studies have positioned it as a response to ETO-project complexity in achieving SCI (Cannas and Gosling, 2021). The interplay between SCI-dimensions, complexity characteristics, and procurement responses is shown in Figure 2.

Theoretical implications

We argue that complexity provides a basis for balancing integration efforts in procurement. Moving beyond the notion that increased integration is always better (cf. Frohlich and Westbrook, 2001; Ataseven and Nair, 2017), the findings suggest that procurement can be deliberately sequenced and prioritised for specific integration efforts depending on the balance and level of structural and dynamic complexity. Consequently, since managing complexity consumes significant costs, resources, time, and effort, it is essential to distinguish between these two forms. Structural complexity, such as the number of components and suppliers, remains a core theme in the SCI ETO literature, while dynamic complexity, which requires adaptation to technical and process changes over time (cf. Iakymenko *et al.*, 2022), extends beyond traditional integration concepts. In this way, procurement is not only a facilitator but also a mediator of trade-offs, aligning scarce resources with the project's complexity profile.

Adding nuance to Dixit *et al.* (2019), we challenge the role of procurement as only an early-stage integrator, arguing instead for continued engagement throughout the project to mediate, facilitate, and integrate. We highlight that SCI must be continuously addressed not only upstream with suppliers but also downstream with customers, to achieve integration, an aspect less developed in prior ETO research (Cannas and Gosling, 2021). This contrasts with earlier, more limited views of procurement's role in ETO-projects (cf. Moretto *et al.*, 2022), underscoring procurement's strategic influence on project outcomes. Similarly, while Ataseven and Nair (2017) argue that internal precedes external integration, our findings contrast with this linear view, showing instead that external customer and supplier engagement can trigger and reinforce internal integration. Finally, we extend contributions on obsolescence management (Howard and Miemczyk, 2010; Romero Rojo *et al.*, 2010) by showing how procurement mediates lifecycle continuity as part of dynamic responses.

Managerial implications

For managers in ETO environments such as project, design and procurement, the findings show that complexity can serve as a decision criterion for sequencing and balancing integration. Rather than pursuing maximal integration, managers should assess whether structural or dynamic complexities dominate in different phases and allocate resources accordingly. When structural complexity is high, formal role optimisation, supplier alignment, and lifecycle planning should be prioritised. Conversely, when dynamic complexity prevails, adaptive routines, flexible contracting and close customer–supplier dialogue are critical.

Based on the findings, we would encourage practitioners to firstly, ensure procurement and delivery teams remain closely linked to respond to changing integration needs over time. The tables and figures can be used at the project level as templates to guide collaborative, integrated planning meetings, as well as joint workshops. At a more aggregated level, they may be used proactively to help integrate teams in technology road mapping exercises with the inclusion of procurement professionals. Second, we emphasise the importance of understanding the mediating role of procurement within the overall management, and the critical role of customer engagement and involvement. Third, we propose a proactive, systematic and holistic view of complexity to analyse its impact and focus integration efforts. Tables 4 and 5 offer templates to consider procurement's mediating role, and Figure 2 offers a structure for reflecting on appropriate internal and external responses to various complexities.

Limitations and further studies

This study is constrained by its single-case focus on defence-sector ETO projects within DefCo, a setting marked by high technical complexity, strict regulation and pronounced risk sensitivity (Gosling and Naim, 2009). While this context provides valuable insights into procurement integration under conditions of structural and dynamic complexity (Williams, 1999), its empirical generalisability to other industries remains underexplored. In sectors such as construction, shipbuilding, energy or IT, procurement may follow distinct logics, calling for cross-sectoral research to identify which integration mechanisms are context-specific and which hold more universal relevance. Future studies could therefore pursue comparative, cross-industry designs to validate and extend the framework, while longitudinal approaches would capture how procurement practices and their effects evolve across project life-cycles. Such research would not only strengthen external validity but also advance theoretical understanding of procurement's role in managing various levels of complexity within ETO supply chains.

The development of defence supply chains that can deliver at speed and scale is a societal undertaking. This study highlights the need for a research agenda focused on procurement's role in building robust defence supply chains. A central theme is how procurement can orchestrate SCI under conditions of structural and dynamic complexity (Maylor and Turner, 2017). Future studies should explore how procurement simultaneously aligns internal processes, multi-tier supplier networks, and international collaborations, particularly in cross-border initiatives such as those supported by the EU or NATO (Caldwell *et al.*, 2009). Research is also needed on the inclusion of SMEs and of firms offering dual-use products, which remain underexplored despite their potential to extend capacity and innovation. Another important strand concerns resilience. Modern supply networks operate as adaptive systems where disruptions propagate rapidly (Choi *et al.*, 2001), demanding procurement-led approaches that extend beyond conventional risk management. Further studies are required to investigate how procurement can balance speed, scalability, and sovereignty while enabling resilient integration in defence ETO contexts.

Notes

1. Internal document – Project Description Alpha.
2. Internal document – Role and process description.
3. Internal document – process description.
4. Internal document – product profitability/design-to-cost
5. Internal document; project description.

References

Adrodegari, F., Bacchetti, A., Pinto, R., Pirola, F. and Zanardini, M. (2015), "Engineer-to-order (ETO) production planning and control: an empirical framework for machinery-building companies", *Production Planning and Control*, Vol. 26 No. 11, pp. 910-932, doi: 10.1080/09537287.2014.1001808.

Agyei-Owusu, B., Asamoah, D., Nuertey, D. and Acquah, I.N. (2022), "Examining the relationship between dimensions of supply chain integration, operational performance and firm performance: evidence from Ghana", *Management Research Review*, Vol. 45 No. 12, pp. 1644-1669, doi: 10.1108/mrr-06-2021-0464.

Alfnes, E., Gosling, J., Naim, M. and Dreyer, H.C. (2021), "Exploring systemic factors creating uncertainty in complex engineer-to-order supply chains: case studies from Norwegian shipbuilding first tier suppliers", *International Journal of Production Economics*, Vol. 240, 108211, doi: 10.1016/j.ijpe.2021.108211.

Ataseven, C. and Nair, A. (2017), "Assessment of supply chain integration and performance relationships: a meta-analytic investigation of the literature", *International Journal of Production Economics*, Vol. 185, pp. 252-265, doi: 10.1016/j.ijpe.2017.01.007.

Azadegan, A., Patel, P.C., Zangoueinezhad, A. and Linderman, K. (2013), "The effect of environmental complexity and environmental dynamism on lean practices", *Journal of Operations Management*, Vol. 31 No. 4, pp. 193-212, doi: 10.1016/j.jom.2012.12.003.

Baccarini, D. (1996), "The concept of project complexity–a review", *International Journal of Project Management*, Vol. 14 No. 4, pp. 201-204, doi: 10.1016/0263-7863(95)00093-3.

Bäckstrand, J. and Fredriksson, A. (2022), "The role of supplier information availability for construction supply chain performance", *Production Planning and Control*, Vol. 33 Nos 9-10, pp. 863-874, doi: 10.1080/09537287.2020.1837933.

Bhalla, S., Alfnes, E. and Hvolby, H.-H. (2022), "Tools and practices for tactical delivery date setting in engineer-to-order environments: a systematic literature review", *International Journal of Production Research*, Vol. 61 No. 7, pp. 1-33, doi: 10.1080/00207543.2022.2057256.

Birkie, S.E. and Trucco, P. (2016), "Understanding dynamism and complexity factors in engineer-to-order and their influence on lean implementation strategy", *Production Planning and Control*, Vol. 27 No. 5, pp. 345-359, doi: 10.1080/09537287.2015.1127446.

Bozarth, C.C., Warsing, D.P., Flynn, B.B. and Flynn, E.J. (2009), "The impact of supply chain complexity on manufacturing plant performance", *Journal of Operations Management*, Vol. 27 No. 1, pp. 78-93, doi: 10.1016/j.jom.2008.07.003.

Brehmer, P. and Rehme, J. (2009), "Proactive and reactive: drivers for key account management programmes", *European Journal of Marketing*, Vol. 43 7/8, pp. 961-984, doi: 10.1108/03090560910961447.

Browning, T.R. and Heath, R.D. (2009), "Reconceptualizing the effects of lean on production costs with evidence from the F-22 program", *Journal of Operations Management*, Vol. 27 No. 1, pp. 23-44, doi: 10.1016/j.jom.2008.03.009.

Buzzetto, R.R., Bauli, M.R. and Carvalho, M.M.d. (2020), "The key aspects of procurement in project management: investigating the effects of selection criteria, supplier integration and dynamics of acquisitions", *Production*, Vol. 30, e20190112, doi: 10.1590/0103-6513.20190112.

Caldwell, N. and Howard, M. (2014), "Contracting for complex performance in markets of few buyers and sellers: the case of military procurement", *International Journal of Operations and Production Management*, Vol. 34 No. 2, pp. 270-294, doi: 10.1108/ijopm-10-2013-0444.

Caldwell, N.D., Roehrich, J.K. and Davies, A.C. (2009), "Procuring complex performance in construction: London Heathrow Terminal 5 and a Private Finance Initiative hospital", *Journal of Purchasing and Supply Management*, Vol. 15 No. 3, pp. 178-186, doi: 10.1016/j.pursup.2009.05.006.

Cannas, V.G. and Gosling, J. (2021), "A decade of engineering-to-order (2010-2020): progress and emerging themes", *International Journal of Production Economics*, Vol. 241, 108274, doi: 10.1016/j.ijpe.2021.108274.

Cannas, V.G., Gosling, J., Pero, M. and Rossi, T. (2019), "Engineering and production decoupling configurations: an empirical study in the machinery industry", *International Journal of Production Economics*, Vol. 216, pp. 173-189, doi: 10.1016/j.ijpe.2019.04.025.

Cannas, V.G., Gosling, J., Pero, M. and Rossi, T. (2020), "Determinants for order-fulfilment strategies in engineer-to-order companies: insights from the machinery industry", *International Journal of Production Economics*, Vol. 228, 107743, doi: 10.1016/j.ijpe.2020.107743.

Choi, T.Y., Dooley, K.J. and Rungtusanatham, M. (2001), "Supply networks and complex adaptive systems: control versus emergence", *Journal of Operations Management*, Vol. 19 No. 3, pp. 351-366, doi: 10.1016/S0272-6963(00)00068-1.

Choi, T.Y. and Krause, D.R. (2006), "The supply base and its complexity: implications for transaction costs, risks, responsiveness, and innovation", *Journal of Operations Management*, Vol. 24 No. 5, pp. 637-652, doi: 10.1016/j.jom.2005.07.002.

Christiansen, P.E. and Maltz, A. (2002), "Becoming an 'interesting' customer: procurement strategies for buyers without leverage", *International Journal of Logistics*, Vol. 5 No. 2, pp. 177-195, doi: 10.1080/13675560210148678.

Cigolini, R., Gosling, J., Iyer, A. and Senicheva, O. (2022), "Supply chain management in construction and engineer-to-order industries", *Production Planning and Control*, Vol. 33 Nos 9-10, pp. 803-810, doi: 10.1080/09537287.2020.1837981.

Cohee, G.L., Barrows, J. and Handfield, R. (2018), "Early supplier integration in the US defense industry", *Journal of Defense Analytics and Logistics*, Vol. 3 No. 1, pp. 2-28, doi: 10.1108/jdal-03-2018-0007.

de Araújo, M.C.B., Alencar, L.H. and de Miranda Mota, C.M. (2017), "Project procurement management: a structured literature review", *International Journal of Project Management*, Vol. 35 No. 3, pp. 353-377, doi: 10.1016/j.ijproman.2017.01.008.

Dixit, V., Chaudhuri, A. and Srivastava, R.K. (2019), "Assessing value of customer involvement in engineered-to-order shipbuilding projects using fuzzy set and rough set theories", *International Journal of Production Research*, Vol. 57 No. 22, pp. 6943-6962, doi: 10.1080/00207543.2019.1572928.

Dowlatshahi, S. (1992), "Purchasing's role in a concurrent engineering environment", *International Journal of Purchasing and Materials Management*, Vol. 28 No. 1, pp. 21-25, doi: 10.1111/j.1745-493x.1992.tb00553.x.

Dubois, A. and Gadde, L.-E. (2002), "Systematic combining: an abductive approach to case research", *Journal of Business Research*, Vol. 55 No. 7, pp. 553-560, doi: 10.1016/s0148-2963(00)00195-8.

DuHadway, S., Mena, C. and Ellram, L.M. (2022), "Let the buyer beware: how network structure can enable (and prevent) supply chain fraud", *International Journal of Operations and Production Management*, Vol. 42 No. 2, pp. 125-150, doi: 10.1108/ijopm-05-2021-0310.

Duncan, R.B. (1972), "Characteristics of organizational environments and perceived environmental uncertainty", *Administrative Science Quarterly*, Vol. 17 No. 3, pp. 313-327, doi: 10.2307/2392145.

Eisenhardt, K.M. (1989), "Building theories from case study research", *Academy of Management Review*, Vol. 14 No. 4, pp. 532-550, doi: 10.2307/258557.

Ekström, T., Hilletofth, P. and Skoglund, P. (2021), "Towards a purchasing portfolio model for defence procurement–a Delphi study of Swedish defence authorities", *International Journal of Production Economics*, Vol. 233, 107996, doi: 10.1016/j.ijpe.2020.107996.

Ellegaard, C. and Koch, C. (2014), "A model of functional integration and conflict: the case of purchasing-production in a construction company", *International Journal of Operations and Production Management*, Vol. 34 No. 3, pp. 325-346, doi: 10.1108/ijopm-03-2012-0108.

Eriksson, P.E. (2015), "Partnering in engineering projects: four dimensions of supply chain integration", *Journal of Purchasing and Supply Management*, Vol. 21 No. 1, pp. 38-50, doi: 10.1016/j.pursup.2014.08.003.

Flynn, B.B., Huo, B. and Zhao, X. (2010), "The impact of supply chain integration on performance: a contingency and configuration approach", *Journal of Operations Management*, Vol. 28 No. 1, pp. 58-71, doi: 10.1016/j.jom.2009.06.001.

Flynn, B.B., Koufteros, X. and Lu, G. (2016), "On theory in supply chain uncertainty and its implications for supply chain integration", *Journal of Supply Chain Management*, Vol. 52 No. 3, pp. 3-27, doi: 10.1111/jscm.12106.

Foerstl, K., Hartmann, E., Wynstra, F. and Moser, R. (2013), "Cross-functional integration and functional coordination in purchasing and supply management: antecedents and effects on purchasing and firm performance", *International Journal of Operations and Production Management*, Vol. 33 No. 6, pp. 689-721, doi: 10.1108/ijopm-09-2011-0349.

Fortes, C., Tenera, A., Cunha, P. and Teixeira, J. (2023), "Engineering-to-order manufacturing: a criticality analysis of key challenges and solutions based on literature review", *Advances in Production Engineering and Management*, Vol. 18 No. 2, pp. 187-198, doi: 10.14743/apem2023.2.466.

Frohlich, M.T. and Westbrook, R. (2001), "Arcs of integration: an international study of supply chain strategies", *Journal of Operations Management*, Vol. 19 No. 2, pp. 185-200, doi: 10.1016/s0272-6963(00)00055-3.

Gioia, D.A., Corley, K.G. and Hamilton, A.L. (2013), "Seeking qualitative rigor in inductive research: notes on the Gioia methodology", *Organizational Research Methods*, Vol. 16 No. 1, pp. 15-31, doi: 10.1177/1094428112452151.

Golafshani, N. (2003), "Understanding reliability and validity in qualitative research", *The Qualitative Report*, Vol. 8 No. 4, pp. 597-607.

Gosling, J. and Naim, M.M. (2009), “Engineer-to-order supply chain management: a literature review and research agenda”, *International Journal of Production Economics*, Vol. 122 No. 2, pp. 741-754, doi: 10.1016/j.ijpe.2009.07.002.

Gosling, J., Hewlett, B. and Naim, M. (2020), “Procurement and contractual choices for engineer-to-order supply chains”, *IEEE Engineering Management Review*, Vol. 49 No. 1, pp. 174-180, doi: 10.1109/emr.2020.3028027.

Guy, S.P. and Dale, B.G. (1993), “The role of purchasing in design: a study in the British defense industry”, *International Journal of Purchasing and Materials Management*, Vol. 29 No. 2, pp. 26-32, doi: 10.1111/j.1745-493x.1993.tb00010.x.

Hicks, C., McGovern, T. and Earl, C.F. (2000), “Supply chain management: a strategic issue in engineer to order manufacturing”, *International Journal of Production Economics*, Vol. 65 No. 2, pp. 179-190, doi: 10.1016/s0925-5273(99)00026-2.

Hicks, C., McGovern, T. and Earl, C.F. (2001), “A typology of UK engineer-to-order companies”, *International Journal of Logistics*, Vol. 4 No. 1, pp. 43-56, doi: 10.1080/13675560110038068.

Howard, M. and Miemczyk, J. (2010), “Supply management in naval defence: the case for PCP”, in *Procuring Complex Performance*, Routledge, pp. 155-174.

Howard, M., Wu, Z., Caldwell, N., Jia, F. and König, C. (2016), “Performance-based contracting in the defence industry: exploring triadic dynamics between government, OEMs and suppliers”, *Industrial Marketing Management*, Vol. 59, pp. 63-75, doi: 10.1016/j.indmarman.2016.05.030.

Iakymenko, N., Brett, P.O., Alfnes, E. and Strandhagen, J.O. (2022), “Analyzing the factors affecting engineering change implementation performance in the engineer-to-order production environment: case studies from a Norwegian shipbuilding group”, *Production Planning and Control*, Vol. 33 Nos 9-10, pp. 957-973, doi: 10.1080/09537287.2020.1837939.

Johnsen, T., Howard, M. and Miemczyk, J. (2009), “UK defence change and the impact on supply relationships”, *Supply Chain Management: An International Journal*, Vol. 14 No. 4, pp. 270-279, doi: 10.1108/13598540910970108.

Khanuja, A. and Jain, R.K. (2019), “Supply chain integration: a review of enablers, dimensions and performance”, *Benchmarking: An International Journal*, Vol. 27 No. 1, pp. 264-301, doi: 10.1108/bij-07-2018-0217.

Kjersem, K. and Giskeødegård, M. (2020), “Planning procurement activities in ETO projects”, *Advances in Production Management Systems. Towards Smart and Digital Manufacturing: IFIP WG 5.7 International Conference, APMS 2020*, Novi Sad, August 30–September 3, 2020, pp. 565-572, Proceedings, Part II, doi: 10.1007/978-3-030-57997-5_65.

Laari, S., Lorentz, H., Jonsson, P. and Lindau, R. (2023), “Procurement’s role in resolving demand–supply imbalances: an information processing theory perspective”, *International Journal of Operations and Production Management*, Vol. 43 No. 13, pp. 68-100, doi: 10.1108/ijopm-06-2022-0382.

Leuschner, R., Rogers, D.S. and Charvet, F.F. (2013), “A meta-analysis of supply chain integration and firm performance”, *Journal of Supply Chain Management*, Vol. 49 No. 2, pp. 34-57, doi: 10.1111/jscm.12013.

Maylor, H. and Turner, N. (2017), “Understand, reduce, respond: project complexity management theory and practice”, *International Journal of Operations and Production Management*, Vol. 37 No. 8, pp. 1076-1093, doi: 10.1108/ijopm-05-2016-0263.

McGovern, T., Hicks, C. and Earl, C.F. (1999), “Modelling supply chain management processes in engineer-to-order companies”, *International Journal of Logistics Research and Applications*, Vol. 2 No. 2, pp. 147-159, doi: 10.1080/13675569908901578.

Mello, M.H. and Strandhagen, J.O. (2011), “Supply chain management in the shipbuilding industry: challenges and perspectives”, *Proceedings of the Institution of Mechanical Engineers - Part M: Journal of Engineering for the Maritime Environment*, Vol. 225 No. 3, pp. 261-270, doi: 10.1177/1475090211406836.

Mello, M.H., Strandhagen, J.O. and Alfnes, E. (2015a), "Analyzing the factors affecting coordination in engineer-to-order supply chain", *International Journal of Operations and Production Management*, Vol. 35 No. 7, pp. 1005-1031, doi: 10.1108/ijopm-12-2013-0545.

Mello, M.H., Strandhagen, J.O. and Alfnes, E. (2015b), "The role of coordination in avoiding project delays in an engineer-to-order supply chain", *Journal of Manufacturing Technology Management*, Vol. 26 No. 3, pp. 429-454, doi: 10.1108/jmtm-03-2013-0021.

Moretto, A., Patrucco, A.S., Walker, H. and Ronchi, S. (2022), "Procurement organisation in project-based setting: a multiple case study of engineer-to-order companies", *Production Planning and Control*, Vol. 33 Nos 9-10, pp. 847-862, doi: 10.1080/09537287.2020.1837938.

Munir, M., Jajja, M.S.S., Chatha, K.A. and Farooq, S. (2020), "Supply chain risk management and operational performance: the enabling role of supply chain integration", *International Journal of Production Economics*, Vol. 227, 107667, doi: 10.1016/j.ijpe.2020.107667.

Murfield, M.L.U., Ellram, L.M. and Giunipero, L.C. (2021), "Moving purchasing & supply management beyond a cost-focused identity", *Journal of Purchasing and Supply Management*, Vol. 27 No. 3, 100687.

O'Connor, C. and Joffe, H. (2020), "Intercoder reliability in qualitative research: debates and practical guidelines", *International Journal of Qualitative Methods*, Vol. 19, doi: 10.1177/1609406919899220.

Pagell, M. (2004), "Understanding the factors that enable and inhibit the integration of operations, purchasing and logistics", *Journal of Operations Management*, Vol. 22 No. 5, pp. 459-487, doi: 10.1016/j.jom.2004.05.008.

Petersen, K.J., Handfield, R.B. and Ragatz, G.L. (2005), "Supplier integration into new product development: coordinating product, process and supply chain design", *Journal of Operations Management*, Vol. 23 Nos 3-4, pp. 371-388, doi: 10.1016/j.jom.2004.07.009.

Pfeifer, S. and Fisher, L. (2024), "UK sets out reform of its 'broken' defence procurement system", *Financial Times*, (February 28, 2024).

Picaud-Bello, K., Johnsen, T. and Calvi, R. (2022), "Purchasing involvement in new product development: an absorptive capacity perspective", *Industrial Marketing Management*, Vol. 104, pp. 150-166, doi: 10.1016/j.indmarman.2022.04.011.

Reitsma, E., Haug, A., Hilletofth, P. and Johansson, E. (2023), "Engaging with 'engineer for supply chain' (EfSC): insights from two engineer-to-order manufacturers", *Production Planning and Control*, Vol. 36 No. 3, pp. 1-16, doi: 10.1080/09537287.2023.2273989.

Reitsma, E., Haug, A., Hilletofth, P. and Johansson, E. (2024), "A conceptualization and empirical investigation of strategic sourcing approaches for engineer-to-order manufacturers", *Production Planning and Control*, Vol. 36 No. 13, pp. 1-19, doi: 10.1080/09537287.2024.2414331.

Roehrich, J. and Lewis, M. (2014), "Procuring complex performance: implications for exchange governance complexity", *International Journal of Operations and Production Management*, Vol. 34 No. 2, pp. 221-241, doi: 10.1108/ijopm-01-2011-0024.

Romero Rojo, F.J., Roy, R. and Shehab, E. (2010), "Obsolescence management for long-life contracts: state of the art and future trends", *The International Journal of Advanced Manufacturing Technology*, Vol. 49 Nos 9-12, pp. 1235-1250, doi: 10.1007/s00170-009-2471-3.

Scherer, J. and Biemans, W.G. (2025), "Unite and conquer–end-to-end value creation through intra-organizational purchasing-sales integration", *Industrial Marketing Management*, Vol. 126, pp. 236-250, doi: 10.1016/j.indmarman.2025.02.021.

Shurrab, H., Jonsson, P. and Johansson, M.I. (2022), "A tactical demand-supply planning framework to manage complexity in engineer-to-order environments: insights from an in-depth case study", *Production Planning and Control*, Vol. 33 No. 5, pp. 462-479, doi: 10.1080/09537287.2020.1829147.

Strandhagen, J.W., Vallandingham, L.R., Alfnes, E. and Strandhagen, J.O. (2018), "Operationalizing lean principles for lead time reduction in engineer-to-order (ETO) operations: a case study", *IFAC-PapersOnLine*, Vol. 51 No. 11, pp. 128-133, doi: 10.1016/j.ifacol.2018.08.246.

Tatikonda, M.V. and Rosenthal, S.R. (2000), "Technology novelty, project complexity, and product development project execution success: a deeper look at task uncertainty in product innovation", *IEEE Transactions on Engineering Management*, Vol. 47 No. 1, pp. 74-87, doi: 10.1109/17.820727.

Voss, C., Tsikriktsis, N. and Frohlich, M. (2002), "Case research in operations management", *International Journal of Operations and Production Management*, Vol. 22 No. 2, pp. 195-219, doi: 10.1108/01443570210414329.

Williams, T.M. (1999), "The need for new paradigms for complex projects", *International Journal of Project Management*, Vol. 17 No. 5, pp. 269-273, doi: 10.1016/s0263-7863(98)00047-7.

Willner, O., Powell, D., Gerschberger, M. and Schönsleben, P. (2016), "Exploring the archetypes of engineer-to-order: an empirical analysis", *International Journal of Operations and Production Management*, Vol. 36 No. 3, pp. 242-264, doi: 10.1108/ijopm-07-2014-0339.

Wong, C.W.Y., Boon-Itt, S. and Wong, C.Y.H. (2011), "The contingency effects of environmental uncertainty on the relationship between supply chain integration and operational performance", *Journal of Operations Management*, Vol. 29 No. 6, pp. 604-615, doi: 10.1016/j.jom.2011.01.003.

Wynstra, F., Weggeman, M. and Van Weele, A. (2003), "Exploring purchasing integration in product development", *Industrial Marketing Management*, Vol. 32 No. 1, pp. 69-83, doi: 10.1016/s0019-8501(01)00197-3.

Corresponding author
Joakim Aspeteg can be contacted at: joakim.aspeteg@liu.se