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Overcoming Scalability Barriers in Manufacturing Marketplaces: A Framework for Trust-Centric Platforms

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Abstract

Purpose: Despite heavy investment, digital manufacturing marketplaces have struggled to scale beyond niche adoption. This study examines the underlying causes and proposes a new framework for building a trust-centric, scalable platform. The framework identifies three core principles: (1) efficient matchmaking, (2) enduring trust, and (3) effortless collaboration, as levers for transforming fragmented manufacturing networks. It demonstrates how trust-enabled platforms can trigger network effects, lower external transaction costs, and reshape supply chain strategies.

Materials and Methods: An exploratory mixed-method approach was used, combining an extensive literature review of academic and industry sources with semi-structured interviews involving platform architects, manufacturing SMEs, and supply chain managers. Insights from these interviews, analyzed thematically, were synthesized with the literature to develop the proposed framework.

Findings: The study finds that today's manufacturing marketplaces lack scalability and broad adoption due to limited transparency in supplier capabilities, cost-centric matchmaking, and "black box" models that hinder communication and customization. To overcome these barriers, platforms must actively engineer trust by promoting performance-based visibility and enabling direct, accountable collaboration. A platform grounded in Efficient Matchmaking, Enduring Trust, and Effortless Collaboration can create self-reinforcing network effects and substantially reduce external transaction costs. As these costs decline, firms are increasingly incentivized to outsource manufacturing, potentially decoupling production from product development and allowing greater focus on innovation.

Unique Contribution to Theory, Practice, and Policy: The findings extend Transaction Cost Theory (TCT) by demonstrating that trust-enforced digital marketplaces can reduce firm boundaries. Theoretically, this suggests expanding TCT to account for platform-enabled trust mechanisms that lower coordination costs. In practice, firms are advised to reconsider make-or-buy decisions as outsourcing via high-trust platforms becomes safer and cheaper. This allows firms to externalize manufacturing and devote internal resources to innovation. Policymakers are urged to update trade and antitrust policies to accommodate hyper-scalable manufacturing service platforms that are redefining industrial structures.

Keywords: *Manufacturing Platforms; Supply Chain Management; Digital Marketplace; Trust, Transaction Cost Theory*

JEL Codes: L14, L15, O33, D23

1.0 INTRODUCTION

These days, manufacturing is undergoing a major transformation driven by digitalization, customization, and pressure for rapid adaptability. For instance, Industrial Internet of Things (IIoT) technologies are empowering manufacturers with real-time monitoring, analytics, and smart automation to boost flexibility and responsiveness (Hu et al., 2024). Simultaneously, modular production and cloud-enabled factory systems, key components of Industry 4.0, are continuously enabling localized and mass production (Singha et al., 2020; Höse et al., 2023). Yet, these advances also fragment production processes and create greater coordination challenges across distributed manufacturing networks.

Traditional vertically integrated supply chain models and rigid supplier relationships increasingly fall short in this modular, digital environment. The operational complexity associated with managing fragmented supply networks often diverts resources away from innovation and product development, slowing the launch of new product developments (Spieske et al., 2021).

This bottleneck in manufacturing is not new but has become more pronounced in recent years. Although human inventiveness continues to drive remarkable technological inventions from autonomous machines to global positioning systems, the path from innovation to commercialization frequently hesitates at scale. This phenomenon, known as the "valley of death." refers to the critical gap between promising pilot initiatives and large-scale adoption (Markham, 2002). Despite over 3.5 million patent applications filed globally each year, fewer than 5% are ever commercialized into market-ready products that generate revenue (World Intellectual Property Organization, 2024; Design2Market, 2023). In hardware-driven sectors, especially, the challenge is not merely inventing but building: sourcing components, designing tooling, validating quality, and managing logistics are operational burdens that require expertise far removed from the core innovation. Unlike software, scaling physical products demands substantial investment in manufacturing infrastructure, often creating friction that delays or derails commercialization (Compagnucci et al., 2025).

These challenges are the critical role of manufacturing ecosystems. Real-world manufacturing depends on orchestrating complex networks of suppliers, manufacturers, tooling partners, and logistics providers (Kumar Kanite, 2023; Gerrikagoitia et al., 2019). In highly integrated hubs like Shenzhen, where ecosystem actors are both digitally and geographically integrated, rapid scaling is possible (Hossain, 2022). However, in regions, manufacturing ecosystems remain fragmented and siloed, leading to higher operational costs, slower production cycles, and diminished responsiveness. Prior studies further confirm that supply chain disruptions amplify these weaknesses, with operational costs increasing by 3-5% and sales reduction by up to 7% in affected firms (Procurement Tactics, 2023; Spieske et al., 2021).

In response, digital manufacturing platforms such as Xometry and Fictiv have emerged, aiming to streamline sourcing by providing instant quoting, supplier matching, and distributed production networks. While they have made significant steps in providing access to manufacturing services, platform adoption remains partial (Evans & Timme, 2024). Similarly, Frandsen & Lefebvre's (2022) systematic literature review concludes that digital manufacturing platforms remain "supplementary sourcing tools rather than primary production infrastructures," citing low adoption in high-complexity sectors and the lack of deep integration with enterprise systems. Compagnucci et al. (2025) find that digital business-to-business platforms for manufacturing have not yet matured into foundational infrastructures for production, due to a fragmented technological landscape, limited value propositions that fail to cover diverse manufacturing needs, and persistent trust and governance challenges. They have not created scalable, trust-centric ecosystems capable of addressing the underlying challenges of modern manufacturing (Schöppenthau et al., 2023).

While analogies to retail or transportation platforms (e.g., Uber, Lyft, Airbnb) are useful in highlighting the potential of digital platforms to reshape industries, they oversimplify the realities of manufacturing. Manufacturing, unlike service-oriented platforms, involves intricate processes, rigorous regulatory requirements, and significant capital investment in physical assets (Ji et al., 2025). Platform design and governance in manufacturing entail domain-specific solutions, rather than direct transplants of models from consumer-facing industries (Springer et al., 2025). Hence, the need for scalable, transparent, and collaborative manufacturing ecosystems is more pressing than ever if the sector is to meet the demands of today's global economy.

To address these challenges, we seek to investigate why existing manufacturing marketplaces have struggled to scale despite repeated attempts. We focus on three structural limitations: (1) inefficient matchmaking, (2) absence of trust mechanisms, and (3) constrained collaboration. Prior research on trust and platform economics underscores that marketplaces lacking robust reputation systems and collaborative governance struggle to establish critical network effects and reduce transaction costs (Luca, 2017; Doroudi et al., 2020). Building on Transaction Cost Theory (TCT), which emphasizes how platform-mediated governance can reduce coordination frictions, standardize transactions, and shift firm boundaries (King & Navarra, 2024; Zhu, 2024), we propose a comprehensive new framework to overcome these barriers. Finally, we examine how a scalable, trust- and connectivity-oriented manufacturing platform can transform industrial structures by reducing transaction costs, redefining firm boundaries, and fostering an innovation-centric manufacturing ecosystem.

1.1. Problem Statement

The core problem addressed is that existing digital manufacturing platforms fail to achieve industry-wide scalability and adoption. Despite numerous platform offerings/developed in the Industry 4.0 era, none have become the de facto standard for manufacturing outsourcing or fundamentally transformed supply chain dynamics. Previous research indicates that adoption remains partial, as manufacturers view these platforms as supplementary sourcing tools rather than primary production infrastructures, citing concerns over transparency, quality assurance, and governance (Frandsen & Lefebvre, 2022; Compagnucci et al., 2025). Similarly, Evans & Timme (2024) argue that firms continue to view digital manufacturing platforms as peripheral sourcing options, reflecting a persistent hesitation to rely on them for mission-critical tasks.

The adoption gap is majorly present among Small and Medium-sized manufacturers (SMMs), who represent over 95% of the U.S. industrial base. Yet, these firms lag in adopting smart manufacturing technologies (e.g., IoT, analytics), especially compared to larger OEMs, due to cost, technological readiness, and integration challenges (Yarbrough et al., 2023, Auburn ICAMS Report, 2023). Similarly, technology adoption among SMEs is influenced by organizational readiness, digital competencies, and entrepreneurial orientation, indicating that reluctance may stem from structural and cultural factors, rather than just platform design (Sudirman, 2025).

Current platforms remain constrained by three persistent issues: (1) they provide only superficial matchmaking, often reduced listings or aggregated quotes; (2) they lack robust mechanisms to build, enforce, and port trust across transactions; and (3) they limit direct collaboration between buyers and suppliers, especially in complex or custom projects. Consequently, product companies remain hesitant to scale through these marketplaces, and the vision of a seamless, internet-scale manufacturing ecosystem remains unfulfilled.

This study addresses both a knowledge and practice gap. We aim to contribute to the platform and supply chain literature by demonstrating how engineered trust mechanisms and collaboration protocols can reduce coordination and enforcement costs, building on insights from platform economics and Transaction Cost Theory (TCT). To address this in practice, we propose a framework that offers design guidelines for platform design, adoption insights for manufacturers, and policy recommendations for supervisors/managers seeking to foster scalable, transparent, and innovation-friendly ecosystems. By systematically examining barriers and proposing solutions, the study aims to help digital platforms overcome the "valley of death" in manufacturing innovation, smoothing the transition from prototype to profitable systems using a trust-based distributed manufacturing network.

1.2. Research Objective

The primary objective of this study is to develop a trust-centric framework that can enable scalable manufacturing marketplaces. This entails: (1) Diagnosing the limitations of existing manufacturing platform models (in matchmaking, trust provision, and collaboration support) that prevent them from achieving network effects and widespread adoption; and (2) Designing a new conceptual model referred to as the KNIT framework in this paper that addresses these limitations through efficient partner matching, enforced trust mechanisms, and seamless collaboration tools. By achieving this objective, the research provides actionable insights for platform architects, manufacturing firms, and policymakers on how to build and support next-generation manufacturing ecosystems capable of scaling.

2.0 LITERATURE REVIEW

2.1. Theoretical Background

Two theoretical perspectives are relevant to this study. The first is Platform ecosystem theory, which explains how digital marketplaces succeed or fail by orchestrating interactions among distinct user groups and harnessing network effects. In two-sided or multi-sided contexts, the value to one side of the market increases as participation grows on the other side, creating cross-side network effects that can drive rapid adoption or, if weak, stall growth (McIntyre & Srinivasan, 2017). Previous research indicates that these effects are neither automatic nor uniform; platform design choices, such as pricing, openness, and governance, significantly influence regardless of whether participation reaches a critical mass (Hagiu & Wright, 2015; Cennamo & Santaló, 2013).

Cennamo & Santalo (2013) introduce a central strategic issue known as multi-homing. Multihoming refers to the extent to which users simultaneously affiliate with multiple platforms. When buyers and suppliers multi-home, network effects diffuse, and no single platform becomes "de facto infrastructure". Platforms respond with differentiation, bundling, and envelopment strategies to concentrate participation by integrating adjacent functions like quoting. The authors show that winner-take-all outcomes are not automatic. Trade-offs around exclusivity, differentiation, and complementor support shape competition and user stickiness.

Therefore, because platforms mediate high-stakes transactions, implementing clear rules and safeguards for access, pricing, reputation, and conflict resolution becomes central to ecosystem health. Effective governance lowers risks, aligns incentives, and sustains user engagement (Jacobides et al., 2018). For example, reputation systems, ratings and reviews, and dispute resolution mechanisms act as trust signals that mitigate perceived risk, encouraging cross-side participation. Lee et al. (2018) discussed that trust perceptions directly shape willingness to engage on platforms: users in sharing economy contexts, such as Uber, report higher participation when trust signals are clear and reliable. Similarly, platform users depend on social interaction cues and transparency mechanisms to reduce uncertainty and build confidence in exchanges (Hesse et al., 2020). Chan et al. (2022) find that governance features such as calibrated reputation systems strongly influence engagement quality and ultimately shape platform growth trajectories. Jacobides et al. (2018) emphasize modularity as a defining trait of ecosystems characterized by well-defined interfaces that allow diverse actors (e.g., buyers, contract manufacturers, logistics providers, and quality-control partners) to interact effectively without the need for hierarchical integration. In manufacturing contexts, such modularity underpins scalability by enabling distributed but coordinated production activities.

A second perspective is Transaction Cost Theory (TCT), introduced by Coase (1937) and further developed by Williamson (1975, 1985, and 2010). TCT helps explain why firms internalize some activities while outsourcing others, depending on relative governance costs. Williamson (2010) and Rindfleisch (2019) identified three central hazards: (1) asset specificity, (2) bounded rationality, and (3) opportunism.

Asset specificity refers to the degree to which investments are tied to a particular transaction. Bounded rationality captures the limits of foresight, since no contract can anticipate every contingency. Lastly, opportunism reflects the possibility that one party may exploit such gaps for its own self-interest. Together, these hazards help explain why many firms have historically preferred vertical integration, as market-based contracting becomes risky and costly (Rindfleisch, 2019).

Further research extends TCT by showing how governance mechanisms mitigate these hazards. For instance, Xue et al. (2017) demonstrate that relational exchanges such as trust, shared norms, and repeated interaction can lead to reducing transaction costs in formal contracts within complex environments. Park et al. (2024) show that digital platforms can reduce negotiation costs and opportunism by embedding structured trust signals and bargaining protocols. Indeed, these findings illustrate how platforms are moving beyond the role of neutral intermediaries to act as governance structures that build rules and safeguards directly into their design.

Moreover, within the manufacturing context, Cao et al. (2015) and Lumineau et al. (2020) provide evidence that design choices such as standardized workflows and monitoring tools can lower coordination costs and reduce exposure to TCT's hazards. For instance, asset specificity is mitigated through standardized digital interfaces such as qualification badges and reputation portability, enabling transferability across multiple suppliers. Bounded rationality is alleviated through verifiable workflows such as version-controlled handoffs, structured change-order protocols, and milestone-based service agreements, which provide flexibility under changing conditions. Lastly, opportunism is constrained by calibrated ratings, transparent reviews, and formal dispute-resolution mechanisms, which create accountability and recourse.

In practice, platforms not only reduce the traditional transaction costs of search, contracting, and enforcement but also reshape the balance between integration and outsourcing. When external governance costs are lower than internal coordination costs, TCT predicts that firms will favor market exchange over vertical integration. In digital manufacturing networks, this boundary shift enables greater modularity, flexibility, and scalability, allowing firms to focus on innovation while relying on platforms for distributed production services (Rindfleisch, 2019; Xue et al., 2017; Park et al., 2024).

To complete the theoretical foundation, it is also necessary to examine how these two perspectives complement or contradict one another in digital manufacturing contexts. Indeed, the interaction between Platform Ecosystem Theory and TCT in digital manufacturing can be argued as both complementary and sometimes contradictory. Following McIntyre & Srinivasan

(2017) and Williamson (2010), when platform mechanisms enhance trust and transparency, through capability performance dashboard, verified performance histories, escrow or dispute-resolution processes, and standardized interfaces, they reduce external transaction costs. Lower costs expand the feasible set of outsourcing arrangements, shifting firm boundaries in line with TCT. At the same time, stronger trust and quality signals amplify cross-side network effects, reinforcing platform growth. Nevertheless, complementarities coexist with tensions. Platform strategies that increase lock-in (e.g., proprietary file formats, data silos, or exclusivity policies that suppress multi-homing) can increase asset specificity and perceived hold-up risks, raising transaction costs even as network size expands. Similarly, aggressive bundling or envelopment may create gatekeeping power and new forms of platform opportunism, requiring governance mechanisms such as fair access rules and reputation portability to mitigate these risks (Jacobides et al., 2018).

2.2. Trends in Manufacturing and Need for Platforms

Manufacturing is experiencing profound change driven by the demand for mass customization and the advent of advanced digital technologies. Sudha et al. (2022) observe that growing consumer preferences for personalized products are forcing manufacturers to adopt flexible production systems, moving beyond traditional high-volume, low-variety models. Technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and blockchain are reshaping operational frameworks, rendering conventional vertically integrated supply chains increasingly unsustainable. Paul et al. (2021) highlight that the COVID-19 pandemic exposed vulnerabilities in rigid supply networks, underscoring an urgent need for resilient and adaptive manufacturing partnerships. Similarly, Zhang and Hou (2023) argue that firms must adopt intelligent, modular manufacturing models to navigate complexities introduced by Industry 4.0 innovations. In this context, many scholars and practitioners point to digital platforms as a coordination mechanism to handle the complexity. By acting as central hubs for data exchange and transactions, platforms could help orchestrate fragmented manufacturing resources into cohesive supply chain solutions.

A major development is the exploration of blockchain technology to improve transparency and trust in supply chains. Oriekhoe et al. (2024) and Wan et al. (2020) suggest that blockchain's distributed ledger can reduce information asymmetry and enhance accountability among manufacturing partners. Blockchain-enabled platforms create immutable records of transactions and quality data, which can increase confidence between parties who lack prior relationships. Ma et al. (2024) and Chikhi et al. (2022) provide evidence that blockchain can foster trust in decentralized production networks a critical attribute if manufacturing is to be orchestrated across independent suppliers. Gupta et al. (2024) further assert that building resilient supply chain platforms requires integrating multiple technologies (IoT for real-time data, AI for decision support, blockchain for trust) to optimize overall performance. As manufacturing processes fragment and become more distributed geographically, the imperative for cohesive, digitally orchestrated platforms grows. Without such platforms, the costs of coordination and the risks of misalignment in multi-party manufacturing projects may remain prohibitive. This literature reinforces the idea that next-generation manufacturing requires platform-based ecosystems to sustain innovation and competitiveness in the global market.

2.3. Smart Manufacturing Maturity Models and Cyber-physical Systems in Production

The deployment of Industry 4.0 has forced major firms and researchers to develop smart manufacturing maturity models to assess readiness for digital transformation. These models typically examine factors such as technological infrastructure, organizational processes, workforce competencies, and the degree of system integration. Yet, much of the existing work has been criticized for remaining largely conceptual. Onyeme & Liyanage (2021), for example, argued that most framework platforms are described as too generic, failing to reveal the actual or specific conditions of individual industries accurately. Similarly, Vance (2023) reviewed nineteen different models, raising concerns about their reliability in practice, as most models overlap in the dimensions considered, but minimal consensus on validation.

Recent publications attempt to address these gaps. For instance, Senna et al. (2023) propose a digital maturity model grounded in the Technology Organzation Environment (TOE) framework, offering empirical support for how contextual factors influence Industry 4.0 adoption. Saari (2024) takes a different approach with the Manu Maturity model, embedding sustainability and data sharing into assessments of manufacturing readiness. Together, these newer models suggest a shift: while maturity assessments remain uneven in scope, the field is moving toward more multidimensional and context-sensitive approaches to smart manufacturing.

On the other hand, literature on cyber-physical systems (CPS) and cyber-physical production systems (CPPS) underscores their centrality to modern industrial transformation. CPS refers to tightly coupled computational and physical processes in which sensing, connectivity, and control enable real-time decision-making in production environments. Monostori (2016) states that CPS is one of the cornerstones of Industry 4.0, summarizing all the achievements of the interplay between the virtual world (e.g., AI, computer vision, cloud computing) and the physical world (e.g., robotics, grid manufacturing). Building on this foundation, a more recent large-scale review by Oks et al. (2024) categorizes CPS research and highlights unresolved issues in interoperability, standardization, and human–machine interaction, underscoring that many implementations remain fragmented despite rapid theoretical development.

Taken together, research on maturity models and CPS demonstrates that technological and organizational readiness are prerequisites for scaling digital manufacturing platforms. Maturity models reveal that many firms lack the organizational processes and integration capacity to fully engage in platformized production ecosystems. Meanwhile, CPS literature shows that without robust cyber-physical integration, platforms cannot achieve the interoperability and modularity required to orchestrate distributed manufacturing networks. Therefore, both streams agree that digital manufacturing platforms must operate within environments where firms exhibit sufficient maturity and CPS capabilities. Otherwise, the scaling of trust-centric, network-driven platforms will remain challenging.

2.4. Manufacturing Platforms: Current Landscape and Limitations

Digital manufacturing platforms have emerged as a strategic response to the need for agility and collaboration in modern production. These platforms leverage cloud computing and IoT connectivity to link designers, manufacturers, and suppliers in real time. Fraile et al. (2019) and Gerrikagoitia et al. (2019) note that IoT-supported platforms enable real-time data sharing and interactions among stakeholders, greatly enhancing supply chain visibility and responsiveness. Bahga and Madisetti (2016) similarly highlight the transformative potential of real-time data in strengthening decision-making across the manufacturing value chain. Cloud manufacturing models as described by Xin et al. (2022) and Schmitz & Tang (2018) offer pay-per-use access to advanced manufacturing resources, thus democratizing capabilities for small and medium-sized enterprises (SMEs). In theory, such platforms could allow SMEs to tap into cutting-edge fabrication technologies or excess capacities of large factories without hefty capital investments.

Despite these advances, significant limitations persist in the current generation of manufacturing marketplaces. Zhang & Hou (2023) point to the lack of interoperability and standardized frameworks across platforms, leading to information silos and inefficient cross-platform collaboration. Menon et al. (2017) emphasize that sustaining open digital platforms requires continuous community engagement; without active participation, platforms can quickly stagnate. Many manufacturing platforms struggle to attract a critical mass of users due to trust deficits and unclear value propositions. Industry-specific nuances also pose challenges: Okano et al. (2021) observe that generic platform models often fail to account for specialized operational requirements (e.g., aerospace machining tolerances or pharmaceutical quality compliance), resulting in a mismatch between platform capabilities and user needs. Hayman & Dennehy (2021) illustrate this in the context of vaccine manufacturing, where extremely specific technical and regulatory demands limit the applicability of general manufacturing platforms.

In addition to technical and structural barriers, empirical studies show that organizational and strategic factors play a decisive role in firms' hesitation to adopt manufacturing platforms. Marzi et al. (2023) conducted a survey of 318 manufacturing firms. They found that SMEs often perceive high complexity and adoption costs as prohibitive, while the lack of perceived benefits further dampens their intention to adopt two-sided B2B platforms. This survey result is consistent with the conclusion of Wong et al. (2020) that the perceived costs and challenges associated with integrating two-sided manufacturing platforms into existing business processes may deter their adoption. Evidence from Chinese SMEs further indicates that digital platform adoption requires extensive capability reconfiguration, making it particularly difficult for resource-constrained firms (Zhang et al., 2022). Trust-related concerns are also critical: Kohtamäki et al. (2022), based on 40 in-depth interviews, found that firms often resist sharing operational and usage data on platforms due to fears of competitive disadvantage and loss of control.

These studies collectively highlight that while digital platforms hold promise, they have not yet realized their full transformative potential in manufacturing. Structural and operational gaps such as data fragmentation, insufficient trust, inadequate customization for industry needs, and lack of user engagement hinder the scalability and effectiveness of current solutions. This gap in the literature and practice directly motivates the present study's focus on a new framework to overcome these barriers.

2.5. Characteristics and Features of Manufacturing Marketplaces

Effective manufacturing marketplaces must integrate a range of features to support the dynamic needs of industrial production ecosystems. However, not all features contribute equally to platform adoption. Empirical studies using quantitative methods reveal a hierarchy of factors, with security, trust, and perceived reliability constituting the non-negotiable foundation for adoption.

Security and trust mechanisms are foundational, as highlighted by multiple sources (Menon et al., 2017; Lee et al., 2018), because companies will only commit critical projects to a platform if they trust the data handling and transaction integrity. This theoretical importance is validated by empirical research conducted by Horstmann et al. (2023), which found that perceived security and trust were the most significant direct predictors of behavioral intention to use. Platforms must protect sensitive intellectual property and pricing data through strong cybersecurity measures. Hu et al. (2024) also advocate for localization strategies: tailoring platform interfaces, language, and supplier listings to regional markets can improve relevance and user alignment. A "one-size-fitsall" global platform may not account for local manufacturing standards or business norms, whereas localized versions can foster closer supplier–buyer matches.

Yenipazarli (2020) notes that marketplace competitiveness increasingly hinges on quality assurance attributes, necessitating stringent vetting and performance monitoring of suppliers to meet buyer expectations. Quantitative surveys support this, showing that quality assurance is a key driver, but primarily after foundational trust is established (Ghobakhloo & Fathi, 2019; Raj et al., 2020). Marketplaces must implement robust quality management systems including certification checks, process audits, and outcome tracking as core functions rather than afterthoughts.

Another critical characteristic is the use of real-time data analytics. Rahman et al. (2020) stress the importance of analytics in enabling stakeholders to make performance-driven decisions. By analyzing production data, lead times, defect rates, etc., platforms can provide insights or optimizations (e.g., recommending a supplier that can deliver faster based on historical data). Yang et al. (2015) underline the significance of user-centric design in marketplaces: a clean, intuitive interface and seamless user experience can greatly influence platform adoption. This is particularly critical for overcoming the "ease-of-use" barrier, which quantitative studies consistently rank as a top challenge, especially for small and medium-sized enterprises (Mittal et al., 2018). If engineers and procurement managers find the platform cumbersome, they will revert to traditional methods or competitor systems.

Beyond basic transaction facilitation, servitization is a growing trend. Beyond basic transactions, Hu et al. (2024) observe that platforms are evolving to offer integrated services such as logistics, financing, and quality assurance, thereby delivering holistic value to users. Frank et al. (2019) also found that such integrated service offerings are a significant predictor of competitive advantage and adoption, as they directly enhance the platform's perceived usefulness. The value of these bundled services is supported empirically; for example, Zhu et al. (2018) found that data analytics services significantly enhance supply chain transparency and performance, which in turn increases adoption and reliance on the platform providing them. A platform that bundles manufacturing with related services can streamline the user experience and build loyalty, whereas one that leaves users to manage those aspects externally may see lower adoption.

In summary, the literature suggests that a thriving manufacturing marketplace strikes a balance between a core foundation of trust and security and value-adding layers of data-driven intelligence, usability, local relevance, and service integration. The empirical literature confirms that this foundation of trust is the primary driver, upon which other features depend to maximize adoption and retention.

2.6. The Importance and Fragility of Trust in Marketplaces

Trust stands at the center of successful platform-based manufacturing ecosystems. A buyer entrusting an external supplier with a critical component, or a supplier committing capacity to an unknown client, both entail risk. Lee et al. (2018) and Hesse et al. (2020) argue that participant trust is shaped by perceptions of platform reliability, service quality, and the broader community's experiences. If users perceive the platform as unreliable or biased, their trust in transacting through it diminishes. Conversely, transparent governance and consistent enforcement of rules by the platform can enhance trust. Sun and Qu (2025) show that transparent governance structures – such as clear dispute resolution policies and accountability for rule-breakers – directly increase user trust by signaling fairness and predictability.

User feedback and reputation systems are among the most powerful trust-building tools. Liu and Tang (2018) note that features like customer reviews, supplier star ratings, and third-party verifications serve as vital cues that reduce perceived risk. However, these systems are vulnerable to manipulation, which can catastrophically undermine trust. Common tactics include fake reviews, where sellers create fake accounts to inflate their own ratings or damage competitors', and review withholding, where buyers are pressured to only post positive feedback (Luca & Zervas, 2016). When a platform openly displays supplier performance histories and client feedback, new users can rely on this collective knowledge to make informed decisions, provided the platform has robust mechanisms to detect and mitigate such fraud. Advanced technologies are increasingly being employed to bolster trust. Dann et al. (2020) demonstrate that blockchain can enhance platform credibility by ensuring transparency and immutability of transaction records. In a blockchainbacked marketplace, key milestones (e.g., delivery confirmation, quality inspection results) could be recorded on a shared ledger, making it virtually impossible to falsify performance data. Kayhan (2022) provides a striking example in the pharmaceutical sector, where a blockchain-enabled trust system improved the traceability and trustworthiness of drug supply chains; this success offers insights transferrable to manufacturing platforms that require high trust. Nevertheless, technological solutions are not a panacea; they must be designed to avoid governance bias, such as the arbitrary or opaque enforcement of smart contracts, which can erode user trust just as quickly as human bias (Ganne, 2020).

Trust also emerges from social and community dynamics. Wang et al. (2022) highlight that in cloud manufacturing environments, trust needs to be agile and dynamic participants must continually earn trust through performance. Mechanisms such as dynamic trust scores that update with each completed job can adapt to changing behavior. Li and Wang (2020) and Beck et al. (2023) suggest that proactive community-building (forums, user groups, knowledge sharing sessions) can create a collective sense of identity and trust among platform users. When users feel part of a community, they may be more forgiving of occasional issues and more willing to collaborate to improve the platform.

Ultimately, the potential for failure must be a core design consideration. A platform's trustworthiness is proven not when systems work perfectly, but when they effectively respond to and mitigate attempts at manipulation, bias, and fraud. Overall, the literature converges on a key point: trust in manufacturing marketplaces must be actively engineered and maintained. It is not a passive byproduct of transactions but a prerequisite that requires vigilant and robust design from technical solutions like blockchain to social solutions like reputation and community engagement. This insight heavily informs our framework, where trust is elevated as a central "pillar".

2.7. Research Gaps

Through this review, several research gaps become evident. First, while prior studies have identified piecemeal issues (interoperability, trust, engagement) with manufacturing platforms, there is a lack of an integrated framework that addresses all major barriers to scalability simultaneously. Most existing research examines either technical enablers (e.g., IoT, blockchain) or management aspects (e.g., community engagement, governance) in isolation. This siloed approach misses the opportunity to design a comprehensive solution. Second, the literature lacks empirical insights into why none of the current platforms have become dominant in manufacturing, despite analogous success stories in other industries. There is a gap in understanding the unique challenges of the manufacturing context (such as the critical need for quality assurance and deep collaboration) that generic platform models have not solved. Third, while Transaction Cost Theory has been applied to supply chain decisions, there is limited theoretical development around how trust-enforcement on digital platforms might alter transaction cost dynamics in manufacturing. We currently lack formal models that incorporate trust mechanisms (reputation systems, smart contracts, etc.) into transaction cost evaluations for make-or-buy decisions. This study seeks to fill these gaps by proposing and examining the KNIT framework, which holistically combines matchmaking, trust enforcement, and collaboration facilitation. In doing so, it links technological design with economic theory, extending TCT and providing guidance for building the next generation of manufacturing platforms.

3.0 MATERIALS AND METHODS

3.1 Study Design

The study followed a qualitative, exploratory design aimed at developing and refining the proposed framework. To do so, it combined descriptive case analysis with elements of theory-building, allowing both empirical observation and conceptual generalization. The empirical context consisted of digital manufacturing platforms active across North America, Europe, and Asia, regions selected because they represent diverse levels of platform maturity and adoption. Interviews were conducted remotely via video conferencing, allowing participation of experts from multiple regions in the United States.

3.2 Population and Sample

The target population was industry professionals with direct experience in supply chain, procurement, and manufacturing marketplaces. From this population, we used purposive sampling to select a sample of 25 experts, including platform executives, manufacturing firm managers who have used such platforms, and independent industry consultants. These participants were chosen to provide diverse perspectives on platform performance and challenges. Data Collection: Two primary data sources informed the study: (1) an extensive literature review (as summarized in the previous section) that gathered existing knowledge on manufacturing platforms, and (2) semi-structured interviews with industry experts. The interview protocol covered topics such as participants' experiences with platform matchmaking efficacy, trust or mistrust in using platforms, collaboration needs in manufacturing projects, and suggestions for improvement. Interviews typically lasted 45–60 minutes and were audio-recorded with consent.

3.3 Data Analysis

Interview notes were reviewed and analyzed using a simplified thematic analysis approach. Key points were extracted from the notes to identify recurring themes related to platform limitations (e.g., "visibility issues," "communication barriers," "trust concerns", "high cost") and success factors. These emergent themes were compared against insights from existing literature to validate or challenge prior assumptions. Triangulating between literature, interviews, and case documents strengthened the validity of our findings. To enhance the credibility of our conceptual findings, preliminary results, and the draft KNIT framework were shared with two interview participants (a manufacturing chief procurement officer and a manufacturing firm CTO) for feedback. Their input was incorporated to refine the framework. No statistical analysis was conducted, as the emphasis remained on conceptual development grounded in practitioner insights.

4.0 FINDINGS

4.1. Barriers to Scalability in Current Manufacturing Marketplaces

Our research confirms that despite numerous entrants in the digital manufacturing marketplace arena, significant limitations prevent these platforms from scaling into mainstream solutions. First, most existing platforms function essentially as directories or marketplaces rather than deeply integrated systems. They might list suppliers and broker quotes, but they do not provide rich visibility into supplier capabilities, capacities, or quality performance. Buyers using these platforms often must vet supplier's offline because the platform's information is insufficient to establish trust. We also found that matchmaking is often superficial: due to limited data, platforms tend to match based on easily quantifiable criteria (like price) while neglecting crucial factors like quality records, lead time adherence, or innovation capability. Buyers thus frequently default to choosing the lowest-cost quote, which can lead to poor outcomes if the cheapest supplier is not actually the best fit for the job. This price-centric matching undermines trust - when quality or delivery suffers, buyers blame the platform experience.

Second, nearly all current platforms impose an intermediary model that restricts direct interaction between buyers and suppliers. While this is intended to streamline communication and protect against disintermediation, it paradoxically severs the relationships needed for complex manufacturing projects. Many hardware development processes require iterative back-and-forth (for design adjustments, troubleshooting, etc.). On some platforms, however, buyers are not allowed to speak directly with the engineers or production managers at the supplier firm; instead, all communication is funneled through platform account managers or messaging proxies. Both our interviewees and prior studies note that this setup increases miscommunications and slows down problem-solving. It also leaves suppliers feeling commoditized and squeezed, since they cannot build a direct rapport with clients. As a result, suppliers may not invest extra effort or prioritize platform orders, seeing them as one-off transactions with thin margins due to platform fees. This dynamic was highlighted by a supplier who had abandoned a well-known platform: “They didn't let us talk to the customer, yet held us responsible for any issue. It just wasn't worth it beyond some spare capacity work.” The lack of enduring partnerships fostered on these marketplaces means there is little cumulative value each transaction is isolated, failing to contribute to a growing network effect.

Another structural barrier evident from our findings is the persistent trade-off between time, cost, and control in manufacturing, which current platforms have not resolved. Figure 1 illustrates a conceptual “performance frontier” for manufacturing sourcing options, based on our analysis. Traditional options in-house manufacturing, contract manufacturing, job shops, on-demand platform suppliers occupy different points on a curve where increasing speed or flexibility often comes at a higher cost or reduced control over quality. None of the existing platform models successfully break this trade-off. For instance, using a fast-turnaround on-demand manufacturer might speed prototyping (saving time) but at a high price per part and with less control over the process. Conversely, using a low-cost job shop through a platform saves money but can introduce delays and quality uncertainty. Ideally, a scalable platform should enable firms to achieve both speed and cost efficiency with reasonable control, effectively shifting the curve outward. However, as of now, companies still find that to gain confidence and control, they revert to trusted suppliers or internal manufacturing for essential projects, accepting slower turnaround or higher cost as necessary evils. Our interview insights and industry reports both indicate that no current marketplace has provided a solution where companies feel they can rapidly outsource manufacturing without incurring major trade-offs in either cost or risk. This unmet ideal - high control with minimal investment remains a guiding target for platform innovation. (See Figure 1.)

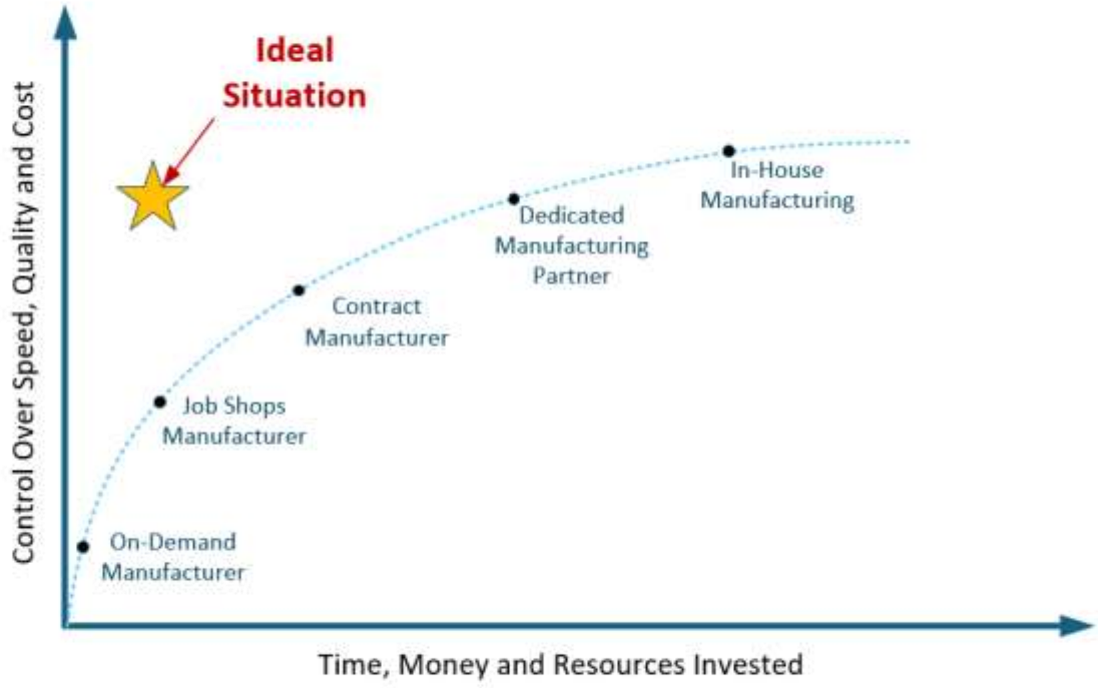

Figure 1: Manufacturing Sourcing Trade-off Curve Traditional Options vs. Ideal Outcome

A final and perhaps most critical factor underlying all these issues is the absence of robust trust mechanisms. Trust deficits are both a cause and a consequence of the problems. Because platforms don’t thoroughly screen or transparently rate suppliers, buyers approach them with skepticism. Because buyers engage cautiously or infrequently, suppliers do not invest in platform-specific improvements (and some high-quality suppliers avoid joining platforms altogether due to fear of reputational dilution). This results in a classic chicken-and-egg problem that stalls network growth. Our literature review showed that trust is fundamental to marketplace success, yet “trust by design” is largely missing in current manufacturing platforms. There are typically no stringent onboarding requirements (some platforms allow any machine shop with a minimal profile to join), and limited, if any, third-party quality certifications are visible. Without credible performance data or guarantees, firms use platforms only for low-risk, low-value tasks (e.g., small prototype runs or non-critical components). This severely limits the volume and significance of transactions flowing through the platform, thereby inhibiting the attainment of scale. In summary, current manufacturing marketplaces face a confluence of issues shallow data, restricted relationships, persistent cost-speed-quality trade-offs, and lack of trust that explain why they have not achieved transformational scale. These findings set the stage for the framework we propose to overcome these barriers.

4.2. Proposed KNIT Framework for Scalable Manufacturing Platforms

To address the systemic limitations identified above, we propose a new framework for building scalable, high-trust manufacturing ecosystems, referred to here as the KNIT framework. This name signifies the interweaving of critical elements, much like knitting threads to create a tightly integrated platform. As shown in Figure 2, the framework is conceptualized as a temple-like structure with four distinct components: (1) the top block, representing the overarching goal of easier, faster, and more flexible manufacturing, (2) the core system, our propose KNIT

Ecosystem, which serves as the integrating layer that channels capabilities upward, (3) the three pillars: (i) Efficient Matchmaking, (ii) Enduring Trust, and (iii) Effortless Collaboration, that provide the essential supports for scalability, and (4) the foundation, which signifies the underlying digital and organizational infrastructure upon which the entire system rests.

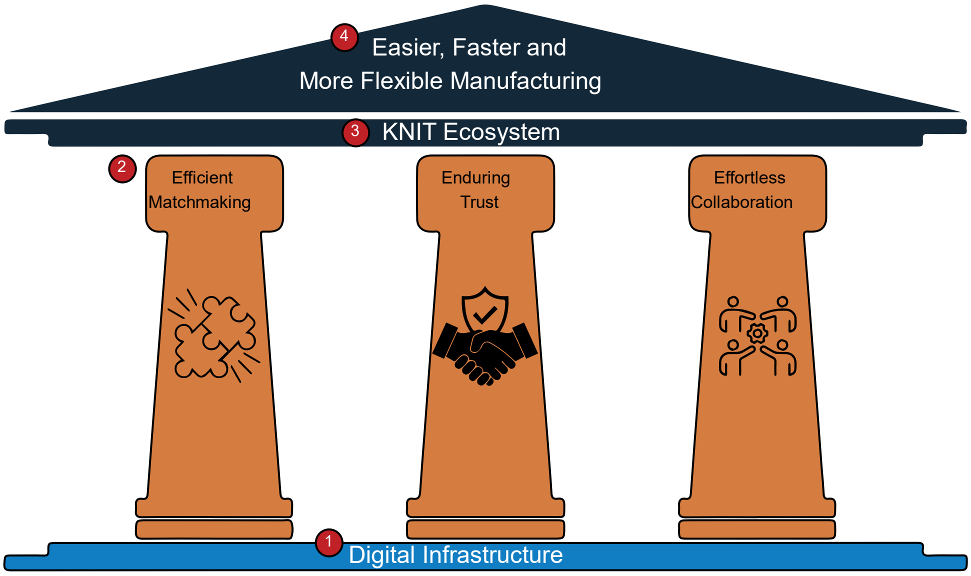

Figure 2: KNIT Conceptual Framework Pillars of a Scalable Manufacturing Platform

Each pillar embodies a distinct capability:

- **Efficient Matchmaking**

The first pillar ensures that the platform transcends the role of a simple supplier directory to become an intelligent matching system. This involves integrating advanced algorithms and rich data feeds to consistently identify optimal buyer–supplier pairs.

Rather than defaulting to lowest-cost bidding, the platform under KNIT would consider multidimensional attributes: supplier capacity and specialization, quality history, lead time performance, certifications, past reliability, and even contextual factors (like current factory load or geographic proximity for logistics). By accessing verified performance data and employing AI-driven recommendation systems, the platform can shift from random or manual supplier selection to strategic matchmaking. For example, if a buyer needs a complex CNCmachined part in aluminum with tight tolerances, the platform's algorithm might weigh a supplier's historical defect rate on similar parts, their machine capabilities, and on-time delivery record more heavily than price. Over time, as data accumulates, the matchmaking becomes increasingly precise, improving outcomes for both sides. Our interviewees expressed strong interest in this kind of "smart matching" – one noted that "having the platform suggest a supplier because it has a 98% on-time record for similar aerospace parts would immediately inspire confidence." Efficient matchmaking thus drives better production results (fewer delays, higher quality) and fosters long-term partnerships by introducing compatibility in the selection process. This pillar directly tackles the earlier-identified problem of superficial matching by making the platform a knowledgeable broker, not just a listing service.

- **Enduring Trust**

The second, central pillar is the enforcement and cultivation of trust. Trust is treated not as a byproduct but as a deliberate design goal of the platform. In the KNIT framework, trust is built through two primary mechanisms: performance incentivization and radical transparency. Performance incentivization means the platform actively rewards good performance. For instance, suppliers with excellent quality and delivery records gain higher visibility in search results, receive badges or certifications on their profiles, and get first access to top-tier job opportunities. Conversely, sub-par performance has tangible consequences (reduced visibility, probation, or suspension for serious breaches). This creates a selfreinforcing feedback loop where all participants are motivated to uphold high standards. Buyers are also incentivized to be reliable (e.g., timely payments and clear specifications might earn them a "preferred buyer" status that attracts the best suppliers). Radical transparency complements this by providing platform users with comprehensive, verified information. Instead of sparse profiles, a supplier's page might show their detailed capabilities, machine list, past project metrics (e.g., average deviation from promised delivery, rejection rate), and customer feedback narratives. Importantly, data integrity must be assured – possibly via blockchain or third-party audits – so that users trust that the information is accurate and tamper-proof. By offering this level of transparency, the platform significantly reduces the information asymmetry that currently plagues outsourcing decisions. Figure 3 summarizes the major systems required for trust enforcement in the KNIT ecosystem: from robust review systems and dispute resolution processes to secure data sharing protocols and perhaps escrow-based payments to protect both parties. When trust is engineered in this way, companies become willing to outsource more critical, higher-value manufacturing tasks through the platform. In theoretical terms, this pillar lowers the perceived transaction costs related to partner uncertainty and contract enforcement, making external transactions more comparable to the assurance of internal operations.

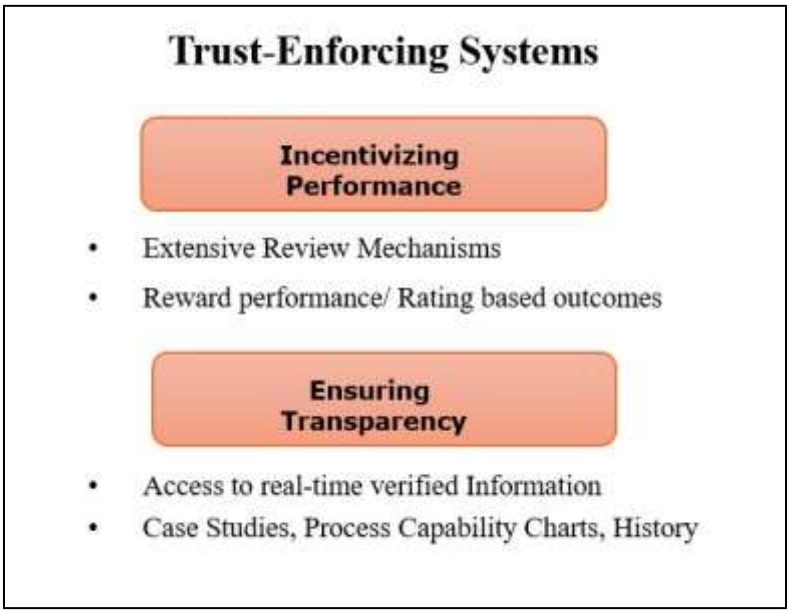

Figure 3: Trust Enforcement Systems in KNIT Marketplace

- **Effortless Collaboration**

The third pillar focuses on reducing friction in the collaboration and communication necessary for complex manufacturing projects. Traditional outsourcing often falters due to miscommunications or coordination delays. In the KNIT framework, the platform provides a suite of collaboration tools that make working together almost as seamless as if the teams were in the same organization. This could include integrated project workspaces where buyers and suppliers share design files, discuss adjustments via built-in chat or video conferencing, and track progress milestones on a standard dashboard. There may be version control for CAD drawings, a log of agreed-upon changes, and instantaneous notification systems for any updates or issues. By having these tools natively on the platform, there is no need to switch to email or external systems, which often leads to information loss or security risks. The platform can also integrate with standard project management or PLM (Product Lifecycle Management) software that larger firms use, creating a synchronized data environment. For example, if a buyer updates a 3D model, the supplier is immediately alerted and always sees the latest version, avoiding the classic error of manufacturing to an outdated spec. Effortless collaboration extends to multi-party scenarios as well: if a project involves a designer, a contract manufacturer, and a materials supplier, the platform can host a shared space where all three coordinate, mediated by appropriate data permissions. The goal is to move beyond transactional interactions into co-creative relationships. In practical terms, this pillar addresses the complaint that current platforms "get in the way" of necessary communication. Instead, the platform becomes an enabler of rich interaction, which is crucial for iterative development and rapid problem resolution. One of our interview participants, a project engineer, noted that having an on-platform system where "I could quickly jump on a call with the supplier's machinist, look at the same 3D model and draw annotations in real time" would have saved him weeks of back-and-forth on a recent prototype order. That exemplifies the kind of fluid collaboration experience KNIT aims to provide.

When implemented together, these three pillars create a self-reinforcing network – a digitally connected ecosystem of companies that collectively support each other's growth and performance. Efficient matchmaking brings the right participants together; enduring trust keeps them engaged and willing to transact repeatedly; effortless collaboration makes each transaction (or joint project) smooth and successful. As this network scales in size and activity, it gains critical mass, which further enhances the platform's value proposition, attracting even more users. The result is a positive feedback loop of growth and improvement. Companies in this ecosystem find that the traditional trade-offs in manufacturing (time vs. cost vs. control) begin to diminish. For example, because trust is high and collaboration is seamless, a buyer might confidently outsource a complex assembly to a supplier on short notice (speed) without a significant risk premium (cost) and still ensure specifications are met (control). In other words, the KNIT ecosystem breaks traditional constraints by enabling high levels of control, speed, and customization simultaneously and without prohibitive resource investment. This kind of paradigm shift – a modular yet tightly coordinated production network – represents a new manufacturing paradigm optimized for innovation at scale. The following sections delve deeper into how the KNIT framework triggers network effects and what implications it holds for transaction cost economics and industry structure.

4.3. Enforcing Trust and Accountability on the Platform

Given its central role in the KNIT framework, trust deserves focused examination regarding how it can be operationalized on a manufacturing platform. In our proposed model, trust enforcement relies on two complementary strategies: performance incentivization and radical transparency, outlined below:

Performance Incentivization: The platform implements robust review and rating systems for every completed transaction. Both buyers and suppliers are required (or strongly encouraged) to rate each other on multiple dimensions e.g., for suppliers: quality of output, adherence to lead time, communication effectiveness; for buyers: clarity of specifications, timeliness of payment, and collaboration. Rather than a simplistic 5-star average, the platform may maintain a composite scorecard. For instance, a supplier's profile might show a Quality Score (percentage of orders meeting quality criteria), a Reliability Score (on-time delivery percentage), and a Communication Score (peer-rated). Advanced analytics could also compute an overall "Trust Index." The platform's algorithms use these metrics to influence future matchmaking: high-performing suppliers rank higher in search results and get priority in algorithmic matches for new inquiries, as noted. Conversely, suppliers with declining performance see fewer job opportunities – a direct economic incentive to maintain standards. The platform could periodically recognize top performers with badges like "Gold Supplier" or even tangible benefits (lower commission fees or access to premium clients), thus rewarding excellence. Importantly, these incentives must be clearly communicated to all users so that they understand that better performance means more business. Several interviewees from supplier companies voiced that such a merit-based system would make them more invested in platform success; one noted, "If I know landing a five-star rating gets me in front of marquee customers, you bet I'll treat those small jobs seriously." In addition, the platform can encourage continuous improvement by providing analytics back to the suppliers – for example, a supplier could see how their on-time rate compares to the platform average, motivating them to improve if they lag behind.

From the buyer's side, performance incentives mean that buyers who develop a reputation for fair dealing and good project management will be favored by suppliers. The platform might allow suppliers to bid more aggressively (i.e., offer better prices or terms) for buyers tagged as "trusted" because they know working with such buyers carries less risk. This dynamic encourages buyers to also adhere to best practices (like freezing design changes after a cutoff, providing prompt feedback, etc.), creating mutual accountability. Overall, the performance incentive system instills a culture of meritocracy and accountability reminiscent of successful gig-economy and ecommerce platforms, but here tailored to manufacturing's specific trust factors.

Radical Transparency: The second prong of trust enforcement is making information as transparent as possible to all parties, within the bounds of confidentiality. Platforms will verify supplier claims for example, requiring evidence of ISO certifications or performing site audits for key suppliers and mark profiles as "Verified" for certain attributes. A "Verified Capacity" badge might indicate the platform has confirmed a supplier's machine equipment and throughput capabilities via an audit or data integration. Where confidentiality permits, detailed process data is shared: suppliers might upload process capability indices (Cpk values for critical dimensions they can hold), example case studies of past work, and photographs or videos of their facilities. Buyers thus gain a richer impression akin to visiting the supplier's factory virtually. On the other hand, suppliers can view a buyer's order history and reliability, including the frequency of order cancellations and their average rating from suppliers, which helps them decide with whom to partner.

A crucial aspect of transparency is the handling of problems. In a trust-rich platform, issues like delays or defects are not swept under the rug but documented and resolved openly. For instance, if a supplier delivers parts late, the incident and its resolution (e.g., discount given, root cause addressed) might be noted in the transaction record. This may seem risky – why would a supplier want future buyers to see that they had a late delivery? However, if managed properly, it builds trust: a future buyer sees not just the late delivery, but that the supplier took responsibility and has since improved. Open dispute resolution mechanisms could allow an impartial platform moderator or even community arbitration for conflicts, with outcomes logged. This approach, advocated by Sun & Qu (2025) in the governance context, ensures accountability.

To make transparency viable, the platform may need to implement data permission controls. For example, a supplier might allow only logged-in vetted buyers to see certain sensitive information, such as client names in case studies. But within a closed, vetted community, more information sharing leads to more trust. Notably, blockchain technology can underpin this transparency by providing an immutable audit trail of all transactions and performance records. If each job's key parameters (dates, outcomes, ratings) are recorded on a blockchain ledger accessible to stakeholders, it becomes challenging for anyone to falsify their record or hide breaches. This permanence encourages honesty and consistency. Kayhan (2022) demonstrated how such an approach increased trust in pharma supply chains; applied here, it means that when a platform user sees a supplier's track record, they can trust that record's authenticity.

Combining these features, the KNIT platform's trust environment would make it normal and safe for companies to outsource even core manufacturing activities. As one policy implication (discussed later), regulatory bodies or industry groups might even come to rely on platform transparency (for instance, seeing an unbroken blockchain trail of material certifications could satisfy regulatory audits). Trust enforcement transforms the platform from a risky unknown into a dependable partner. This is the linchpin that allows transaction cost calculations to shift in favor of using the market (platform) over hierarchy (vertical integration), aligning with an updated Transaction Cost Theory perspective that includes digital trust.

4.4. Self-Reinforcing Network Effects and Platform Scaling

A critical aspect of achieving scalability is leveraging network effects – the phenomenon where the platform's value increases as more participants join and engage. The KNIT framework is explicitly designed to trigger and sustain strong network effects in manufacturing. We identify two intertwined feedback loops (commercial and operational) that drive growth, as shown in Figure 4. Both "Bigger Ecosystem" and "Increased Manufacturing" are highlighted as the convergence points of the two loops. *Bigger Ecosystem* anchors the commercial loop, capturing how growing participation and reinvestment expand the network's scale, while *Increased Manufacturing* anchors the operational loop, reflecting how efficiency and utilization improvements translate into higher output. These nodes mark the reinforcing outcomes that sustain the self-propelling cycles of platform growth.

Figure 4: Dual Network Effect Loops in a Scalable Manufacturing Platform

In the left loop, the Commercial Loop focuses on the platform's financial sustainability and reinvestment capacity. As user activity grows, the platform generates higher revenue (through transaction fees, subscriptions for value-added services, etc.). With a stronger revenue base, the platform company can reinvest in improvements, such as developing even more sophisticated matching algorithms, adding new collaboration features, or expanding into new regions and manufacturing processes. These investments lead to superior services and user experience. For instance, incorporating machine learning to predict and preempt supply chain disruptions for users, or launching an integrated RFQ-to-invoice financial system to streamline transactions. Better services attract more participants, as the platform now offers an even more compelling value proposition. Additionally, increased scale can allow the platform to reduce per-unit costs or fees, sharing economies of scale benefits with users, which further attracts usage (similar to how larger e-commerce platforms can charge lower commissions). This forms another positive feedback loop: growth funds improvements, which fuel more growth.

On the right side loop, the Operational Loop, the dynamics of Increased Manufacturing come into focus. As the platform attracts more suppliers and buyers, the efficiency of matchmaking and resource utilization improves. With a larger pool of suppliers, the likelihood of an excellent match for any given job increases, meaning buyers get better service (faster lead times, better prices, higher quality). For suppliers, a larger demand pool means they can achieve higher capacity utilization and smoother order flow. These improvements lead to tangible outcomes: shorter production cycle times, optimized production loads, and enhanced supply chain agility for participants. For example, a buyer who might have taken 4 weeks to source a specialized part now finds a capable supplier in 4 days on the platform and receives the part in 2 weeks, cutting their lead time in half. Such success stories draw more buyers (seeking speed and reliability) to the platform.

Meanwhile, suppliers that see consistent work coming from the platform will invest further, perhaps adding capabilities or joining premium tiers. The resulting increase in activity strengthens the platform's network, which further improves matching and efficiency a virtuous circle. This aligns with classical network effect theory: more users beget more value, which in turn begets more users. In manufacturing, this dynamic was not guaranteed (because of trust and complexity issues), but the KNIT design ensures that increased participation actually yields better outcomes through the pillars we've established.

These loops are intertwined. For example, improved operational performance (first loop) leads to happy customers who advocate for the platform, contributing to growth, which feeds the second loop. Conversely, new features from reinvestment might include operational analytics that further improve efficiency, boosting the first loop. Once these self-reinforcing cycles are set in motion, the platform can achieve a dominant position, reaching the critical mass where competitors find it hard to lure users away, and the value of staying on the platform exceeds any benefits of alternative arrangements. In manufacturing, reaching critical mass could have profound implications: it might become disadvantageous for a supplier not to be on the platform, because so many clients use it as their primary sourcing tool. Likewise, product companies might risk missing out on the best suppliers if they stick to traditional procurement.

Importantly, in the manufacturing context, achieving this momentum can disrupt traditional sourcing models. As the platform consolidates a previously fragmented market, it can reduce inefficiencies like redundant supplier searches, inconsistent standards, and slow manual negotiations. The overall industry can see a productivity boost effectively, the platform becomes part of the manufacturing infrastructure. Our findings highlight that designing for early network effect triggers is essential: by focusing initially on specific sectors or regions to build density, for instance, the platform can demonstrate the network loops at a smaller scale, then expand outward. Additionally, ensuring continuous quality improvement through trust and collaboration features prevents adverse network effects where growth could bring in low-quality participants that deter others. By carefully curating quality while scaling, the platform avoids the fate of some marketplaces that grew quickly but lost quality control.

The network effect analysis underscores that technology alone isn't enough it is the systemic alignment of user incentives, economics, and experience that creates a self-propelling ecosystem. By simultaneously addressing those factors (efficient matches improve incentives, trust governance aligns economics, and collaboration tools enhance experience), the KNIT framework lays the groundwork for network effects to flourish. If successful, the manufacturing platform becomes a natural monopoly-like utility for outsourced production needs, creating a new landscape where the cost to produce custom products drops and speed to market increases for all participants leveraging the network.

4.5. Implications for Transactional Costs, Firm Boundaries, and Supply Chains

One of the most intriguing aspects of a scalable, trust-based manufacturing platform is its potential to reshape classic firm boundaries and supply chain structures, echoing themes from Transaction Cost Economics. Our findings suggest that if the KNIT framework were realized in practice, it would significantly lower external transaction costs to the point of altering the fundamental makeor-buy calculus for firms. In traditional manufacturing contexts, companies often chose to vertically integrate (make in-house) because the transaction costs of outsourcing finding reliable suppliers, negotiating contracts, ensuring quality, and protecting intellectual property were too high (Coase, 1937; Williamson, 1981). For many complex products, outsourcing each component to different suppliers would introduce high coordination costs and risks, outweighing the market's production cost advantages. Thus, large firms kept extensive internal manufacturing capabilities to avoid these external frictions.

However, a trusted manufacturing platform at scale changes that equation. With efficient matchmaking, enforced trust, and seamless collaboration, many of the historical transaction costs are drastically reduced or practically eliminated. The cost and time to find a capable supplier becomes minimal – a quick query on the platform yields vetted options. The cost of negotiating and enforcing a contract is lowered by the platform's standardized terms, escrow services, and reputation system, which deters malfeasance. Quality assurance costs decrease because the platform offers transparency and potentially integrated quality control services. Essentially, when the external market (platform) can deliver manufacturing services with low coordination overhead and high reliability, outsourcing becomes far more attractive economically.

Our study reinforces this outcome: interviewees from product firms indicated that with sufficient trust in a platform, they would be willing to outsource not just auxiliary parts but core components as well something they would never consider today. As one executive put it, "If I had a nearguarantee of quality and on-time delivery, why would I keep running an expensive machine shop in-house? I'd much rather focus on R&D and product design." This sentiment suggests that firms may become lean organizations, focusing on their unique value such as design, IP, and branding and leveraging the platform for manufacturing execution. In essence, the manufacturing capability turns into a "utility" accessible on demand. When external transaction costs fall below internal governance costs, Transaction Cost Theory predicts firms will favor the market solution (outsourcing) (Xue et al., 2017; Park et al., 2024). Our findings exemplify this: as the platform mitigates risk and coordination efforts, even large OEMs might reduce their in-house production facilities.

The consequence would be shrinking firm boundaries: companies evolve into more specialized entities, focusing on what they do best and outsourcing the rest through the platform. We could see the rise of highly specialized manufacturing providers who serve many product firms via the platform, and product companies that no longer own factories but still bring complex products to market through orchestration. This reconfiguration aligns with trends in other industries (e.g., the way the cloud computing platform AWS led companies to shut down their own data centers in favor of renting capacity). In manufacturing, this is a more radical shift given the physical nature, but a trusted platform makes it plausible.

As more companies decouple manufacturing from their core operations, industry structures would tilt towards networks of specialized firms. Manufacturing-as-a-service could become common. Specialized contract manufacturers may grow in prominence, competing based on innovation, speed, and efficiency on the platform. These firms might not have famous brand names to end consumers, but they become critical partners behind many products, analogous to how semiconductor foundries operate behind numerous electronics brands. Product firms, freed from the constraints of owning and maintaining production lines, can funnel resources into product development, design innovation, and marketing. This could accelerate overall innovation, as each party in the ecosystem focuses on its comparative advantage.

Our findings also indicate that this transformation promotes innovation-centric competition both among product companies and manufacturing providers. Product companies will compete on design ingenuity, customer experience, and their ability to integrate the best capabilities from the platform's network. Manufacturers on the platform will compete to offer the best performance, because the platform transparently rewards it (as discussed in trust enforcement). The net effect is a decentralized yet highly coordinated manufacturing landscape where vertical integration is less common. Instead of one giant company owning everything from design to production to distribution, we may have many interlinked companies collaborating via the platform on a per project basis.

Policymakers and industry leaders must note that such a shift would require adaptations. Supply chain policies might need to ensure such platforms do not create monopolistic control or unfairly exclude SMEs. Antitrust considerations might evolve a dominant platform would concentrate a lot of market information and power, though ideally governed by fair rules. But from an economic standpoint, lowering transaction costs and enabling hyper-specialization can lead to significant efficiency gains and agility in supply chains. We already see hints of this in some sectors (e.g., electronics firms' fabless manufacturing), and the KNIT framework could extend it to a broader manufacturing domain.

In summary, the successful scaling of a trust-centric manufacturing platform as envisioned could diminish the traditional rationale for vertical integration in manufacturing. Firms could safely rely on the "market" (in the form of the digital platform) for production needs, leading to leaner organizations and a more dynamic, specialized supply chain network. This is not merely a theoretical outcome; it is supported by the convergence of evidence in our study and aligns with modern interpretations of Transaction Cost Theory in the digital age. The following section will discuss concrete recommendations stemming from these findings, for theory, practice, and policy, to realize the potential benefits while managing the transition challenges.

5.0 CONCLUSION AND FUTURE RECOMMENDATIONS

5.1. Conclusion

This study set out to investigate why existing manufacturing marketplaces have failed to scale and to propose a new framework to overcome these challenges. Through a comprehensive analysis of literature, industry evidence, and expert insights, we identified that current platforms are hindered by superficial matchmaking, deficient trust mechanisms, and constrained collaboration all of which prevent the emergence of powerful network effects in the manufacturing domain. In response, we introduced the KNIT framework, built on the pillars of Efficient Matchmaking, Enduring Trust, and Effortless Collaboration, as a holistic solution. The framework reimagines a manufacturing platform not merely as a transactional intermediary but as an integrated ecosystem orchestrator that tightly knits together producers and consumers of manufacturing services.

The findings underscore several key conclusions. First, trust is the linchpin of scalable manufacturing networks. Without deliberate trust-building measures such as robust supplier vetting, transparent performance data, and fair incentive structures, companies will remain reluctant to outsource critical manufacturing activities on a platform. Our proposed trust enforcement mechanisms demonstrate a viable path to creating credibility and accountability in online manufacturing exchanges, converting them from high-risk ventures into dependable partnerships. Second, technology must be complemented by governance. Advanced algorithms for matchmaking and collaboration tools for project execution are necessary but insufficient on their own. The success of a manufacturing marketplace equally depends on governance policies that ensure quality control, protect intellectual property, and maintain a level playing field for participants. This study contributes a framework that blends technical design with governance principles to address those needs.

Third, the research highlights that scaling manufacturing platforms can fundamentally reshape industry economics. By dramatically lowering external transaction costs, a high-trust platform enables firms to make outsourcing decisions based on strategic advantage rather than fear of coordination failure. The likely result, as we conclude, is a shift towards more specialized, agile firms and a more networked industry structure. This conclusion aligns with an extended view of Transaction Cost Theory in the digital era: as digital platforms reduce coordination frictions, market-based structures become more efficient relative to hierarchies. Over time, we anticipate that product companies will increasingly adopt asset-light models, focusing on design and innovation while leveraging platform-linked manufacturing partners for production. Manufacturing firms, in turn, will concentrate on operational excellence and innovation in their niches, serving a diverse array of clients through the platform.

Finally, our study closes the loop by demonstrating that a well-designed platform can create self-reinforcing growth in the manufacturing sector. The KNIT framework's elements collectively cultivate network effects that benefit all participants' faster times to market for product developers, higher capacity utilization and expanded reach for manufacturers, and accelerated diffusion of manufacturing innovations across the network. In an era where speed and flexibility determine competitiveness, such platforms could become essential infrastructure, doing for physical production what cloud computing did for IT infrastructure. The conclusion we draw is optimistic: the longstanding "valley of death" in manufacturing innovation can be narrowed by an ecosystem that effectively connects ideas to manufacturing capacity at scale. Realizing this vision, however, requires concerted efforts from platform designers, industry practitioners, and policymakers. In the next section, we put forward specific recommendations for each of these stakeholders to help turn the KNIT framework into reality and to ensure the resulting ecosystem develops in a healthy, inclusive, and innovative manner.

5.2. Future Recommendations

Based on the study's findings, we offer a set of practical, theoretical, and policy recommendations to support the development of trust-centric manufacturing platforms. Practically, platform developers should adopt the KNIT framework by strengthening data-driven matchmaking, building robust trust infrastructure, and integrating collaborative tools tailored to manufacturing workflows. Fostering a sense of community among users through mentorship, knowledge-sharing, and success stories can further enhance engagement and trust. Manufacturers are encouraged to adopt a phased approach to platform usage, update procurement processes, and revisit make-orbuy decisions in light of reduced coordination costs and enhanced responsiveness offered by digital platforms. Theoretically, scholars should expand models like Transaction Cost Economics and platform ecosystem theory to account for trust, data, and new digital coordination mechanisms such as blockchain and AI. Empirical research should explore constructs like network trust, platform stickiness, and multi-sided value creation. From a policy perspective, there is a need for standardized frameworks governing data exchange, cybersecurity, and certification to ensure supplier interoperability and trust. Modernizing contract law to support digital agreements, providing incentives for SME participation, and ensuring fair access across the ecosystem will be crucial in enabling inclusive and competitive platform-based manufacturing.

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