# The Elastic Supply Chain: Scaling Additive Manufacturing for End-to-End Orchestration

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***Abstract*—This paper examines the integration of additive manufacturing (AM) into an elastic, end-to-end orchestrated supply chain, with a focus on internal organizational implementation rather than external network integration. AM's core benefits, including virtual warehousing, distributed and localized manufacturing, and product customization, offer organizations lower fixed costs, reduced lead times, and rapid responsiveness to demand volatility. Realizing these benefits, however, requires overcoming significant obstacles including intellectual property, quality assurance, and high capital expenditure. The paper highlights that cloud computing, digital twins, and the Internet of Things (IoT) form the essential technology infrastructure underpinning an elastic AM supply chain, while master data management remains a critical prerequisite that many organizations underestimate. Building on this foundation, the paper proposes a practical path for embedding additive manufacturing into existing operations and evaluates several methods for digitizing legacy product data. Finally, the paper explores emerging trends, including AI-driven production, expanded digital twin simulation, and bio-based materials, that are expected to shape the next phase of additive manufacturing in supply chain management.**

***Index Terms*—Elastic Supply Chain, Additive Manufacturing, Automated Orchestration, Industry 4.0**

## I. Introduction and Background

The main purpose of a company is to increase its shareholders' value over time. Therefore, executives tend to focus more on financial metrics that affect the top and bottom line, such as earnings before interest, taxes, depreciation, and amortization (EBITDA), earnings per share (EPS), gross margin, and return on capital employed (ROCE), to name a few, while forgetting the importance of the cost reductions achieved through modification of the supply chain and its operations [1]. This may lead to insufficient attention to the development of this critical function. Many companies are left with the rigidity of the traditional supply chain, which suffers from inflexibility of sourcing, holds back on demand and supply cycles, and maintains a low level of coordination between various supply chain stakeholders from sourcing to consumer [2].

Contrasting with the traditional supply chain is the elastic supply chain, which is defined as the responsiveness of one variable to changes in another. The concept is applied in the supply chain by shifting from high fixed costs to variable costs in its operations. It enables processes to rapidly expand or contract their capabilities in response to market volatility, and it supports the strategic goal of minimizing inventory and storage management. However, it requires heavy technological integration and support [3].

Additive manufacturing is a key complementary component of a true elastic supply chain. Additive manufacturing, or 3D printing, is a technology that uses a variety of materials, such as plastic or metal, to build a three-dimensional product by layering materials on top of each other, with each layer typically measuring from 0.001 to 0.1 inches thick. AM significantly influences the supply chain by enabling on-demand manufacturing, desensitization of product manufacturing, product customization, and simplified logistics, all at a lower cost. Nevertheless, scaling AM in the supply chain involves overcoming many barriers, from limitations in printing size and speed to regulation [4].

On top of that, end-to-end orchestration introduces an additional layer of complexity to the challenge of integrating the supply chain with additive manufacturing. This orchestration approach demands a robust technological infrastructure alongside seamless system integration. At a minimum, the system must provide a strong material master data catalogue, high visibility for easily obtaining information, and tools that enable communication and information exchange. Other factors, such as risk assessment and predictive capabilities, play a role in adapting to external supply chain disruptions [5].

This paper aims to shed light on the main benefits and challenges that supply chains might encounter when adopting orchestration and additive manufacturing. In its discussion, the paper focuses on implementation of an elastic additive manufacturing supply chain within the organization, rather than on integration with external networks. Lastly, it explores future prospects, including emerging trends.

## II. Additive Manufacturing in Supply Chain

According to Attaran [4], although additive manufacturing technology has existed for decades, it has recently gained popularity due to the expiration of key patents, decreasing costs, and the development of more capable printers. Common additive manufacturing technologies include:

- **Stereolithography:** use of an ultraviolet laser to cure and solidify resin.
- **Selective Laser Sintering:** use of a high-powered laser to fuse polymer powder.
- **Direct Digital Manufacturing:** produces parts directly from a digital file, skipping some steps required in other 3D printing technologies.
- **Fused Deposition Modeling:** use of a heat extruder to melt and extrude filament.

Moving from additive manufacturing technologies to global market estimates, the size of the additive manufacturing market will be close to $50 billion by 2030. The breakdown of the market size is as follows: molds and tools, $21 billion; end-use components, $19 billion; and prototyping, close to $10 billion [6]. Combining the variety of additive manufacturing technologies and filaments with exponential global market growth makes the inclusion of additive manufacturing in the supply chain a strategic

move toward achieving elasticity. The key benefits this paper focuses on are the transition to virtual warehousing, distributed and localized manufacturing, and product customization.

*A. Benefits of Integrating Additive Manufacturing*

The concept of virtual warehousing involves storing digital product files, in specific formats, integrated into a system that enables on-demand manufacturing and the application of a virtual just-in-time logistics strategy, thereby eliminating the need for physical inventory. This digital inventory, comprising product files, serves as one element of the virtual warehouse. Beside the benefits of supply chain resilience and cost and time savings, additive manufacturing has a positive environmental impact by minimizing scrap waste and transportation emissions through decentralized local production. On the other hand, companies may face challenges, including a lack of digital data (CAD files) for legacy products and lower product quality compared with traditionally manufactured parts [7].

Distributed and localized manufacturing is another major benefit of additive manufacturing adoption. The cyber supply chain represents a shift from physical to digital movement, where interconnected networks are used to request digital files and localize manufacturing accordingly. A case study built around this concept tested the benefits and challenges of localizing manufacturing and its effect on high-mix, low-volume products. The results highlighted an improvement in operational resilience, with 65% less order backlog, as well as an improvement in environmental sustainability, with a 17% reduction in $CO_2$ emissions. However, the cyber supply chain has its own unique challenges due to heavy dependence on technology, cost of implementation, and intellectual property concerns [8].

Additive manufacturing builds each unit directly from a digital file, which differs from molding or subtractive processes; it removes many of the fixed tooling costs that traditionally discourage manufacturers from offering high product variety. This allows organizations to employ more engineers and provides freedom for incremental design improvement of product geometry between successive builds, unlike conventional subtractive or molding methods. In an elastic supply chain, responsiveness is valuable in industries characterized by high product variety, short life cycles, or highly specific customer requirements [9]. This capability allows organizations to customize products or redesign components for improved performance without added lead time and capital expenditure. AM has shifted the economy-of-scale concept from traditional production of large, uniform batches to efficient production of low-volume product variants. Fig. I shows a comparison between the cost trend of AM and traditional production as volumes increase, while Fig. II shows the trend of AM and traditional production costs as geometric complexity increases.

FIG. I. COST TREND OF AM AND TRADITIONAL PRODUCTION AS VOLUME INCREASES.

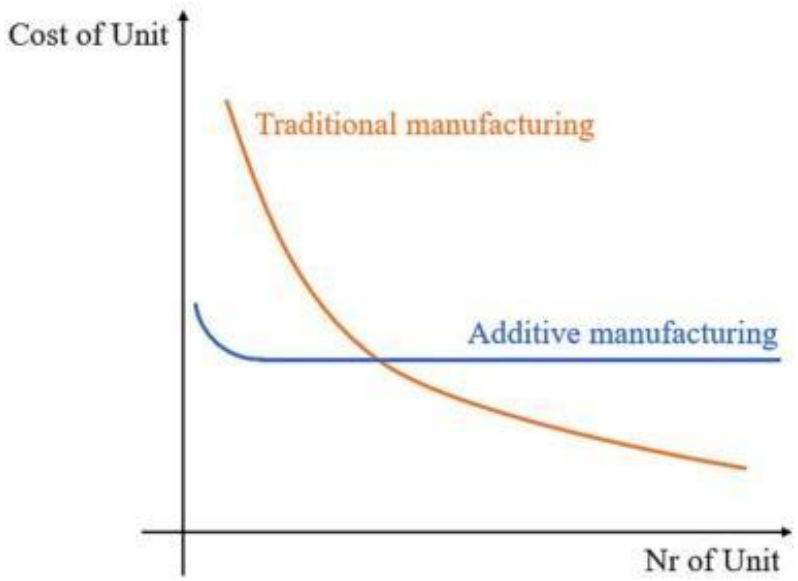
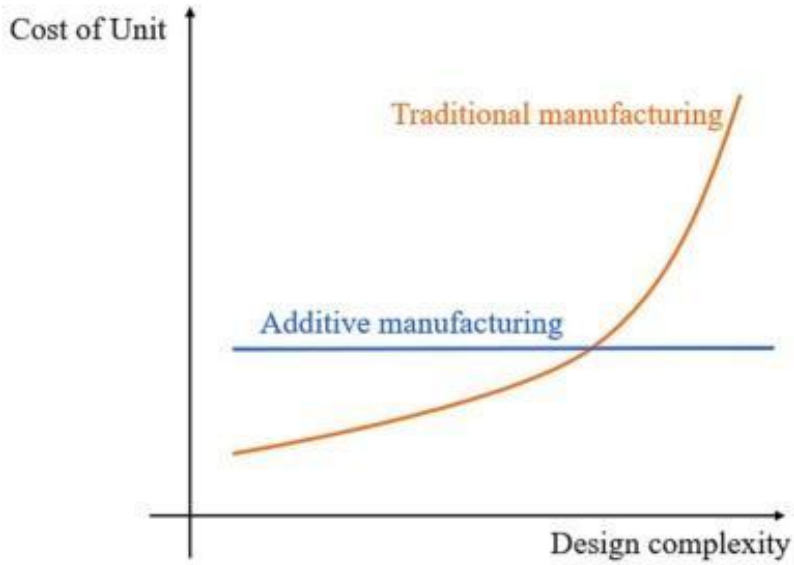


FIG. II. COST TREND OF AM AND TRADITIONAL PRODUCTION AS COMPLEXITY INCREASES.




This transition is closely tied to a broader redesign of the supply chain around customer requirements, with production decisions increasingly triggered by confirmed orders rather than demand forecasts. However, implementing such a concept requires investment in technology infrastructure and engineers who can convert customer requirements into printable designs [10].

Even though additive manufacturing provides cutting-edge benefits, integrating it into an elastic orchestrated supply chain is guarded by several challenges. The three primary challenges surrounding adoption are the protection of intellectual property, maintenance of part quality across distributed production sites, and capital expenditure and post-processing requirements.

### *B. Challenges of Integrating Additive Manufacturing*

Intellectual property protection is widely regarded as one of the most significant challenges limiting organizations from adopting additive manufacturing, because AM relies on the transmission of digital design files rather than the physical movement of parts. This vulnerability may lead to unauthorized use, redistribution, or reverse engineering. Quantitative survey results show that even with an acknowledgement of the advantages AM brings to the supply chain, significant concern about the security of intellectual property is still held within organizations [11]. A further complication is the lack of established standards for how digital designs should be handled and protected, leaving organizations to develop firm-specific governance or ad hoc policies that may hinder supply chain integration [12]. Existing copyright and patent frameworks were also developed with physical reproduction in mind, leaving a gap in how to handle digital designs for personal use [10]. Overall, organizations aiming to adopt an elastic additive manufacturing supply chain must evaluate the return on investment, including the potential risk of contractual breaches and design leakage [14].

Another significant challenge for AM is quality assurance, in terms of consistency and reliability, relative to parts produced through traditional production methods. AM still has a wider tolerance range in manufacturing due to small variations in process parameters, such as layer thickness, laser or extruder power, and material feed rate. Despite advances in monitoring techniques such as point-cloud fusion and optical metrology, ensuring consistent quality across successive builds remains an unresolved challenge that limits expanded use of the technology [13]. As technology rapidly develops, the emerging application of artificial intelligence to defect detection, parameter optimization, and predictive maintenance shows promise for improving production quality. However, these approaches require standardized protocols and heavy validation before they can be relied upon, since AI-driven quality control could introduce new sources of variability [14].

The last challenge of adopting AM within an elastic supply chain relates to high initial capital expenditure and the additional post-processing requirements that AM products demand. AM machines, particularly metal powder-bed and directed-energy-deposition systems, are costly and require sustained high utilization to offset the initial investment [15]. A further challenge is that a printed part is rarely ready for use straight off the build plate. Often, a part requires build-plate and support-structure removal, heat treatment, and surface finishing, and for some metal processes, additional steps such as debinding and sintering are typically required before a part meets its final specification. Detailed cost-breakdown studies show that these post-processing steps, together with machine, material, and labor costs, can represent a substantial share of total part cost, in some cases exceeding the cost of the print itself [16]. Return-on-investment frameworks conclude that additive manufacturing is feasible when equipment is utilized for complex, low-volume, high-variability products, while AM remains less economically attractive for simple, stable, high-volume products [17].

## III. Role of Technology in Elastic Supply Chain

### *A. Technology Infrastructure: Cloud, Digital Twin, and IoT*

Essential prerequisites for successful adoption of additive manufacturing in an elastic supply chain include virtual warehousing, distributed and localized manufacturing, and product customization. The primary requirement is a technology layer that serves as the foundation for infrastructure integration and a material master data system, which contains print-ready design files alongside the metadata needed to select an appropriate machine, material, and process for each order [5]. Cloud computing orchestration enables analysis and automation of multiple workflows, including quotation generation, feasibility screening, and production scheduling per customer specification. By executing these tasks on an aggregated basis, organizations can substantially reduce manual intervention and operational overhead [18].

A second technological requirement is real-time visibility and scenario replication across demand planning, inventory management, production, and procurement. Digital twins fulfill this role by providing a virtual replication of actual organizational processes that is continuously updated with operational data to mitigate risk and improve efficiency. Digital twins support the kind of proactive capacity planning that an elastic supply chain requires [19]. Building on this simulation capability, artificial intelligence and machine learning models are increasingly adopted to forecast demand and optimize the allocation of print jobs across available machines [12].

The Internet of Things (IoT) complements cloud computing and digital twins, as IoT sensors feed the cloud with data from various inputs, such as raw material stock and logistics, to create an interconnected system capable of dynamic reconfiguration. Embedded sensors on AM machines report variables such as temperature, material consumption, and machine status in real time. Feeding this live operational data into cloud orchestration platforms enables the supply chain to reallocate resources more quickly and efficiently during periods of disruption [10].

Because the success of elastic supply chains depends on a continuous stream of accurate operational data, their effectiveness is closely tied to the quality of the underlying technology infrastructure, enterprise resource planning (ERP) systems, and the broader orchestration platform; where interconnection is weak, demand planning and recommendations lose their reliability.

### *B. Implementation Barriers: Interoperability, Cybersecurity, and Master Data*

Organizations attempting to build their technology infrastructure face substantial implementation barriers of their own, distinct from additive manufacturing challenges. The first barrier is the lack of a standardized platform across the machines, software, and file formats used in additive manufacturing. Integrating various AM machines into a single cloud platform or existing organizational ERP system is a complex task that may lead to data misalignment [8]. Researchers are exploring the possibility of seamless integration and data exchange through artificial intelligence and machine learning; achieving this integration can reduce the complexity of using separate software tools [14].

Because of excessive reliance on technology, the elastic supply chain becomes vulnerable to cyberattacks, which can have a severe impact on the entire supply chain. Intellectual property leakage through unauthorized access or data breaches elevates costs for organizations, especially regarding sensitive CAD files. One solution to mitigate some of the risks associated with the leakage of design files is a digital passport: creating a blockchain-encrypted digital passport for each design file that tracks IP ownership while maintaining the least amount of sensitive data [8]. Yet this solution brings organizations back to reliance on technology once again.

Master data management is a major barrier; without digitized design files, the whole process becomes meaningless. Building a master data management portfolio is often challenging, as effective implementation requires not only technical specifications and geometry but also manufacturability and material data [7].

## IV. Discussion

Most organizations already have their supply chain functions established; therefore, this discussion proposes a solution that fits both existing and new startup companies. The discussion centers on the importance of Kaizen within the supply chain domain. The implementation of small, continuous, incremental improvement steps is an essential component of an elastic supply chain and its agility to respond to a dynamic environment [20], whether the change comes internally, due to a shift in organizational strategic objectives, or in response to external factors such as geopolitical shifts or competitive pressure. Any organization, regardless of how far behind its operations may be, can excel by adopting this simple methodology, which also illuminates the strategic importance of the supply chain and its direct impact on a company's revenue and profitability.

### *A. Path for Master Data Management*

Embedding digital inventory into the supply chain involves implementing two parallel paths. The first is to establish a methodology for procuring a digital blueprint for any product the organization procures. This step is relatively straightforward, requiring only the inclusion of a clause for a digital blueprint of the product in any released request for proposal (RFP). Prior to issuing an RFP, the system checks whether a blueprint of the product already exists in master data; this verification is essential for reducing procurement cost, as suppliers might charge additional fees for providing digital files. The second path is building digital profiles for existing inventory, which is far more complex than acquiring them from suppliers for procured products. There are various methods for building a digital inventory, and the choice largely depends on the nature of a company's existing inventory and the amount of capital it is willing to invest to convert physical inventory to digital form; a company might implement several methods at the same time. Table I lists several proposed methods with a description and five implementation-difficulty criteria: cost, time, implementation expertise, equipment, and error rate, each scaled as high, medium, or low. The scale was determined through general engineering judgment rather than empirical measurement, and further study is required to validate these assumptions.

TABLE I. Methods for Digitizing Legacy Product Inventory

| Method | Description | Cost | Time | Expertise | Equipment | Error Rate |
|---|---|---|---|---|---|---|
| 3D Laser Scanning | Uses a laser scanner to capture a dense point cloud of the part's surface, which is then converted into a mesh. | High | Medium | High | High | Low |
| Structured Light Scanning | Uses projected light and cameras to capture surface geometry. | Medium | Medium | High | Medium | Low |
| Sourcing from OEM | Contacting the original manufacturer or industry databases to obtain the original CAD file directly. | High | Low | Low | N/A | Low |
| Industrial CT Scanning | X-ray computed tomography that captures both external and internal geometry. | High | Medium | High | High | Low |

| Method | Description | Cost | Time | Expertise | Equipment | Error Rate |
|---|---|---|---|---|---|---|
| Third-Party Digital Libraries | Sourcing CAD files from external repositories, part libraries, or digitization-as-a-service platforms. | Medium | Low | Low | N/A | Medium |
| 2D-to-3D Conversion | Scanned paper drawings are processed and algorithmically lofted into 3D models. | Medium | High | Medium | Low | Medium |
| Fuzzy Logic Similarity Analysis | Compares a legacy part's measured geometry against an existing CAD database using fuzzy matching logic to identify the closest existing model. | Low | Medium | Low | Low | High |

*B. Embody Additive Manufacturing in Demand Planning*

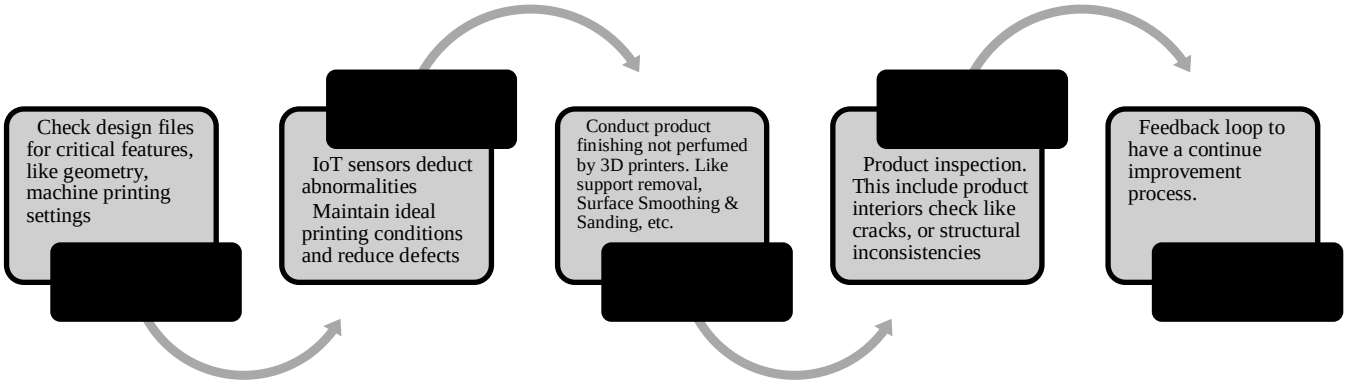
Demand planning is a fundamental part of the elastic supply chain. Integrating it with additive manufacturing shifts the strategy from forecasting to real-time responsiveness. Traditional demand planning relies heavily on historical trends and lead-time buffering to predict off-site batch production, often resulting in bloated safety stock or costly stockouts. By embedding additive manufacturing directly into the planning cycle, organizations transition from a forecast-to-stock model to a demand-driven framework. This capability is especially transformative for low-volume, high-mix products, slow-moving replacement parts, and early-stage products, as it drastically reduces physical inventory holding costs, eliminates long manufacturing lead times, and mitigates supply chain disruptions.

To integrate additive manufacturing into demand planning, any product request must go through a series of verifications prior to release for procurement, following a systematic business workflow. The first step verifies availability of CAD files; if files are missing, it triggers an additional process for engineers to produce CAD files, while simultaneously adding a clause to procurement requiring digital files from suppliers. The second step checks lead time, comparing the historical delivery time from the supplier against the queue and manufacturing time of 3D printing machines, taking customer needs into consideration. The final step compares the total cost of ownership between procured and printed products. The total cost of ownership is an estimate of all direct and indirect costs incurred, thereby accounting for the hidden, ongoing expenses that accumulate over time.

*C. Re-designation of Warehouse*

Installing additive manufacturing machines within main distribution hubs, warehouses, or manufacturing sites centralizes the production process. By keeping machines at primary hubs, companies achieve multiple goals: avoiding scattered raw materials, minimizing the capital required to implement the strategy, and ensuring quality control of printed parts. This consolidation allows businesses to pool resources, simplify quality control, and quickly dispatch printed parts directly into the existing shipping network.

Establishing a quality assurance process within the warehouse is vital for creating a feedback loop that addresses variance in 3D printing quality. The quality assurance cycle proceeds from design verification, to fault detection during production, post-printing processing, fit-for-delivery checks, and finally process control. It is wise to budget for additional inspection, certification, and occasional rework, particularly for components used in regulated industries.




## VI. Future Trend

Beside the development of additive manufacturing machines, printing technologies, flexibility, and speed, the future of AM is characterized by a shift toward data-driven processes, advanced material integration, and customized production in new fields, particularly the healthcare sector. The first trend observed is the integration of AM with artificial intelligence and machine learning tools, which shape AM processes by converting them from a trial-and-error method to a data-driven production system with minimal errors. Second is the expansion of digital twins and advanced simulation; virtual replication accelerates the process of qualification, certification, and fault prevention. The third trend is the exploration of bio-based materials. In healthcare applications, this is reflected in the development of bioactive and biodegradable ceramic scaffolds that can be tailored to support bone growth and biological response [21].

## V. CONCLUSION

Additive manufacturing offers a compelling path toward a truly elastic supply chain, enabling organizations to shift from rigid, forecast-driven operations to a flexible, demand-responsive model. The benefits explored in this paper—virtual warehousing, distributed and localized production, and product customization—demonstrate that AM can meaningfully reduce inventory costs, shorten lead times, and improve resilience to market volatility. However, these gains are not automatic. Organizations must first address foundational challenges, including intellectual property protection, quality consistency across distributed sites, and the capital and post-processing costs that accompany AM adoption.

Equally important is the underlying technology infrastructure: cloud orchestration, digital twins, and IoT connectivity are what allow an elastic supply chain to function as an integrated, self-adjusting system rather than a collection of disconnected initiatives. Master data management stands out as a recurring dependency across nearly every benefit discussed, underscoring that digital readiness, not printer capability alone, ultimately determines an organization's ability to scale AM. As the technology matures, continued advances in artificial intelligence, digital twin simulation, and bio-based materials will likely expand where and how additive manufacturing can be applied. Organizations that begin building the digital and organizational foundation now, rather than waiting for these tools to mature, will be best positioned to capture the strategic advantages of an elastic, additive-manufacturing-enabled supply chain.

## REFERENCES

[1] S. M. Leon, Financial Intelligence for Supply Chain Managers: Understand the Link Between Operations and Corporate Financial Performance. Pearson FT Press, 2016.

[2] H. Huang, T. Qu, X. Qiu, L. Ma, and Z. Zhang, "Collaborative reconfiguration of supply networks based on GNN and ALC," IFAC-PapersOnLine, vol. 58, no. 19, pp. 1–6, 2024, doi: 10.1016/j.ifacol.2024.09.063.

[3] S. Al Kaabi, V. Bathmanathan, and M. Z. Lydia Ncube, "Elastic supply chain management as strategic tool in improving global logistics service," in Accelerating Transformation towards Sustainable and Resilient Business: Lessons Learned from the COVID-19 Crisis, vol. 1, European Proceedings of Finance and Economics, 2023, pp. 501–509, doi: 10.15405/epfe.23081.44.

[4] M. Attaran, "The rise of 3-D printing: The advantages of additive manufacturing over traditional manufacturing," Business Horizons, vol. 60, no. 5, pp. 677–688, 2017, doi: 10.1016/j.bushor.2017.05.011.

[5] A.-L. Andersen et al., "Manufacturing-as-a-Service (MaaS) to increase value chain resilience and circularity: Towards a systematic methodology for manufacturing process servitization and value chain orchestration," IFAC-PapersOnLine, vol. 59, no. 10, pp. 464–469, 2025, doi: 10.1016/j.ifacol.2025.09.080.

[6] M. Akbari, "Data-driven review of additive manufacturing on supply chains: Regionalization, key research themes and future directions," Computers & Industrial Engineering, vol. 184, 109600, 2023, doi: 10.1016/j.cie.2023.109600.

[7] E. Sharifi, A. Chaudhuri, S. D. Farahani, L. G. Staal, and B. V. Waehrens, "Virtual warehousing through digitalized inventory and on-demand manufacturing: A case study," Computers in Industry, vol. 164, 104184, 2025, doi: 10.1016/j.compind.2024.104184.

[8] M. Gladkikh, Y. Shan, J. Ayers, E. Tackett, and H. Mao, "Blueprint and case study for the cyber supply chain: Distributed additive manufacturing enables resilience and sustainability," Manufacturing Letters, vol. 44, suppl., pp. 1699–1707, 2025, doi: 10.1016/j.mfglet.2025.06.189.

[9] A. Balloni, L. Monferdini, and E. Bottani, "The impact of additive manufacturing on supply chain management: Trends, challenges and future directions," Procedia Computer Science, vol. 253, pp. 2961–2970, 2025, doi: 10.1016/j.procs.2025.02.020.

[10] F. Calignano and V. Mercurio, "An overview of the impact of additive manufacturing on supply chain, reshoring, and sustainability," Cleaner Logistics and Supply Chain, vol. 7, 100103, 2023, doi: 10.1016/j.clscn.2023.100103.

[11] K. Adu-Amankwa, J. Corney, A. Rentizelas, and A. Wodehouse, "Intellectual property management challenges of additive manufacturing in replacement part supply chains," IFAC-PapersOnLine, vol. 55, no. 10, pp. 1527–1532, 2022, doi: 10.1016/j.ifacol.2022.09.607.

[12] K. Adu-Amankwa, A. Rentizelas, A. Daly, J. Corney, and M. Peron, "Decision considerations for securing and managing intellectual property within additive manufacturing supply chains," IFAC-PapersOnLine, vol. 56, no. 2, pp. 6543–6548, 2023, doi: 10.1016/j.ifacol.2023.10.304.

[13] D. Seifert, P. Grzona, K. Raval, and M. Thürer, "Quality control techniques in additive manufacturing: Current trends and their prototypical implementation," Procedia Computer Science, vol. 253, pp. 1206–1215, 2025, doi: 10.1016/j.procs.2025.01.182.

[14] M. Soori, F. Karimi Ghaleh Jough, R. Dastres, and B. Arezoo, "Additive manufacturing modification by artificial intelligence, machine learning, and deep learning: A review," Additive Manufacturing Frontiers, vol. 4, no. 2, 200198, 2025, doi: 10.1016/j.amf.2025.200198.

[15] M. Sæterbø and W. D. Solvang, "Evaluating the cost competitiveness of metal additive manufacturing—A case study with metal material extrusion," CIRP Journal of Manufacturing Science and Technology, vol. 45, pp. 113–124, 2023, doi: 10.1016/j.cirpj.2023.06.005.

[16] A. Mahadik and D. Masel, "Implementation of additive manufacturing cost estimation tool (AMCET) using break-down approach," Procedia Manufacturing, vol. 17, pp. 70–77, 2018, doi: 10.1016/j.promfg.2018.10.014.

[17] P. Spalt and T. Bauernhansl, "A framework for integration of additive manufacturing technologies in production networks," Procedia CIRP, vol. 57, pp. 716–721, 2016, doi: 10.1016/j.procir.2016.11.124.

[18] J.-P. Rudolph and C. Emmelmann, "A cloud-based platform for automated order processing in additive manufacturing," Procedia CIRP, vol. 63, pp. 412–417, 2017, doi: 10.1016/j.procir.2017.03.087.

[19] L. Benhamou, V. Giard, and S. Lamouri, "Digital twins in supply chain management: Scope and methodological issues," International Journal of Production Economics, vol. 291, 109842, 2026, doi: 10.1016/j.ijpe.2025.109842.

[20] J. Singh and H. Singh, "Continuous improvement approach: State-of-art review and future implications," International Journal of Lean Six Sigma, vol. 3, no. 2, pp. 88–111, 2012, doi: 10.1108/20401461211243694.

[21] M. Ali, W. Ullah, J. Hussain, K. Balasubramanian, R. K. Rajamony, S. Mirza, K. Singh, and I. Hussain, "Additive manufacturing: A multidisciplinary review of techniques and applications," Resources Chemicals and Materials, 100216, 2026, doi: 10.1016/j.recm.2026.100216.