

IMPACT OF ADDITIVE MANUFACTURING ON SUPPLY CHAIN FLEXIBILITY- A DETAILED STUDY

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1. ABSTRACT:

Additive manufacturing is a new technique that is gaining traction in a variety of industries, including medicine, industrial manufacturing, and consumer product printing. To perish in the global market, manufacturers are being compelled to switch to low-volume production of innovative and customised products with high added value. Three-dimensional printing, also known as additive manufacturing (AM) or quick prototyping, enables the production of small to large numbers of individual things that can be customised. The technology is truly ground-breaking, offering limitless product design options and the ability to improve global supply chain capabilities. Due to this method, efficiency of supply chain is increased on all levels- assembly, distribution expenses, delivery and even the component.

2. KEYWORDS:

Supply chain, Additive manufacturing, 3-D Printing, supply chain flexibility, Supply chain performance, automotive industry, customized demand, dynamic supply chain design, resource utilization

3. INTRODUCTION:

We live in a fast-paced world. The fourth Industrial Revolution is about to begin throughout the world. Technology is rapidly evolving and revolutionizing society, such as mobile supercomputing, artificial intelligence, robots, and autonomous cars. These and other reasons, such as fast global population expansion, customer awareness, sustainability difficulties, and globalization, have all created new performance challenges for supply chains during the previous few decades. A supply chain (SC) is a group of three or more companies or individuals participating in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer. SC management's overarching goals include providing customer value, saving costs, enhancing responsiveness, co-creation, controlling demand changes, and, eventually, creating a competitive edge. SC design is a strategic issue for every firm, and it may be characterized as a series of decisions for SC management related structure, partners, locations, capacities, and systems. Traditional SC approaches can no longer enable managing the trade-offs between supply chain objectives because of these new issues. Multiple objectives can be met at the same time by utilizing modern technology. An incipient tool is Additive Manufacturing (AM), also known as 3-D printing, Rapid Prototyping (RP), Rapid Tooling (RT), Rapid Manufacturing (RM), or (Direct) Digital Manufacturing. Additive manufacturing enables the fabrication of lighter, more sophisticated designs that would be impossible or prohibitively expensive to produce using standard dies, molds, milling, and machining techniques. Rapid prototyping is another area where AM shines. Additive manufacturing eliminates material waste, streamlines production processes, and enhances supply chain flexibility by allowing the finished product to be built close to the end-user. The reason that additive manufacturing avoids the additional expenses generally associated with developing more complex geometries is strongly tied to its capacity to build complicated geometries more easily than traditional production processes.

The recent times have seen rapid advancement of additive manufacturing technology. Components and parts made with additive manufacturing are increasingly becoming the focus of the space sector, thanks to recent breakthroughs in design optimization tools and manufacturing capabilities.

4. METHODOLOGY:

The paper provides a current literature review of 40 research papers to provide a thorough explanation of flexibility in the perspective of supply chains. A review of the literature on supply chain flexibility was conducted.

The development of supply chain and additive manufacturing market and their co-dependency has been studied.

The era of supply chain management has necessitated recognizing the need of looking beyond the flexible factory to the flexible supply chain. An attempt has been made to advance our knowledge of supply chain flexibility.

5. SYSTEMATIC LITERATURE REVIEW:

SNO.	AUTHOR, YEAR AND JOURNAL	TITLE	FINDINGS
1.	M Delic, DR Eyers - International Journal of Production Economics, 2020 - Elsevier	The effect of additive manufacturing adoption on supply chain flexibility and performance: An empirical analysis from the automotive industry	The paper fills an imperative gap in the supply chain literature. The research illustrates how supply chain flexibility mediates the impact of Additive Manufacturing adoption on supply chain performance in the European automobile market. According to the findings, the use of additive manufacturing has a favorable influence on supply chain flexibility, which in turn has a beneficial impact on supply chain performance. Pg (35-228), volume 228
2.	AA Alogla, M Baumers, C Tuck, W Elmadih - Applied Sciences, 2021 Smart Manufacturing Systems for Industry 5.0: Challenges and Opportunities	The Impact of Additive Manufacturing on the Flexibility of a Manufacturing Supply Chain	In this case study, the supply chain using IM has greater volume and delivery flexibility (65.68 percent and 92.8 percent for IM vs. 58.70 percent and 75.35 percent for AM, respectively), whereas the AM supply chain has greater mix and new product introduction flexibility, as evidenced by the lower changeover time and cost of new product introduction to the system (i.e., 58.70 percent and 75.35 percent for AM, respectively). Pg (5-7)
3.	BD Chung, SI Kim, JS Lee - Applied sciences, 2018 Smart Sustainable Manufacturing Systems	Dynamic Supply Chain Design and Operations Plan for Connected Smart Factories with Additive Manufacturing	This article looks at a dynamic supply-chain design and operations innovation: networked smart factories with replaceable processes that are shared via a cloud-based system for flexible production. Pg 583
4.	Ardeshir Raihanian Mashhadi, Behzad Esmailian, Sara Behdad- Manufacturing, 2015 - asmedigitalcollection.asme	Impact of additive manufacturing adoption on future of supply chains	The characteristics and requirements of a Supply Chain (SC) are described in this study, as well as the modifications AM will bring to the current supply chain structure. In order to depict the use of simulation models, two examples are provided, i.e., of Agent Based Simulation (ABS) and System Dynamics (SD). The ABS findings show that in an AM-based supply chain, lead times can be reduced. In addition, when compared to traditional supply chains, the SD model shows that AM has less of a "pipeline" effect. MSEC2015-9392, V001T02A064; 10 pages
5.	SH Khajavi, J Partanen, J Holmström - Computers in industry, 2014 - Elsevier	Additive manufacturing in the spare parts supply chain	The purpose of this paper is to evaluate the influence of additive manufacturing advances on the structure of spare parts supply chains. The spare parts supply chain for the F-18 Super Hornet fighter jet was chosen as the case study. In the case example, it was discovered that centralized manufacturing is the preferred supply chain arrangement employing current AM technologies. Dispersed spare parts manufacturing becomes possible when AM machines become less capital-intensive, more autonomous, and provide shorter production cycles. Pages 50-63
6.	Stefan Kurpjuweit, Christoph G. Schmidt, Maximilian Klöckner, and Stephan M. Wagner - Swiss Federal Institute of	Blockchain in additive manufacturing and its impact on supply chains	This research combines inductive in-depth interviews with the Delphi method to explore what potentials blockchain technology in AM creates, which adoption barriers firms need to overcome, and how supply chains will be affected by the integration of these two potentially disruptive technologies. The results

	<p>Technology Zurich Stefan Kurpjuweit, Christoph G. Schmidt, Maximilian Klöckner, and Stephan M. Wagner Swiss Federal Institute of Technology Zurich S Kurpjuweit, CG Schmidt, M Klöckner Journal of Business Logistics, 2021</p>		<p>suggest opportunities that are related to intellectual property (IP) rights management, the monitoring of printed parts throughout their lifecycle, process improvements, and data security. This study combines inductive in-depth interviews with the Delphi method to investigate the potential of blockchain technology in AM, the adoption barriers that companies must overcome, and how supply chains will be impacted by the merging of these two potentially revolutionary technologies. The findings point to potential opportunities in the areas of intellectual property rights management, printed part monitoring throughout their life cycle, process improvement, and data security. Pages 46-70</p>
7.	<p>R Handal - Journal of Operations and Supply Chain, 2017</p>	<p>An implementation framework for additive manufacturing in supply chains</p>	<p>In order to investigate the deployment of additive manufacturing in supply chain management, this study used a substantial amount of existing supply chain approaches and frameworks. By creating a framework, this paper explains how supply chain management is affected by additive manufacturing. Pages 6-8</p>
8.	<p>Tasé Velázquez, Daniel R. Simon, Alexandre Tadeu Helleno, André Luís Mastrapa, Lorena Hernández Independent Journal of Management & Production, ISSN-e 2236-269X, Vol. 11, Nº. 4, 2020,</p>	<p>Implications of additive manufacturing on supply chain and logistics</p>	<p>The consequences of AM as an advanced manufacturing paradigm on SC and logistics are explored in this essay. The following are the important issues that have been recognized as having major consequences for SC and logistics because of AM.: supply chain complexity reduction; more flexible logistics and inventory management; better spreading and popularization of mass customization; decentralization of manufacturing; greater design freedom and rapid prototyping; increasing of resource efficiency and sustainability, and the need to have clearly defined legal and safety aspects. Pages 1279-1302</p>
9.	<p>Vissarion Manginas, Eftihia Nathanail, Ioannis Karakikes Conference on Sustainable Urban Mobility 2020: Advances in Mobility-as-a-Service Systems</p>	<p>Investigating the Impacts of Additive Manufacturing on Supply Chains</p>	<p>Through a case study of the LEAP-1A jet engine fuel nozzle supply chain, the essay tries to build a business model for its best utilization. The most effective supply chain model is a decentralized additive manufacturing model, according to the analysis and evaluation of the indicators. Based on the findings, additive manufacturing simplifies the supply chain, boosts design and production flexibility, and lowers transportation and logistics costs. Pages 192-201</p>
10.	<p>Luciano R. Novais, Juan M. Maqueira, Sebastián Bruque Journal of Business & Industrial Marketing-2019</p>	<p>Supply chain flexibility and mass personalization: a systematic literature review</p>	<p>This paper looks at the current state of supply chain flexibility (SCF) and mass personalization (MP) research to identify existing findings, research gaps, and recommendations for future research in these areas. Vol. 34 No. 8, pages 1791-1812</p>
11.	<p>M Attaran - Journal of Service Science and Management, 2017</p>	<p>Additive manufacturing: the most promising technology to alter the supply chain and logistics</p>	<p>This paper explains how additive manufacturing (AM) may help manufacturers be more cost-effective, efficient, and environmentally responsible. It predicts that the rise of additive manufacturing would have a significant impact on traditional (subtractive) production and supply chains. AM will revolutionize the way manufacturing is done in</p>

			the future. AM can make it possible for everyone to be a manufacturer. Vol.10 No.03, pages 12-18
12.	Katrin Oettmeier, Erik Hofmann Journal of Manufacturing Technology Management, 2016	Impact of additive manufacturing technology adoption on supply chain management processes and components	In an engineer-to-order context, this study provides a systematic investigation of the implications of additive manufacturing (AM) technology adoption on supply chain management (SCM) procedures and SCM components. A switch to AM affects not only the internal processes and management activities of producers, such as production and order fulfilment, but also the SCM processes and components linked to the supply and demand side of a firm's supply chain. Endogenous and AM technology-related factors are contingency factors that can assist explain why AM technology adoption has different effects on SCM processes and components. Vol. 27 No. 7, pages 944-968
13	Leslie K. Duclos , Robert J. Vokurka, Rhonda R. Lummus Industrial Management & Data Systems- 2003	A conceptual model of supply chain flexibility	An integrated supply chain flexibility conceptual model is proposed in this article. It explores flexibility categorization methods and the commonalities of flexibility typologies offered in the literature to lay a theoretical foundation for understanding the components of supply chain flexibility. This study discusses the cross-enterprise nature of supply chain flexibility, as well as the need to improve flexibility indicators across organizations. Future cross-functional research opportunities that build on this theoretical framework and lead to more effective supply chain strategy design are suggested. Vol. 103 No. 6, pp. 446-456.
14.	Mark Stevenson, Martin Spring International Journal of Operations & Production Management- 2007	Flexibility from a supply chain perspective: definition and review	By conducting a thorough review of the literature, this study improves our understanding of supply chain flexibility. The paper provides a thorough definition of flexibility in the context of supply chains, as well as a current literature review. With a focus on supply chain design, supply chain collaboration, and interorganizational information systems, the essay also discusses how to combine a flexible supply chain strategy with proactive measures to minimize supply chain uncertainty. Vol. 27 No. 7, pages 685-713.
15.	Marta Rinaldia, Mario Caterino, Pasquale Mancoa, Marcello Feraa, Roberto Macchiarolia Procedia Computer Science Volume 180, 2021,	The impact of Additive Manufacturing on Supply Chain design: a simulation study	This article presents a quantitative assessment of the effects of Additive Manufacturing on supply chain performance, considering various system configurations. To replicate the behavior of the gamers and evaluate different scenarios, a simulation model was built. To compare the efficiency of additive and traditional methods, models of each have been created. Furthermore, many supply chain configurations have been studied to determine the practicality of additive manufacture when integrated with various supply chain topologies. The findings show that additive manufacturing improves supply chain effectiveness and provides significant benefits in decentralized systems. Volume 180, Pages 446-455
16.	Malte Brettel Prof. Dr., Manuel Klein, Niklas Friederichsen	The Relevance of Manufacturing Flexibility in the Context of Industrie 4.0	This document highlights the various research streams related to production flexibility, expanding on Donald Gerwin's seminal work. It

	Procedia CIRP Volume 41, 2016,		establishes a link between flexibility and performance by methodically charting empirical data from the literature and connecting this development to Industrie 4.0 manufacturing methods. Volume 41, Pages 105-110
17.	MC Chiu, YH Lin - Industrial Management & Data Systems, 2016	Simulation based method considering design for additive manufacturing and supply chain: An empirical study of lamp industry	This study demonstrates how the additive manufacturing (AM) process can help the SC process perform better in terms of lead time and total cost. It identifies a research gap between AM and SC, as well as a thorough examination of several performance measures such as order fulfilment rate and waste rate. Vol. 116 No. 2, pages. 322-348.
18.	S Chirra, RD Raut, D Kumar - International Journal of Production Research, 2020 - Taylor & Francis	Barriers to sustainable supply chain flexibility during sales promotions	This study augments the existing literature by linking the supply chain flexibility, Sustainability, and Sales promotions and thus clubs the three independent research streams. It examines the barriers to flexibility in the Indian automobile supply chains from a sustainability viewpoint, an indispensable element of the present-day supply chains. Pages 3-7
19.	H Zijm, N Knofius, M van der Heijden Operations, Logistics and Supply Chain Management- 2018	Additive Manufacturing and Its Impact on the Supply Chain	This article discusses the fundamentals of additive manufacturing (AM), its impact on supply chains, and spare part delivery in after-sales service supply chains. It gives an approach for identifying spare components that appears promising for the use of AM in a state-of-the-art report. The report comes to a close with a field study done at an aeronautical service provider. Pages 521-543
20.	Toni Luomaranta , Miia Martinsuo International Journal of Physical Distribution & Logistics Management 2020	Supply chain innovations for additive manufacturing	This research illustrates how supply networks have changed in practise, as well as the prerequisites for AM-related supply chain advancements. It demonstrates that properly exploiting AM will necessitate supply chain innovations, such as improvements in business processes, technology, and structure, as well as supportive changes in the business environment. These developments take place at various regions of the AM supply chain and are emphasised differently by different types of businesses. Vol. 50 No. 1, pp. 54-79
21.	D Ivanov, A Dolgui, B Sokolov - International Journal of Production Research, 2019 - Taylor & Francis	The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics	The results of two independent domains, namely the impact of digitalization on SC management (SCM) and the impact of SCM on ripple effect control, are merged in this research framework. On digitalization and SC risks, it connects the views of business, information, engineering, and analytics. The following questions are addressed in this study: (1) what links exist between big data analytics, Industry 4.0, additive manufacturing, advanced trace & tracking systems, and SC disruption risks; (2) how digitalization can help with ripple effect control; and (3) what digital technology-based extensions can trigger the development of SC risk analytics. Pages 829-846
22.	D Ivanov, A Das, TM Choi - 2018 - Taylor & Francis International Journal of Production Research	New flexibility drivers for manufacturing, supply chain and service operations	Disruption risks, resilience, and the ripple effect in the supply chain are classified in this article, as are digitalization, smart operations, and e-supply chains; sustainability and closed-

			loop supply chains; and supplier integration and behavioral flexibility. It proposes new and innovative flexibility concepts and models as a path to operational improvements in the areas of increased product proliferation, customization, competition, and customer expectations, supply-side disruptions, and improved efficiency and resilience in manufacturing, service, and supply-chain systems. Pages 3359-3368
23.	Samuel H. Huang, Peng Liu, Abhiram Mokasdar & Liang Hou The International Journal of Advanced Manufacturing Technology 2013	Additive manufacturing and its societal impact: a literature review	This research looks at the societal implications of additive manufacturing from a technological approach. It provides evidence to back up additive manufacturing's promises in the areas of (1) customized healthcare products to improve population health and quality of life, (2) reduced environmental impact for manufacturing sustainability, and (3) a simplified supply chain to improve demand fulfillment efficiency and responsiveness. According to the report, more research is needed in the areas of life-cycle energy consumption evaluation and potential occupational hazard assessment for additive manufacturing. pages1191-1203
24.	Miia Martinsuo , Toni Luomaranta Journal of Manufacturing Technology Management 2018	Adopting additive manufacturing in SMEs: exploring the challenges and solutions	According to the study, AM adoption is not only a technological issue for the supply chain, but also a strategic, organizational, and operational one. It indicates that SMEs face specific challenges when it comes to adopting AM and require customized solutions based on their supply chain position. When it comes to adopting AM, SMEs in various supply chain roles have different problems. It recommends strategic and operational initiatives as crucial answers to the problems. The findings provide a framework for identifying AM adoption problems and suggest strategies for overcoming them. Vol. 29 No. 6, pages 937-957
25.	Ben Nanfeng Luo, Kangkang Yu The International Journal of Logistics Management 2016	Fits and misfits of supply chain flexibility to environmental uncertainty: Two types of asymmetric effects on performance	The findings revealed differential consequences in the fits and misfits of environmental unpredictability and supply chain flexibility in general. For the same degree of mismatch, underfitting decreases performance more than overfitting. If a perfect fit is impossible to obtain, managers should seek to prevent the underfit of supply chain flexibility rather than the overfit. Overfitting has a lower negative impact on performance than underfitting, and high-high fit has a higher positive impact than low-low fit, according to the authors. In a broad sample of Chinese manufacturing enterprises, the authors discovered empirical evidence. Vol. 27 No. 3, pages 862-885.
26.	Douglas Thomas The International Journal of Advanced Manufacturing Technology volume- 2015	Costs, benefits, and adoption of additive manufacturing: a supply chain perspective	This paper updates the value of commodities generated. It looks at the literature on the cost of additive manufacturing and determines whether this technology is cost-effective. It also presents a method for analyzing and comprehending the societal costs and benefits of this technology, both financially and in terms of resource usage. The final section examines the state of additive manufacturing adoption today. Additive manufacturing contributes

			\$667 million in value added globally, accounting for 0.1% of total global manufacturing value added. The estimated value of the contribution in the United States is \$241 million. Pages 1857-1876
27.	V Verboeket, H Krikke - Computers in Industry, 2019 - Elsevier	The disruptive impact of additive manufacturing on supply chains: A literature study, conceptual framework and research agenda	Based on 67 peer-reviewed papers, this article gives a comprehensive literature evaluation on the impact of AM on SC design. It uses the SCOR model to address the business circumstances in which AM functions, AM SC design options, and AM SC performance outcomes. While AM is now employed for a wide range of applications, the findings suggest that it is primarily used for tiny, low-demand, and geometrically complicated goods. This article adds to the AM SC design knowledge base by establishing a conceptual framework, which includes 18 propositions, as well as a study agenda that identifies important AM SC design research themes. It also includes a roadmap outlining the steps to a complete implementation of additive manufacturing in the manufacturing sector. Volume 111, Pages 91-107
28.	Abhijeet Ghadge, Georgia Karantoni, Atanu Chaudhuri, Aravindan Srinivasan Journal of Manufacturing Technology Management 2018	Impact of additive manufacturing on aircraft supply chain performance: A system dynamics approach	The study provides advice on how to adopt AM in aircraft SCs and how AM affects spare component inventory systems. The research provides solid data for making important managerial decisions about SC re-design in the face of a new and disruptive technology. The existing demand for material product fulfilment by AM machines will be replaced by next-generation SC and logistics. Vol. 29 No. 5, pp. 846-865.
29.	S Niehues, L Berger, M Henke - The Road to a Digitalized Supply Chain Management: Smart and Digital Solutions for Supply Chain Management, 2018	Additive manufacturing in supply chains - the future of purchasing processes	In future supply chain networks, additive manufacturing will influence purchasing processes and network topologies of producing organizations, according to this article. As a result, a systematic literature review is conducted to investigate relevant literature and current studies, offering an overview of how additive manufacturing may affect purchasing practices. Volume 25, Pages 79-95
30.	Ahmad Azwan Ahmad Shukor, Md. Shah Newaz, Muhammad Khalilur Rahman, Azni Zarina Taha International Journal of Emerging Markets 2020	Supply chain integration and its impact on supply chain agility and organizational flexibility in manufacturing firms	Environmental uncertainty and supply chain integrations, including customer, supplier, and internal integration, are found to have a strong association, according to the paper. There is a significant link between organizational ambidexterity and supply chain integration. Supply chain integrations have been discovered to boost the company's supply chain agility and organizational flexibility. Vol. 16 No. 8, pages. 1721-1744.
31.	H Afshari, MY Jaber, C Searcy - Computers & Industrial Engineering, 2019 - Elsevier	Investigating the effects of learning and forgetting on the feasibility of adopting additive manufacturing in supply chains	This research develops a model for an AM-enabled supply chain and evaluates the influence of disruptions (such as demand fluctuations) on the feasibility of such supply chains. The study was broadened to see how differences in network infrastructures, pricing, and manufacturing technologies can influence supply chain investment decisions in favor of AM. Numerical simulations back up the proposed model for lowering supply chain expenses. The study focuses on the impact of learning-forgetting on AM capacity in supply

			chains and provides ways to avoid these consequences. Volume 128, Pages 576-590
32.	Milad Ashour Pour ORCID Icon, Simone Zanoni ORCID Icon, Andrea Bacchetti ORCID Icon, Massimo Zanardini & Marco Perona ORCID Icon International Journal of Systems Science: Operations & Logistics 2019	Additive manufacturing impacts on a two-level supply chain	With the purpose of capturing the most significant consequences of the AM concept on a two-level supply chain, this paper provides an analytic technique based on the Joint Economic Lot Sizing model. This study of AM from the inventory and logistics perspectives attempts to show how companies can adapt their supply chain planning to suit new AM paradigms. To support and generalize the major findings, a numerical example is presented, followed by a sensitivity analysis of a real industrial case study. Pages 1-14
33.	V Verboeket, H Krikke - Logistics, 2019	Additive Manufacturing: A Game Changer in Supply Chain Design	This study looks into ways to improve SC design for manufacturing by taking advantage of AM's advantages, such as its flexibility in terms of shape design and complexity, and the lack of the necessity for object-specific tools. This article makes a two-fold contribution. First, it creates six AM SC mechanisms based on literature synthesis that can be employed in SC design to realize anticipated SC upshots for AM production applications in certain (commercial) settings. It also highlights AM's unruly, "game-changing" penalties on SC stakeholders. Pages 150-177
34.	Y Li, G Jia, Y Cheng, Y Hu - International Journal of Production Research, 2017 - Taylor & Francis	Additive manufacturing technology in spare parts supply chain: a comparative study	The determination of this paper is to inspect the influence of AM on spare parts supply chain. The research presented in this paper shows that an AM-based spare part supply chain outperforms a traditional one in terms of long-term performance. It also anticipates that AM will make the spare parts supply chain more efficient, resulting in more economic benefits. Pages 1498-1515
35.	M Akbari, N Ha - The Asian Journal of Shipping and Logistics, 2020 - Elsevier	Impact of additive manufacturing on the Vietnamese transportation industry: An exploratory study	The impact and benefits of new technology on logistics services and transportation in Vietnam are examined in this article. The findings of this study offer timely and significant new insights into this phenomenon, as well as a potential mechanism for supporting the transportation industry's revolution toward reducing traffic congestion and pollution. Volume 36, Issue 2, Pages 78-88
36.	Siavash H. Khajavi, Jan Holmström, Jouni Partanen Rapid Prototyping Journal 2018	Additive manufacturing in the spare parts supply chain: hub configuration and technology maturity	In this study the possibility of a production configuration that combines the benefits of centralized production with the flexibility of local manufacturing without the high costs associated with it is explored. It implies that hub production configurations based on the AM machines in use can provide cost-effectiveness and efficacy in reducing equipment downtime. Vol. 24 No. 7, pages 1178-1192
37.	Helen Rogers, Norbert Baricz, Kulwant S. Pawar International Journal of Physical Distribution & Logistics Management 2016	3D printing services: classification, supply chain implications and research agenda	This paper represents an attempt to take stock of a fast-moving and potentially paradigm-shifting market. This paper presents an overview of the rapidly expanding 3D printing services industry, illustrating how the market may evolve as additive manufacturing technology improves. Vol. 46 No. 10, pages 886-907

38.	Daniel R. Eyers , Andrew T. Potter, Jonathan Gosling, Mohamed M. Naim International Journal of Operations & Production Management 2018	The flexibility of industrial additive manufacturing systems	The findings in this paper reveal that the production system can reach seven different levels of internal flexibility. Six of the seven external flexibility capabilities mentioned in the literature were demonstrated to be enabled by this ability. The amount to which each skill can be attained is determined through a categorical assessment, which is accompanied by a full discussion of the facilitators and inhibitors of flexibility for industrial additive manufacturing systems. Vol. 38 No. 12, pp. 2313-2343
39.	S Haghghat Khajavi, I Flores Ituarte, A Jaribion, - 2020	Impact of Additive Manufacturing on Supply Chain Complexity	This paper carries out study to see if additive manufacturing (AM) always makes the supply chain easier. The data show that switching to AM simplified the supply chain in one scenario, while it resulted in somewhat increased complexity in another. In the third scenario, the impact of switching to AM on supply chain complexity is influenced by a number of factors. It clarifies the widely held assumption that AM streamlines the supply chain. It concludes that implementing AM is not a silver bullet for reducing supply chain complexity in all cases. Pages 4-8
40.	M Shekarian, SVR Nooraie, MM Parast - International Journal of Production Research, 2020 - Elsevier	An examination of the impact of flexibility and agility on mitigating supply chain disruptions	The impact of flexibility and agility on supply chain responsiveness is investigated in this research. A numerical example is used to determine the relationship between three objective functions relating to responsiveness, risk, and the cost of new and seasonal items, as well as the impact of flexibility and agility on minimizing supply chain disruptions. Volume 220, February 2020, 107438

This research combines inductive in-depth interviews with the Delphi method to explore what potentials blockchain technology in AM creates, which adoption barriers firms need to overcome, and how supply chains will be affected by the integration of these two potentially disruptive technologies. The results suggest opportunities that are related to intellectual property (IP) rights management, the monitoring of printed parts throughout their lifecycle, process improvements, and data security.

6. RESULTS AND DISCUSSION

The speed with which AM is changing makes establishing business or design case comparisons between AM and more established techniques difficult. It is no longer accurate to classify 3D printing as a single technique. A broad variety of distinct techniques has arisen, particularly in the metal's domain, that all fall under the additive umbrella. Any manufacturer's potential can be limited if new possibilities are not utilized.

SCOPE FOR FUTURE WORK

Additive Manufacturing (AM) is a relatively new and quickly evolving technology that has wreaked havoc on the manufacturing industry. It's not enough to look at AM as a disruptive set of technologies to reflect the whole range of changes that have resulted from its entrance into the industry; instead, consider it as a system. It is important to emphasise that the research of AM's effects should not be restricted to a single actor, but rather should cover the entire supply chain to account for all significant changes in strategic and tactical decision-making and operations.

LIMITATIONS

- The study was done in a small context of the machine construction and process industry, with a limited data collection, limiting the conclusions' generalizability. The findings provide an analytical framework and point to new research directions for investigating partial or entire AM supply chain improvements. It is proposed that

AM's ability to economically build custom products provides the potential to alleviate the common dilemma between product variety and scale economies.

- Traditional manufacturing is limited by the geometrical complexity of the component and the quantity of the production run, so we are forced to adapt techniques and instruments that improve the element's strength on a regular basis
- The study's scope is constrained by its limited scope. The findings suggest that, rather than viewing AM adoption as a firm-specific implementation challenge, it is necessary to view it as a shared issue and systemic innovation in the supply chain.

RESEARCH GAP

There have been few studies devoted to the study of additive manufacturing implementation, and no specialised research has been conducted to describe the viability of additive manufacturing implementation utilising supply chain techniques or product kinds. Furthermore, some manufacturing procedures may not adhere to a commitment to environmentally friendly manufacturing (contamination, recycling, etc.).

7. CONCLUSIONS

- Additive manufacturing is one of the most important tools for addressing growth, added value, and high-quality jobs.
- All manufacturing enterprises are not successful using additive manufacturing technologies.
- Additive manufacturing can be applied if a company prioritises production efficiency or market supply chain responsiveness.
- When the product is complex and made up of high-value components, additive manufacturing is a better option.
- While AM for manufacturing is not yet fully mature, general and logistics managers should keep a close eye on advancements in the field, particularly the removal of impediments to AM adoption.
- Due to the ability of Additive manufacturing techniques to adapt extremely well to the geometrical complexity and customisation of the design of the item to be made, they present major competitive advantages. This can be used by industries and other manufacturers to optimise production and reduce cost.

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