THE IMPORTANCE AND LINK OF ADDITIVE MANUFACTURING WITH LEAN AND SUSTAINABLE MANUFACTURING

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In this paper, a comparison of conventional and additive manufacturing was made. Lean and sustainable manufacturing from the point of view of waste were also analyzed. It was established that conventional manufacturing is slowly being replaced by additive manufacturing, but its role is still significant. Lean manufacturing indicates that waste is everywhere, i.e. at all organizational levels. Sustainable manufacturing analyzes new technologies and measures their impact on environmental protection with as little resource consumption as possible. The paper examined the importance of additive manufacturing in sustainable manufacturing by considering Lean principles. In conclusion, there is a flowchart of documents and activities that methodologically introduce additive manufacturing through respect for Lean principles and sustainable production. Savings in production time, launching new products, and quick replacement of parts have become imperative today, and further continuation of this work should be aimed at defining models and procedures in the company's sustainable development.

Keywords: Waste; Additive manufacturing; Lean manufacturing; Sustainable manufacturing; FDM process.

INTRODUCTION

Additive manufacturing (AM) is widely used in parts of complex geometry. AM enables the extension of the product life cycle, and the manufacturing process itself can be carried out from a remote location. The original application of AM was of great importance in producing plastic parts. However, after extensive research, other materials such as metal, ceramics, and various composites began to be used (Nannan, 2013). The most commonly used polymers are thermoplastic materials, nylon, resins, and elastomers. According to Dizon and colleagues (2018), in the production of parts using AM, the following materials are used: polymers (51%), metals and polymers (29.2%), and metals (19.8%). The device construction for the additive technology (AT) application is simple, and the cost of making the model is cheap, which makes this kind of production very suitable for sustainable enterprise development (Choi & Samavedam, 2002).

This paper investigates the significance of implementing AM in Sustainable manufacturing (SM) concerning Lean manufacturing (LM) principles. It also tried to find the significance and link between Lean and sustainable production if enterprises start to apply AM. In this case, we are talking about gradually bridging Conventional

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manufacturing (CM), although its role is still significant for the manufacturing process.

Conventional and additive manufacturing

CM uses a variety of operations that generate waste. CM is specific to mass production. This production is time-consuming and expensive when it comes to small-scale manufacturing. Before machining centers use, the material is delivered and inserted manually (Eyers & Potter, 2017). All this requires time and effort, affecting work inconsistencies and the realized product's quality later.

From this point of view, AM is significant for small-scale manufacturing. By applying AM, parts are reorganized, the reproduction of parts is enabled, and the weight of components and the finished product is reduced (Huang & Leu, 2014). Products generated by AM can be 50% lighter than the same products generated by CM (Frăţilă & Rotaru, 2017). AM must ensure reliable and consistent quality and adequate selection of materials to enable greater productivity and efficiency in work. However, the issue of manufacturing sustainability indicates that AM will not be able to replace CM for an extended period. From a life cycle point of view, AM enables the reduction of energy and material use through design and its preparation.

Bogers and colleagues (2016) state that AM complements conventional consumer-centric business models. The fused Deposition Modeling process (FDM), or 3D printing, is one of the tools in AM. Applying the FDM process is produced at the customer's request, resulting in increased supply chain efficiency by reducing material waste that directly impacts the environment (Ford et al., 2016). Compared to CM, AM has three main advantages: 1) flexible manufacturing and complex geometry, 2) a short supply chain, and 3) a vital role in reducing environmental impact. In the aviation industry, AM has found application in producing parts for jet engines (Sossou et al., 2018). More than 75% of jet engine parts are suitable for AM application due to specific irregular structures and complex geometry. However, due to specific critical points in design and manufacturing, conventional processing methods still have limitations that prevent the complete application of AM and material requirements in the case of jet engine production. Unfortunately, AM has many limitations in measurement tolerances, dimensional limitations, anisotropic material characteristics, and many other factors (Seepersad et al., 2012).

Lean and additive manufacturing

Lean manufacturing (LM) helps manufacturers reduce waste in all processes (Bevilacqua et al., 2017). AM is located as a supplement to LM; that is, it represents a tool for eliminating waste during the manufacturing process (Ghobadian et al., 2020).

LM and AM are interchangeable and overlap a lot because:

– LM offers better foundations for the realization of serial production; that is, its implementation reduces but does not eliminate process waste.
– AM offers a timely solution to process waste, while its actual implementation is linked to small-scale manufacturing, see Table 1.

Table 1: The importance of AM (Attaran, 2017; Wang et al., 2016)

Additive manufacturing
– Eliminates faults created in CM.
– Design time is shortened.
– Parts of complex geometry are produced.
– Raw materials are used efficiently.
– Recycled material is also used.
– Less need for additional resources.
– Costs are reduced, and spare parts are eliminated.
– The emphasis is on environmental protection

Lean concept (LC) focuses on finding suitable activities and putting things in the right place and at the right time to achieve a perfect workflow while minimizing waste (Dora et al., 2016). LC defines seven types of production waste (Bicheno & Holweg, 2009): 1) overproduction, 2) transportation, 3) stoppages, 4) unnecessary movements, 5) overprocessing, 6) scrap, and 7) stocks.

Although the AM technology is reduced to rapid prototyping or mass production, the essence is also in the rapid implementation of AM in LC. The importance of AM in waste disposal according to the mentioned criteria was shown in Table 2. As seen from the table, all defined wastes do not figure with the application of AM because it can potentially change the supply chain, eliminate waste and create new value streams.

Table 2: AM application in removing LC waste

Lean concept	Waste	Additive manufacturing
Overproduction	– Products are created that do not have a market. – There are unnecessary operations, and there is unnecessary documentation.	– Products are made only according to the customer's request. – No unnecessary operations. – No unnecessary documentation.
Transport	– Unnecessary movement of materials/semi-finished products occurs between operations or warehouses. – There needs to be a more vital flow of information.	– The material is next to the machine. – The human-machine information exists.
Interrupting	– There is material waiting time between two operations, and inactive work is reported. – Awaiting delivery.	– No waiting for materials. – No inactive work. – No waiting for delivery.
Unnecessary motions	– Unnecessary movements because machines need to be in better arrangement.	– No unnecessary movements. – The arrangement and operation of the machines do not depend on the operator's manipulation.
Excessive processing	– There are a large number of machines. – There is unnecessary equipment. – Cleaning occurs between operations. – There are too many processing steps.	– Works on one machine. – No unnecessary equipment. – Model cleaning occurs after creation. – The product is realized with 3D printing technology.
Scrap	– The business process implementation could be better. – Time losses in eliminating the cause of the problem. – Need to be more trained operators. – Lack of standard procedures	– The "Just in Time" strategy is applied. – The causes of the problem are identified at the beginning of the process. – The operator is prepared to work. – No rigorous procedures are required.
Reserves	– Existence of unnecessary quantities of materials and finished products	– There are no warehouses for material and finished products.

Sustainable and additive manufacturing

AM is essential in creating new markets because it reduces production and service costs. AM expands and builds on the principles of LM and SM. SM can be defined as the connection of processes and systems that use less fossil and more renewable energy sources and materials for product realization. Such products must be safe for employees, customers, and the environment during the entire life cycle (Kacar et al., 2023). SM includes cost reduction and better use of resources, better brand reputation, access to new markets, and labor shortage by creating attractive jobs (Veleva & Ellenbecker, 2001).

According to Colorado and others (2020), AM within the framework of sustainable development was identified in the following areas:

– recognition and evaluation of materials after their use;
– the possibility of recycling materials; and
– monitoring and protection of the environment after the material is used.

AM directly impacts the phases of a product's life cycle, while the pace of adoption and expansion varies in different phases. The product's economic life is reduced, forcing enterprises to shorten the time on the market and their development activities. To shorten the time on the market, applying new production technologies where additive technology has found its application is significant (Horst et al., 2018). SM in symbiosis with AM implies detailed monitoring of all activities, from preparing materials and devices to realizing and post-processing activities. AM technology makes it possible to reduce the product mass and the energy required for its realization.

Also, AM in sustainable development enables the repair or modification of an outdated part, and it enables the replacement of a worn-out part with a new one using recycled material (Cozmei & Caloian, 2012; Ford & Despeisse, 2016). The role of AM in the SM concept was shown in Table 3.

Table 3: AM in SM concept (Hegab et al., 2023; Mani et al., 2014).

Sustainable manufacturing	Additive manufacturing
Manufacturing technologies consider processes and equipment.	– Enables flexible design through redesign, and modification of components, products, and processes, which improves product performance: attractive shape, light materials, and improved construction. – Special tools and accessories need to be reduced. – Large amounts of material need to be reduced. – Spare parts are realized at the customer's request, reducing or eliminating stocks.
The product life cycle focuses on product and service design.	– The product life cycle changes supply chains and reduces the resources needed for delivery.
Importance of value creation methodology (in the organization and knowledge management	– It is possible to acquire skills and competencies at the level of the organization. – Employees are increasingly interested in AM. – There needs to be more knowledge and skills. New educational programs must involve AM technologies.
The global impact of production (it includes society, the economy, and the environment).	– Elements are essential during the product life cycle. – The environment is better protected. – The consumption of energy and other resources is reduced. – Workers' health and process safety are taken care of due to the use of various toxic materials.

METHODOLOGY

FDM process

In this paper, the FDM process basics will be presented. In the FDM process, the designer is given greater freedom in the project approach and definition of the optimal product design than was possible with CM. Also, the designer should have advanced technical knowledge in preparation, setting parameters, and the technological process of printing realization (Chabanenko et al., 2020). With CM, removing material creates waste; with AM, the material is added layer by layer only while the product is being made. (Newman et al., 2015; Sun et al., 2016), see Figure 1. AM creates waste but in a much smaller amount.

The FDM process enables changes to the model before the production launch. These changes are made using a CAD program, simplifying communication with the product's customer. The conceptual computer CAD model is later realized as a 3D model on the printer (Campbell et al., 2011). Before the model realization, the geometry and its complexity are first considered, which was not previously the case with conventional processing (Doubrovski et al., 2011).

FDM process steps

The FDM process takes several steps:

1. Product design; is realized with the help of any 3D CAD package based on the existing documentation or with specialized software that downloads the model's configuration (Eyers & Potter, 2017). In the next step, customers' engagement in defining the design is significant; they become part of the value network (Rylands et al., 2016). Also, many preparatory activities are undertaken there, including assessing the manufacturing feasibility, error checking, and manufacturing planning activities to locate existing resources for work on time (Eyers & Potter, 2017). Here the CAD 2D drawing of the model is converted to STL format.
2. The manufacturing process; indicates the preparation and start of the device with parameter adjustment. In the end, the material is delivered. Manipulation with the STL file implies its conversion into G-code, essential for starting the 3D printer (Mazurchevici et al., 2020).
3. The finishing process includes all final actions, from cleaning and removing excess material to product painting (Ghazy, 2012); see Figure 2. Finally, unnecessary material is disposed of to be recycled.

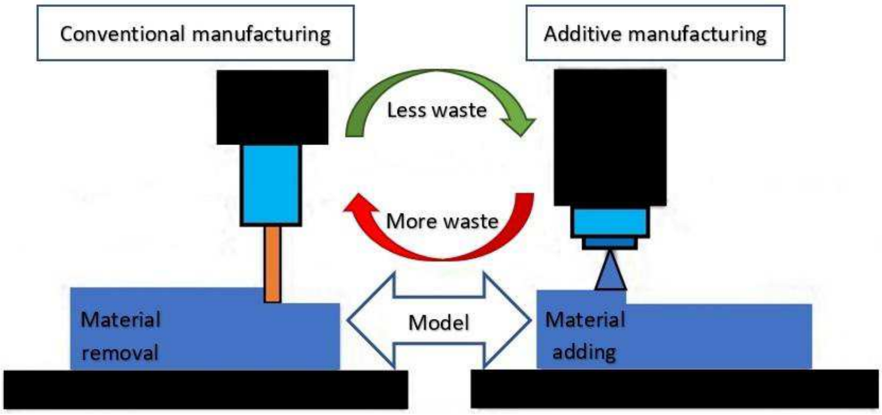

Figure 1: Difference between CM and AM

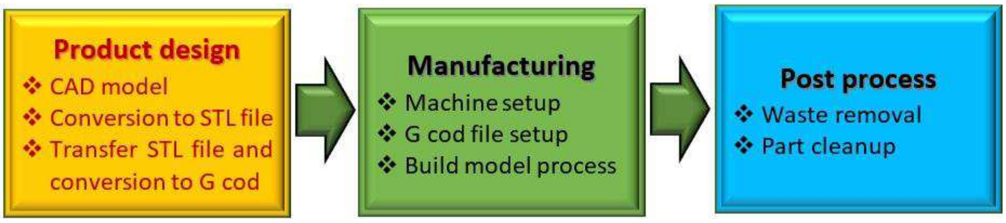

Figure 2: Steps in model realization using AM

RESULTS

In this paper, based on the described links between CM, AM, and SM in Table 4, a flowchart of documents and activities in sustainable product development is given. As a final consideration, the following can be said about AM:

– provides quick realization of prototypes;
– enables quick replacement of parts in critical places;
– reduces the number of components in the assembly;
– complements the CM in places where the technological production of the work is complicated;
– takes into account the principles of sustainability and SM; and a wide range of materials is in use.

CONCLUSION

The path from LM to SM implies AM as the primary tool for achieving defined goals, and this implies a change in business processes, analysis, and product checking in all its phases. Links with LM and SM indicate a reduction in the prototyping time to the manufacturing stage and design changes in the shortest possible time. If AM is implemented in environmental protection, eco-products are obtained where energy consumption is significantly reduced.

In AM, the designer has direct contact with the customer. Valuable information about the end user's needs and creating a unique database of future conceptual and ready-made solutions essential for the enterprise's sustainable development is necessary. The production costs of AM have been reduced to a minimum, while the product's lifetime has been extended. AM has its ecological potential through the well-known principles of sustainability, which are reflected in the efficient use of materials (with particular reference to the nature and toxicity of materials), waste management, preservation, and improvement of the health of employees, as well as other security issues (intellectual property, data protection of individuals and enterprises). In particular, AM offers a significant advantage in the product design phase and enables reprogramming production processes.

Table 4: Timeline of documents and activities in the product realization

No	Flow chart	Activity	Dept	Document	Remark
	Start				
1.		Receiving the product from the customer	PR	– Product list – Contract	Certain benefits are given to the customer when giving over the old product and when they purchase a new product.
2.		Opening a work order	PR	– Contract – TC documentation	The purchasing, receiving, and storage department activates the work order of the manufacturing department.
3.	Yes W No	Is the product correct?			The correct product is placed in the warehouse of finished products.
4.		Product disassembly	MF	– TC documentation – Work order – Checklist	The correctness of components and assemblies is tested.
5.	Yes W No	Can certain parts be used?			The good parts are cleaned (or repaired) and stored in finished or semi-finished warehouses.
6.		Perform component replacement	MF	– Replacement list – TC documentation	Defective parts are replaced with new or modified components. Defective parts are discarded.
7.		Component's modification	MF	– TC documentation – FDM procedure	The AM process is initiated for component modification.
8.		Start AM	MF	– FDM procedure	Repaired or new elements (conventionally produced) are taken from the warehouse, and elements made using additive technology can also be taken over.
9.		Use of components from the warehouse	PR	– Requirements list	Repaired or new elements (conventionally produced) are taken from the warehouse, and elements made using additive technology can also be taken over.
10.		Finished parts control	MF	– TC documentation – Work order – Work list – Checklist	Control of all components is carried out, both those made by conventional processing and those made using additive technology.
11.		Parts assembling	MF	– TC documentation – Work order	The assembly procedure takes place in the workshop, and the sequence of the operation is strictly observed.
12.		Product testing	MF	– TC documentation – Work order – Maintenance Manual	Testing the product's functioning and defined parameters according to the declared purpose is carried out.
13.		Product completion	MF	– Maintenance Manual – List of requirements – Other documents	Different materials play an essential role in packaging. Additive technology has its importance here as well.
14.		Product packaging	MF	– Work order – Output list	Attending documentation and an invoice are issued with the product. The sale department is responsible for handing over the finished or new product to the customer.
	End				

	Start and End		Activity		Control and decision	PR – Procurement MF – Manufacturing

AM has its potential when it comes to the Lean philosophy. The concept of LM is to reduce the use of resources. Many changes in technologies significantly affect changes in organizations. Production productivity and the quality of the manufactured product still need to be solved for AM. Individual or small-scale manufacturing is the basis of AM, which is essentially irrelevant for CM. Companies turn directly to customers to compensate for this lack through rapid product prototyping, production automation, closed system manufacturing, and fast delivery.

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REFERENCES

Attaran, M. (2017). The rise of 3-D printing: The advantages of additive manufacturing over traditional manufacturing. *Business Horizons*, *60*(5), 677-688. https://doi.org/10.1016/j.bushor.2017.05.011

Bevilacqua, M., Ciarapica, F. E., & De Sanctis, I. (2017). Lean practices implementation and their relationships with operational responsiveness and company performance: an Italian study. *International Journal of Production Research*, *55*(3), 769-794. https://doi.org/10.1080/00207543.2016.1211346

Bicheno, J., & Holweg, M. (2008). *The Lean toolbox: The essential guide to Lean transformation, Production, and Inventory Control*. System and Industrial Books*,* UK. ISBN 9780954124458

Bogers, M., Hadar, R., & Bilberg, A. (2016). Additive manufacturing for consumer-centric business models: implications for supply chains in consumer goods manufacturing. *Technological Forecasting and Social Change*. *102*, 225–239. https://doi.org/10.1016/j.techfore.2015.07.024

Campbell, T., Williams, C., Ivanova, O., & Garrett, B. (2011). *Could 3D printing change the world? Technologies, Potential, and Implications of Additive Manufacturing*. Atlantic Council, Washington DC.

Chabanenko, A. V., Kurlov, A. V., & Tour, A. C. (2020, April). Model to improve the quality of additive production by forming competencies in training for high-tech industries. In *Journal of Physics: Conference Series* (Vol. 1515, No. 5, p. 052065). IOP Publishing. https://doi.org/10.1088/1742-6596/1515/5/052065

Choi, S. H., & Samavedam, S. (2002). Modelling and optimisation of rapid prototyping. *Computers in industry*, *47*(1), 39-53. https://doi.org/10.1016/S0166-3615(01)00140-3

Colorado, H. A., Velásquez, E. I. G., & Monteiro, S. N. (2020). Sustainability of additive manufacturing: the circular economy of materials and environmental perspectives. *Journal of Materials Research and Technology*, *9*(4), 8221-8234. https://doi.org/10.1016/j.jmrt.2020.04.062

Cozmei, C., & Caloian, F. (2012). Additive manufacturing flickering at the beginning of existence. *Procedia Economics and Finance*, *3*, 457-462. https://doi.org/10.1016/S2212-5671(12)00180-3

Dizon, J. R. C., Espera Jr, A. H., Chen, Q., & Advincula, R. C. (2018). Mechanical characterization of 3D-printed polymers. *Additive Manufacturing*, *20*, 44-67. https://doi.org/10.1016/j.addma.2017.12.002

Dora, M., Kumar, M., & Gellynck, X. (2016). Determinants and barriers to lean implementation in food-processing SMEs–a multiple case analysis. *Production Planning & Control*, *27*(1), 1-23. https://doi.org/10.1080/09537287.2015.1050477

Doubrovski, Z., Verlinden, J. C., & Geraedts, J. M. (2011, January). Optimal design for additive manufacturing: opportunities and challenges. In *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, 54860, 635-646. https://doi.org/10.1115/DETC2011-48131

Eyers, D. R., & Potter, A. T. (2017). Industrial Additive Manufacturing: A manufacturing systems perspective. *Computers in Industry*, *92*, 208-218. https://doi.org/10.1016/j.compind.2017.08.002

Ford, S., & Despeisse, M. (2016). Additive manufacturing and sustainability: an exploratory study of the advantages and challenges. *Journal of Cleaner Production*, *137*, 1573-1587. https://doi.org/10.1016/j.jclepro.2016.04.150

Ford, S., Mortara, L., & Minshall, T. (2016). The emergence of additive manufacturing: introduction to the special issue. *Technological Forecasting and Social Change*. *102*, 156–159.

Frăţilă, D., & Rotaru, H. (2017). Additive manufacturing–a sustainable manufacturing route. In *MATEC Web of Conferences*, 94, 03004. EDP Sciences. https://doi.org/10.1051/matecconf/20179403004

Ghazy, M. M. S. A. (2012). *Development of an additive manufacturing decision support system (AMDSS)*. Doctoral dissertation, Newcastle University.

Ghobadian, A., Talavera, I., Bhattacharya, A., Kumar, V., Garza-Reyes, J. A., & O'regan, N. (2020). Examining legitimatisation of additive manufacturing in the interplay between innovation, lean manufacturing and sustainability. *International Journal of Production Economics*, *219*, 457-468. https://doi.org/10.1016/j.ijpe.2018.06.001

Hegab, H., Khanna, N., Monib, N., & Salem, A. (2023). Design for sustainable additive manufacturing: A review. *Sustainable Materials and Technologies*, e00576. https://doi.org/10.1016/j.susmat.2023.e00576

Horst, D. J., Duvoisin, C. A., & de Almeida Vieira, R. (2018). Additive manufacturing at Industry 4.0: A review. *International Journal of Engineering and Technical Research*, *8*(8), 3-8.

Huang, Y., & Leu, M. (2014). *Frontiers of additive manufacturing research and education*. University of Florida, Gainesville, FL.

Kacar, B., Turhan, E., Dalkiran, A., & Karakoc, T. H. (2022). Green Airport building certification comparison: A practical approach for Airport Management. *International Journal of Green Energy*, *20*(6), 1-14.

Mani, M., Lyons, K. W., & Gupta, S. K. (2014). Sustainability characterization for additive manufacturing. *Journal of research of the National Institute of Standards and Technology*, *119*, 419. https://doi.org/1010.6028/jres.119.016

Mazurchevici, A. D., Nedelcu, D., & Popa, R. (2020). Additive manufacturing of composite materials by FDM technology: A review. *Indian Journal of Engineering and Materials Sciences*, *27*(2), 179-192.

Nannan, G. U. O. (2013). Additive manufacturing: technology, applications and research needs. *Frontiers of Mechanical Engineering*, *8*(3), 215-243. https://doi.org/10.1007/s11465-013-0248-8

Newman, S. T., Zhu, Z., Dhokia, V., & Shokrani, A. (2015). Process planning for additive and subtractive manufacturing technologies. *CIRP Annals*, *64*(1), 467-470. https://doi.org/10.1016/j.cirp.2015.04.109

Rylands, B., Böhme, T., Gorkin III, R., Fan, J., & Birtchnell, T. (2016). The adoption process and impact of additive manufacturing on manufacturing systems. *Journal of Manufacturing Technology Management*, *27*(7), 969-989. https://doi.org/10.1108/JMTM-12-2015-0117

Seepersad, C. C., Govett, T., Kim, K., Lundin, M., & Pinero, D. (2012). A designer's guide for dimensioning and tolerancing SLS parts. In *2012 International Solid Freeform Fabrication Symposium*. University of Texas at Austin. http://dx.doi.org/10.26153/tsw/15400

Sossou, G., Demoly, F., Montavon, G., & Gomes, S. (2018). An additive manufacturing oriented design approach to mechanical assemblies. *Journal of Computational Design and Engineering*, *5*(1), 3-18. https://doi.org/10.1016/j.jcde.2017.11.005

Sun, Z., Tan, X., Tor, S. B., & Yeong, W. Y. (2016). Selective laser melting of stainless steel 316L with low porosity and high build rates. *Materials & Design*, *104*, 197-204. https://doi.org/10.1016/j.matdes.2016.05.035

Veleva, V., & Ellenbecker, M. (2001). Indicators of sustainable production: framework and methodology. *Journal of Cleaner Production*, *9*(6), 519-549. https://doi.org/10.1016/S0959-6526(01)00010-5

Wang, W. M., Zanni, C., & Kobbelt, L. (2016, May). Improved surface quality in 3D printing by optimizing the printing direction. In *Computer Graphics Forum*, *35*(2), 59-70. https://doi.org/10.1111/cgf.12811

ZNAČAJ I VEZA ADITIVNE PROIZVODNJE SA LEAN I ODRŽIVOM PROIZVODNJOM

U ovom radu, izvršeno je poređenje koncencionalne i aditivne proizvonje. Takođe analizirani su Lean i održiva proizvodnja sa stanovišta otpada. Konstatovano je da se konvencionalna proizvodnja polako zamenjuje aditivnom proizvodnjom, ali da je njena uloga I dalje značajna. Lean proizvodnja ukazuje da je otpad prisutan svuda, odnosno na svim organizacionim nivoima. Održiva proizvodnja analizira nove tehnologije i meri njihov uticaj na zaštitu životne sredine uz što manju potrošnju resursa. U radu je pokušano da se ispita značaj aditivne proizvodnje u održivoj proizvodnji razmatrajući principe Lean proizvodnje. U zaključnom delu dat je hodogram dokumenata i aktivnosti koji metodološki uvode aditivnu proizvodnju kroz poštovanje Lean principa i održive proizvodnje. Ušteda u vremenu proizvodnje, lansiranju novih proizvoda, brzoj zameni delova su danas postali imperative i dalji nastavak ovog rada trebalo bi da bude usmeren na definisanju modela i procedura u održivom razvoju preduzeća.

Ključne reči: Otpad; Aditivna proizvodnja; Lean proizvodnja; Održiva proizvodnja; FDM postupak.