Additive Manufacturing in the Aerospace Industry: Impact on Purchasing Process

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Abstract Additive manufacturing (AM) has become an important tool in manufacturing companies that seek to improve their competitiveness by adapting their manufacturing processes to their customer requirements. In this study, the authors seek to deepen the knowledge about the disruptive potential impact of additive manufacturing (AM) implementation in aerospace sector purchasing processes. During the study it has been analyzed the changes on the purchasing processes, activities, and cost-related issues, when aerospace companies decide to change from their traditional manufacturing models to one new manufacturing model based on AM adoption. Result analysis allow authors to infer quite several relevant changes in terms of purchasing function definitions, investments, and costs involved which could be relevant to consider before AM implementation is decided by aerospace companies.

Keywords Additive manufacturing · Aerospace industry · Aerospace purchasing

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1 Introduction

Additive manufacturing (AM) is a term used to define the process of building new products by adding successive thin layers of material [1]. In 1972, Ciraud launched the first technology that can be considered as a precursor to its modern-day counterpart [2]. Although there are drawings and diagrams of this specific process, there is no evidence that he was able to physically execute it. In the early eighties, Hideo Kodama and Alan Herbert launched the first devices that worked using a technology called "3D printing", which would subsequently be referred to a more comprehensive way as "additive manufacturing" [1, 2]. A few years later, in 1986, Charles Hull developed the "stereolithography machine", considered the first device capable of producing and making 3D parts [3]. The process also should include the proper design of an IT model based on 3D computer-aided design software (CAD) and tools for the production of the model using 3D printing technology.

The main applications of AM are: (i) "rapid prototyping", perhaps the most mature application [4]; (ii) "small batch production", applicable in situations where a single unit or a very limited number of them should be manufactured [5]; and (iii) "on-demand manufacturing", 3D printing can support a simpler and shorter supply chain, meaning that a number of geographically distributed printers could meet local demands while significantly reducing transport costs and order-to-delivery lead times [6]. The disadvantages of AM versus subtractive manufacturing processes, for instance, include (i) the limited volume of products that can be executed, (ii) the limited choice of materials used in making those products, and (iii) limitations on the type of product finishing or color [7].

In terms of future applications [7], AM could be extended to (i) consumer electronics products, toys, and jewelry; (ii) automotive industry, mainly for prototyping, but customized solutions are widely predicted for the near future; (iii) medical and dental solutions, which is currently considered a key market, with more than half of hearing aids and orthotics already being produced using 3D printing; and (iv) aerospace, reducing the buy-to-fly ratio due to the possibility of replacing heavy components with elements made of titanium and nickel. In addition to these highly relevant applications that are already in place, other immediate applications are being developed in completely unrelated fields, for instance, in the food industry [8].

Although the development of this technology is still fairly new, according to authors such as Kietzmann et al. [9], the estimated market value of 3D printing products and services in 2017 had reached USD 3.7 billion and this value is expected to double by 2020. It is important to highlight that this technique is considered to be one of the four main pillars of Industry 4.0 and the aerospace industry is one of the pioneers in the use of AM, exponentially improving the quality of current deposition aerospace manufacturing techniques. AM is now a process with highly disruptive potential in this industry.

For example, at the end of 2015, Boeing introduced more than 20,000 original parts built applying AM technology [10]. Original parts (OP) are those used for the production of a new aircraft, while spare parts are used to manage aircraft service support during its life cycle. These 20,000 pieces were non-metallic (mainly plastic-based parts). Meanwhile, Airbus has also been installing thousands of non-metallic parts in its airplanes since 2014.

Moreover, the first two titanium metal brackets using AM were introduced on Airbus production lines in 2014, and were both introduced in the A350 model, making a breakthrough step forward [11]. According to the Airbus Group (Airbus Press release), the company has achieved several benefits adopting this AM technology (i.e. reducing the cost by 50–55% in one piece and 30–35% reduction in the other) not only on the cost side but also on the design cycle reduction.

2 Objective and Study Methodology

The research is trying to understand to what extent additive manufacturing development and application in aerospace sector companies could influence industry supply chain performance, with a special focus on their purchasing process. The purchasing process is extremely important in the aerospace industry due to the high value of outsourced and purchased materials, operations, and equipment [12].

This study belongs to research that will have different phases and includes different scenarios, combining in-house and outsourced manufacturing of OP aircraft. In this preliminary scenario, the research will be focused on the consequences of the purchasing process when AM is applied to in-house manufacturing.

Published research has tried to describe some benefits of AM in supply chain management [13, 14]. Additional studies sought to understand the main benefits of this technique within the aerospace supply chain industry by (i) reducing inventories, (ii) increasing reaction speed, and (iii) reducing lead times. Even some authors have managed to perform small simulations to compare "traditional supply chains" with AM-based supply chains [15, 16] in order to infer performance improvement difference.

This study goes further and aims to understand the current and future applications of AM technology as a factor that could strongly transform the aerospace industry supply chain by influencing its purchasing process. The authors have based this research on these sources: (i) a detailed review of the published literature, especially focused on recent research; (ii) the direct involvement of one of the authors in the direct leadership of the purchasing process of a top aerospace company, especially on some of the projects that have been analyzed for this research (action research). According to Coughlan and Coghlan [17], action research could bring extra insight into the research due to the specific nature of the matter, and finally (iii) the authors also tried to get valuable knowledge from some field experts who could bring extra veracity and reliability. This part was performed using semi-structured surveys, based on in-depth interviews to gain insight into good industry practices. Five in-depth interviews (personal interviews) were managed with senior executives currently working in two major aerospace companies. Of course, the interviews have been done based on semi-structured questionnaires, and always guaranteeing that the information would only be used for academic research and always managed as an aggregated database.

3 Additive Manufacturing Influence on Aerospace Supply Chain

In the aerospace supply chain, over one thousand companies contribute to the manufacture of a specific aircraft. Any large aircraft is built in its final assembly line, where major structural building blocks are supplied directly. Building blocks arrive from either internal manufacturing plants or some major external supplier. These major suppliers act as risk and revenue sharing partners, participating starting from the initial program launch. Each supplier that delivers parts to the final manufacturer is considered Tier 1 of the process. Those who deliver parts directly to the Tier 1 supplier are considered Tier 2, and consequently, those who deliver to Tier 2 suppliers are considered Tier 3 suppliers. To give an idea of the magnitude of the process, an A380 airplane incorporates 2.5 million different part numbers, of which 70% are sourced from 1,500 suppliers [13]. Purchasing and supply management have thus become one of the key success factors for manufacturing an aircraft [18]. It requires an important dedication of resources, one of the main operating risks, and in a certain sense, it will condition the company's strategy. The main functions involved in the aerospace supply chain within the purchasing process could be described as follows (Table 1).

Table 1 Roles and responsibilities of the main purchasing functions

LEVEL A – Strategic Purchasing:
Responsible for leading the commercial negotiations and the value for money performance, defining the purchasing strategy throughout all aircraft projects, contract management.
LEVEL B – Operational Purchasing:
Accountable for supplier industrial performance. Supports the daily operations, follows up all the deliveries, manages the release of purchasing orders.
LEVEL C – Logistics Control:
Specifically dedicated to logistics and warehousing. It keeps in close contact with the forwarding companies, manages the warehouses and performs the incoming inspections.
LEVEL D – Purchasing Quality:
Oversees supplier quality performance. Level D is accountable for the suppliers' process control, performing audits and industrial capacity assessments, validating quality of the goods.
LEVEL E – Purchasing Coordination:
Ensures the coordination between all purchasing functions. Implement processes, manages the prioritisation of tasks, as well as information distribution.
LEVEL F – Supplier Development:
Works across the board with the other purchasing functions, developing strategic suppliers by applying lean tools.

Source authors' elaboration

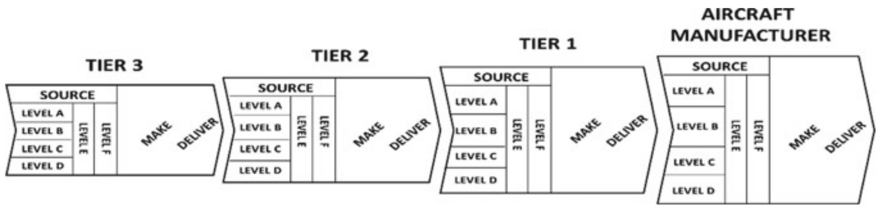


Fig. 1 Purchasing functions manufacturer and supplier. *Source* authors' elaboration

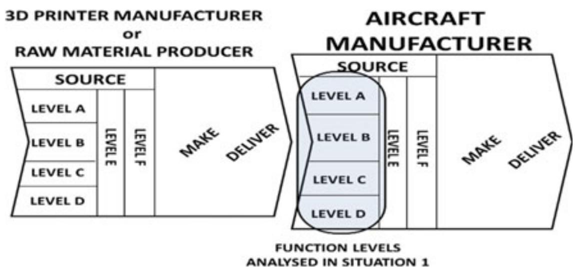
These six functional levels could be found in every department of any company in the aerospace industry, perhaps with different names but with similar functions. It should be noted that any supplier with whom a buyer deals would have its own corresponding purchasing department, with the same functions defined. Figure 1 below summarizes the purchasing processes of a company and its suppliers.

The consequences of adopting a potentially disruptive manufacturing system like AM and its impact on the complex management structures of the supply chain, and more particularly on the main process like Purchasing, require an in-depth analysis, which has not been done so far. Out of the six levels described here, this paper focuses on the first four, from Levels A to D. Levels E and F provide across-the-board support to Levels A to D and have less exposure to any manufacturing technology change.

4 Impact of AM on Original Parts Purchasing Process. Analysis and Discussion

This research looks to analyze how the adoption of AM technology influences the purchasing process when parts are internally manufactured, both using traditional manufacturing and AM. In the below example (Fig. 2), the case of a metallic part that is currently produced internally by the aircraft manufacturer using the conventional manufacturing process is shown. This is compared with a scenario in which the part is produced internally using AM. Being an internally produced original part (OP), the purchasing processes are very focused on the procurement of the components, as well as the purchasing of the machinery and tooling.

Fig. 2 From traditional manufacturing to AM. *Source* authors' elaboration



Prior to the adoption of AM, the Level A function only participates in the negotiation of specific tools and production support equipment. This negotiation takes place once at the beginning of the project launch, and there are many suppliers willing to manufacture these parts (with little bargaining power). When AM is adopted, the Level A function becomes responsible for purchasing new machinery to adapt to this new technology, it leads negotiations with the 3D printer manufacturers. Although this does not imply a radical change in its functional role, it will require technological knowledge. The work will be similar in terms of workload, but different in terms of technical expertise. It will require new skills and training to properly negotiate the machinery purchasing contract.

Prior to AM adoption, the Level B function is mainly occupied with recurring purchases of base material for production. Suppliers are generally large heavy-duty forged metals corporations that are stable in their day-to-day operations and even able to absorb some of the fluctuations in commodity prices. Price fluctuations can be very high, and it is the biggest challenge that faces Level B. The move to AM requires a change of suppliers, namely powdered metal or consumable yarn suppliers, depending on the type of additive process used. As they are generally smaller suppliers, their capacity to absorb cost variations when raw material prices change drastically can be expected to be lower, meaning that there will be fluctuations in raw material final costs. On the other hand, since AM is a production process that optimizes the use of materials, the inventory will probably be reduced, making it easier to manage.

Table 2 Impact on purchasing functions

LEVEL A	Without AM	With AM	Impacts
Commercial negotiations **Contracts management** **Purchasing strategy**	Tooling purchasing	3D printers purchasing	Training needed No relevant change
LEVEL B	**Without AM**	**With AM**	**Impacts**
Purchasing orders **Delivery follow up** **Inventory management**	Materials/components purchasing WIP management	Raw materials purchasing	Easier inventory management Higher variability production direct costs
LEVEL C	**Without AM**	**With AM**	**Impacts**
Logistics management **Wharehousing** **Incoming inspections**	Space management	Less space management	Less space needed Less people Less cost
LEVEL D	**Without AM**	**With AM**	**Impacts**
Process control and deviations **Audits/assessments**	Process control of raw material	Process control of consumable yarn or material dust	Training needed No relevant change

Source authors' elaboration

Level C is mainly involved in the logistics and storage of recurring materials. Considering that one of the greatest benefits when implementing AM is the reduction in the amount of resources used, Level C will be positively impacted, as it will require a lower volume of material, which will mean less storage space, a smaller number of people, and a decrease in stock maintenance. The Level D function is concerned with process control and is responsible for the purchased product. Generally, the base material manufacturers follow very robust production processes, with a very small number of deviations, so quality control has a relatively low weight in this scenario. Both prior to the adoption of AM and after applying it, Level D is responsible for the quality of the base material purchased. Whether in powder form, consumable thread, or conventional forging, an increase in the number of issues should not be experienced (as shown in Table 2).

5 Conclusions

In the specific analyzed scenario, based on the consideration that an aerospace company decides to move from an in-house and traditional manufacturing model to additive manufacturing, it could be inferred that the impact on the purchasing process is mainly perceived on the way of working changes and a purchasing function task refitting. This means that just to introduce this change, theoretically simple but with complex implications, a clear plan and roadmap should be drawn, involving all relevant people involved. The different purchasing levels described in the study would require training to become familiar with the new techniques and their new way of working.

The scope and responsibilities of the main purchasing identified levels would be significantly reduced. This means a huge reduction in the number of references to purchase and in the number of suppliers to deal with.

Purchasing cost drivers (including work in progress, logistics, and the amount of space required) will all be reduced. An optimization of inventory management and lower logistics costs are expected, and a higher standardization of the products to be supplied would probably generate additional savings.

These changes will mean not only an optimization of the company operating margins, but also a remarkable reduction in the need for direct human resources in the aircraft manufacturer purchasing function. Furthermore, the effect on the Tier 1 supplier's purchasing function could be even greater. Vertical integration of the purchasing function could also happen, and the consequences will be studied in future research. Despite previously described consequences, the purchasing team would generally continue to purchase manufacturing equipment and materials for production as usual.

Based on this analysis, it is possible to infer that the purchasing function could be simplified with the application of AM within the aerospace sector, and costs would be reduced. The aerospace supply chain would become shorter, prepared for a breakthrough lead times reduction. All these drivers could bring subsequent benefits such as lower inventories and less capital employed. The total integral cost reduction could be relevant if the potential reduction in human resources is considered.

Statement on Compliance with Ethical Standards The Research Ethical Committee of Universidad Carlos III de Madrid approved the entire procedure followed by the authors in the research (ref. CEI2019_ 014_Morcillo_Jesus). The data has been anonymized. The authors also declare that they have no conflict of interest.

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