

Turning additive manufacturing into business

Opportunities and challenges encountered in discussions on field cases

An Industry 4.0 white paper

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Industry 4.0 and additive manufacturing

The fourth industrial revolution (also known as Industry 4.0) has arrived to the industrial sector and is offering enormous potential for the industry. Industry 4.0 is characterised by the increasing digitisation and interconnection of products, value chains and business models. It is bound to revolutionise the product and service portfolio of companies with the ultimate goal of satisfying customer needs better and more effectively.

Companies will need to overcome several challenges on their way to becoming an Industry 4.0 champion. The scope of application spans the entire value chain, and requires transformation of business and operating models. Furthermore, sufficiently skilled personnel with new capabilities to meet the needs of the digital world must become available. A recent PwC study, on the challenges and opportunities of Industry 4.0, has shown that European companies will be investing more than 140 billion Euros per year in the next five years in Industry 4.0 solutions applications.

This white paper is the first in a series in which PwC shares insights generated from interactions with companies facing the Industry 4.0 challenge. The central theme of this particular white paper is additive manufacturing (also known as 3D printing). In this paper, we present the current state of technology adoption, the business value created, and challenges encountered as experienced by and discussed with a group of forty business and technology leaders during a Think Tank session held at the High Tech Campus in Eindhoven, The Netherlands in October 2015. The group and presenters consisted of business leaders in the industrial and consumer products, transport and energy sectors, as well as representatives from technology firms. This paper highlights how they are implementing additive manufacturing, and their view on the (potential) business value.

Consequently, rather than aiming to be exhaustive, this paper is meant to show a snapshot on how these business leaders see the current and future added value of additive manufacturing.

What is additive manufacturing?

Additive manufacturing, which is also referred to as 3D printing, is a collective name for several technologies through which an object is constructed layer by layer. The industrial materials that are currently printable range from polymers to metals, including for example ceramics. The range of available materials is constantly and rapidly expanding. Whereas additive manufacturing was originally mostly used for prototyping, it is now more and more applied to end-products. In some cases, additive manufacturing can be considered as a supplement to conventional production technologies. In other cases it is the only means through which complex products can be fabricated or a solution to cost-effective upscaling of production capacity at low risk in order to serve new verticals, new geographies, and offer new products that need testing.

The technique offers several advantages that optimize and transform both products and processes, and may result in unprecedented and significant business value.

The generic advantages of additive manufacturing are:

- **Complexity is free**; additive manufacturing offers complete design freedom which allows to design for the exact function of a product without constraints associated with conventional manufacturing.
- **Minimum batch size is one**; the cost per part produced is equal and significantly less dependent on batch size.
- **Manufacturing when and wherever needed**; production at or near point of use is possible.
- **Minimum material waste**; as material is added, not subtracted, material is saved in production which allows for cost savings, especially in cases where material is a significant driver of component cost.

Although the general consensus is that these advantages offer great (potential) business value for both products and processes, there is a much divergence in visions of the type and depth of value that can be achieved. Therefore, we focussed on assessing how much of this value is currently being unlocked by our discussion group. And how much potential do they see in the near future when the technology matures (becomes faster, more reliable and cheaper) and additive manufacturing systems and services improve?

Business value currently achieved by Think Tank participants

The specific business values that are currently being achieved based on the principles mentioned above, are best categorised with respect to added value for processes as well as products. The more this added value applies to customer-end applications, the more we see the occurrence of competitive advantage, new business models and propositions.

Our consultation partners currently see the following pockets of value being created:

Business value for processes:

- The **time-to-market** for new parts and products is reduced significantly. This boosts the speed of product innovation spectacularly.
- **Asset maintenance** or maintenance of machines in the field becomes easier: spare parts and specialised tooling are always available on demand.
- **Assembly time and tooling costs** are reduced if a product or part can be printed in one go, without requiring sub-assembly.

Business value for products:

- Related to the last point, additive manufacturing makes it also possible to **optimize the design** by printing a product that previously consisted of sub-assemblies in one go. This significantly decreases error rates during the lifetime of a

product, and increases the product lifecycle.

- As the **minimum production quantity is one unit**, it is possible to offer (mass)-customisation. As a result, new verticals and geographical markets with specific needs can be opened up at low risk and low cost.
- By means of **rapid prototyping and rapid testing**, design can efficiently be optimized and the ‘voice of the customer’ can be included in new product development.

Current business models

Additive manufacturing opens up new business models and propositions. Our discussion partners indicated that they currently see the following business models emerging:

1. Co-creation platforms enabled by additive manufacturing

Additive manufacturing opens up the possibility to co-create with customers. Co-creation can be introduced in virtually all stages of the lifecycle of a product. During the concept phase of a new product, the voice of the customer can easily be incorporated by testing small batches. It can also be applied to offer customisation of an existing design, or to prolong the lifetime value of a product by offering customized add-ons to the product. In situations where customization is of value to customers, premium pricing is justified.

This type of co-creation results in interaction between the supplier and the customer. The added advantage here is that the supplier obtains relevant data from the users of 3D printed products. Co-creation can be valid in both the industrial market as well as the consumer market. For industrial player Schunk, their co-creation platform also offers a means of partly automating the engineering function of a business and making it available in both real time and on demand (see Field case 1: Gripper customisation at Schunk).

2. Extreme customisation

Combined with tools like measuring guides and scanning tools, companies are now able to mass produce custom-fit items in a cost-effective manner. As the performance of fitted products is generally much higher, customer value will greatly increase as well. From prostheses to glasses to in-ear headphones, there is a surge of business models created around this ultimate form of customisation. Although more and more home scanning tools are becoming available, it is important to note that for medical applications, such as prostheses and hearing aids, sophisticated professional devices are needed to achieve the high level of accuracy needed.

Field case 1

Gripper customisation at Schunk by Materialise

Schunk is a manufacturer of grippers for production processes. As every production facility requires different grippers, these are made to measure. Previously, with the application of conventional technologies, this process was time and resource intensive. A product line designer had to coordinate intensively with the engineering team at Schunk, after which Schunk produced the made-to-measure gripper. In collaboration with the Belgian company Materialise, a provider of Additive Manufacturing software solutions and sophisticated 3D printing services, Schunk has now created an online platform to facilitate digital co-creation based on additive manufacturing. The platform offers standard gripper shapes, which can be customized to the exact requirements needed. Subsequently, the customised gripper is printed and delivered within a week. The entire digital module to customize and order takes about 20 minutes to complete. Additive manufacturing therefore involves substantial time gains and less engineering capacity, as clients can customize and order on demand. Besides, Schunk receives a wealth of data as to what products are needed by whom and when.

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3. Lifecycle management

In the industry, lifecycle management is one of the most prominent current applications of additive manufacturing. Prolonging the lifecycle starts with the design phase of the product or part. Using the design possibilities offered by additive manufacturing, assembly might not be needed, which prolongs the lifecycle of a product and reduces errors. On the after-sales side, the life of machines in the field or the assets employed can be prolonged by using custom-made tooling and difficult to source, expensive to stock, customised spare parts. In general this relates to supply chain excellence (eliminating steps in manufacturing, lowering costs of tooling, and simplifying maintenance processes) which can significantly lower overall supply chain costs as well as offering increased customer service.

4. Additive manufacturing service propositions

The growth in the adoption of additive manufacturing has resulted in the emergence of many new service propositions related to the supply of the technology as well as solutions within the entire associated process. Additive manufacturing requires many new capabilities that businesses have just started to build up, so there is a lot of space for service providers in this area. Understanding the design possibilities and possible product benefits, the specifications of designing for additive manufacturing, material and printing

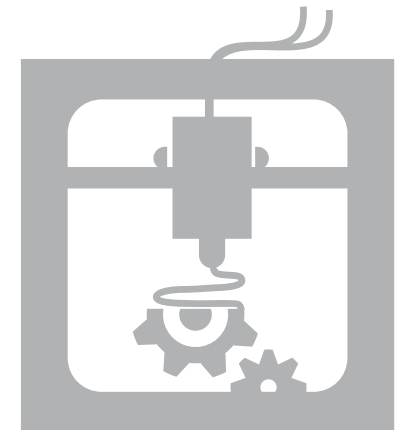
techniques, printer operations and post-processing, as well as the ability to adopt quality measures all require skilled and experienced employees. Businesses of all sorts are increasingly assessing the role they can play in supplying these additive manufacturing services (see Field case 2: A print hub in the Port of Rotterdam and Field case 4: Sharing printing capacity and investments in Adlab).

Future business models

As the general maturity of additive manufacturing increases, the applicability of both a technological as an economical perspective increases as well. Our consultation partners indicated that they see potential; particularly as a result of the repeatability and accuracy of the technology, its increasing speed, the number of materials that can be used, multi-material print capabilities and the size of the printable surface. As soon as the speed of the hardware increases, the depreciation of the machine per printed part will be reduced and costs per product are lowered. This means that a larger portion of the product or part portfolio will be printable from an economic perspective.

In addition, the size of the printable surface has a positive influence on the business case. When you can print larger parts, you can also produce larger series in a single print job. This will lead to a

reduction in the manufacturing time of a product and therefore to a reduction in the total cost of ownership as well.



Field case 2

A print hub in the Port of Rotterdam

Although the general understanding of the value of high-end additive manufacturing is still at its early stages and implementation at many companies is still in the experimental phase, the Port of Rotterdam expects that additive manufacturing will yield much value in the coming years. Adopting a strategic logistical position at the start of the fourth industrial revolution is expected to result in enormous competitive advantages. For this reason, the Port of Rotterdam has developed a vision of creating an industrial print hub in the harbour. As part of their smart port proposition, the Port of Rotterdam envisions to be able to offer a platform for port businesses to source high-quality industrial parts on demand. This printing hub will be qualified to produce parts that meet the requirements for industrial and maritime use. Especially for the maritime business, this is a very interesting proposition as downtimes are extremely expensive. As an initial measure, the Port of Rotterdam set up a pilot in partnership with Innovation Quarter and RDM Makerspace in which they have embarked on a learning process to identify which parts are currently suitable for printing and which are not. This pilot will enable the maritime consortium to acquire thorough knowledge of the technologies, map out the possibilities and challenges, collect business case data and take specific follow-up steps.



Field case 3

Making the business case: LayerWise's view on total cost of ownership

LayerWise, a Belgian based subsidiary of 3D Systems, specialises in selective laser melting (SLM) of metal parts. This metal has the same structure and properties as the metal used in the case of conventional technologies. Consequently, as production costs of this technique are often higher than those of conventional technologies, the company is focussed on educating the market on the added value and benefits that additive manufacturing is bringing to their customers. In addition to improved performance and complex design, the total cost of ownership in the case of additive manufacturing can be lowered compared to products made through conventional technologies. This is partly the result of a longer lifecycle and lower maintenance costs. As additive manufacturing offers the ability to design components fit for function, and reduce material in design where it is not needed (this is called topology optimization), weight savings can be obtained that in some applications can result in reduced usage costs. In the aerospace industry, for instance, a lower weight yields a direct advantage in reduced fuel consumption. All these factors must be included when making a sound business case.

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Field case 4

Sharing printing capacity and investments in Addlab

Frencken, an Eindhoven-based mechatronics company, collaborates in additive manufacturing with other high-tech suppliers under the name AddLab. By means of the open character of both the programme and the physical laboratory, AddLab aims to develop a broad range of high-tech and high-end manufacturing applications for 3D metal printing. They have pooled both financial and physical resources to set up a joint development lab that include several metal printers, storage facilities for raw materials (metal powders), and post-processing facilities that would have been economically out of scope for each single party to invest in.

Frencken aims to leverage this partnership to supply the market with their own additive manufacturing proposition. Their clients can now benefit from their knowledge and skillset in the entire additive manufacturing process chain ranging from the design to secured and certified printing to post-processing. One of the challenges for Frencken is to create awareness among their clients about the advantages of additive manufacturing over the lifetime of the component, so they are willing to pay a premium for components.



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AddLab

Shared facility for 3D metal printing



Challenges encountered

In the current phase of adoption, during which most companies are searching for applications, are experimenting and implementing on a small scale, our consultation partners have indicated that their main challenges are in the following areas:

1. How to develop the business case?

When it comes to introducing this technology, developing a proper business case and correctly estimating the return on investment is a big challenge to decision-makers. Business case exercises will mostly fail if the scope is too narrow: successful business cases include the lifetime of a product as well as the value chain that supplies it. This, as opposed to just considering the direct production costs which in most cases will be lower through conventional manufacturing. Our discussion partners have indicated that for some applications and situations, a sound business case is more easily made: for example in situations where parts need to be available over many years as machine value remains high or where downtime is expensive. Or in situations in which the total cost of ownership of a product can be reduced by extending the service life and reducing the error percentage. In other cases, it is more difficult to make the case. This is especially challenging for applications on the customer side. Mass-customisation is an example of this: are customers willing to pay a

premium? Another example is innovation: how do you quantify the added value of rapid prototyping in product innovation or the reduction in the time-to-market?

Our discussion partners shared the common belief that the technology will provide significant added value both now and in the future. Also, they agreed that not all value can be predicted: a number of applications will only become clear by doing and experimenting.

2. How to start: isolation or collaboration?

Due to the lack of both a widespread understanding of the possibilities as well as necessary skills and high investments associated with additive manufacturing, many of the businesses we spoke to start their additive manufacturing operations in collaboration or in partnership with other parties. Some businesses elect to set up manufacturing facilities or experimental pilots with competitors (see both Field Case 2 and Field Case 4), which demands an approach to facilitate joint learning and eliminate competitive risk. Other companies teamed up with universities, technology experts and service providers to get on the learning curve as soon as possible.

3. Intellectual Property (IP) considerations

Additive manufacturing triggers new challenges from a legal perspective. First of all, companies working with additive manufacturing technology,

or companies calling upon the services of additive manufacturing service providers, are facing new IP questions. When existing objects or designs are redesigned for manufacturing through additive manufacturing, this may constitute a breach of third party IP rights on the original objects or designs. This is the case for example in a scenario in which a company maintains its existing assets by means of 3D printed tooling and spare parts. Here, the issue arises of whether this violates the IP of the original manufacturer.

Some of our discussion partners indicate that they respond to this issue by avoiding it through strictly working with objects which are self-designed or free from third party IP rights. However, this approach forces these companies to manoeuvre their way around innovation, and will thus not support a sustainable long-term innovation strategy. Additive manufacturing – like other new “greenfield” business models and processes – calls for new or modernised legislative frameworks and a redesign of IP laws to provide legal certainty to businesses. Initiatives at EU level to modernise copyright laws are already in place, but they need to further evolve as new “Scan-to-CAD” and additive manufacturing solutions will result in the creation of new types of IP rights, which protect the work done by e.g. designers in transforming physical objects to 3D designs.

4. What are the risks?

We see a similar line of thought in terms of product liability. When manufacturing a previously existing part through additive manufacturing, specific processes and controls need to be put in place to ensure the quality and integrity of parts. In addition, controls need to be in place throughout the entire digital processes through which the file is shared and used. For example, if a company performs maintenance using its own printed parts, what is the situation regarding the asset's original warranty? Who is responsible for any errors that might occur? Does a 3D printed part meet the same safety requirements as a conventionally produced part. As a result, there is a strong call to both legislators and certification organisations to revisit their standards and provide a legal framework, guidance and best practices to support companies through their additive manufacturing innovation strategies.

Meanwhile, service providers and their customers are currently trying to find solutions for these matters. One possibility is to give purchasers the opportunity to inspect and qualify specific additive manufacturing systems at service providers.

Following certification by the customer, the supplier simply prints out the part requested on the approved 3D printer. An additional service could involve making the entire production process traceable and digitally secure. This means it is always possible to determine when a certain 3D element has been made and how the production process was carried out.

5. How to make the internal organisation aware of the opportunities?

The opportunities offered by additive manufacturing require changes to the composition and culture of the organisation. In addition to acquiring and accumulating the right skills, employees have to be made aware of the possibilities offered by additive manufacturing and encouraged to look beyond current applications. Applications such as customisation and co-creation with customers offer unprecedented possibilities, providing that traditional ideas about design, business models and proposition are abandoned. Innovative ideas are required to get ahead in the new world resulting from the fourth industrial revolution. Field Case 5 is an example of a company that is investing heavily to enforce the 'cultural overhaul' that is needed in its workforce. (See Field Case 5: Capturing the potential of additive manufacturing at a Global Energy Company).

Field case 5

Capturing the potential of additive manufacturing at a Global Energy Company

To prepare the internal organisation for the Industry 4.0 revolution, the global energy company understands the necessity of a change in their employees' mind-set. The company is convinced of the advantages offered by additive manufacturing for certain activities in its own business operations, particularly within maintenance of older assets. However, the organization is aware that the further development of effective business cases and the discovery of value added applications demand a new way of thinking. They therefore invest a lot in increasing awareness among its staff with regard to the possibilities and challenges of additive manufacturing. To achieve this, the company is using communication channels such as videos and demos on intranet and internal magazines to build the essential culture that is needed to be open to the possibilities that additive manufacturing offers.



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