

Identify the impact
on business and
unlock the 3D
printing potential

How will 3D printing make your company the strongest link in the value chain?

EY's Global 3D printing Report 2016



■ ■ ■
The better the question. The better the answer.
The better the world works.

EY
Building a better
working world



Table of contents

1. Introduction: EY's Global 3D printing Report 2016	4
2. 3D printing - Have we reached the "slope of enlightenment"?	6
2.1 Additive manufacturing beyond prototyping technology	8
2.2 Technologies, materials and the role of metal printing	12
2.3 3DP operating models: is the manufacturer the strongest link in the value chain?	15
2.4 3DP maturity levels: from testing to strategic implementation	17
2.4.1 Companies with no 3DP experience- reasons and expected changes	19
2.4.2 From testing to strategic implementation	20
2.5 3DP in the company: barriers and challenges	24
3. From optimization to reinvention - how 3DP can benefit business	27
3.1 3DP product redesign as a growth strategy	30
3.1.1 Customization and personalization of products	30
3.1.2 Creating more complex, higher quality products	32
3.2 3DP as an efficiency strategy and its influence on the supply chain	34
3.2.1 Cost-effective product development and swift go-to-market	35
3.2.2 Unlocking the potential for operational excellence in manufacturing	39
3.2.2.1 3DP achieves efficiencies within existing manufacturing	40
3.2.2.2 3DP value stream raises manufacturing efficiency to the next level	41
3.2.3 Low-cost engineering and maintenance	43
3.2.4 Are transportation and warehouses still relevant in a 3DP world?	45
3.2.4.1 How 3DP impacts manufacturing logistics	46
3.2.4.2 How logistics companies can remain competitive	47
3.2.4.3 How 3DP will affect wholesale and retail	49
3.2.5 3DP for superior and flexible after-market performance	50
4. 3DP: Trends, developments and challenges	54
4.1 What does the 3DP industry look like?	55
4.1.1 Market share	57
4.2 M&A analysis	58
4.3 Development of the industry	60
5. How EY supports companies on their 3DP journey	63
Authors and Contributors	66
Footnotes	68

1. Introduction: EY's Global 3D printing Report

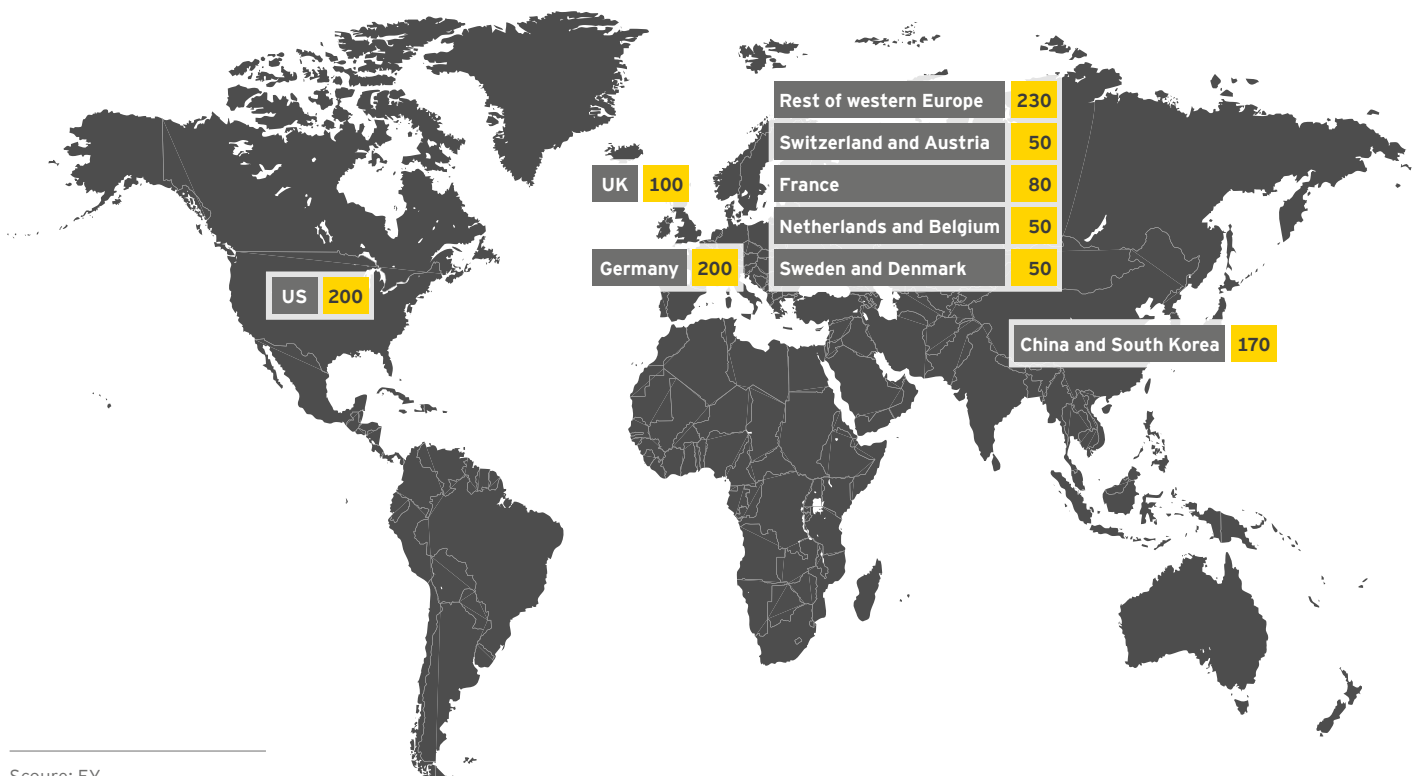


3D printing - or additive manufacturing - technology has been available since the 1980s. But it has only come to the fore in the past decade, as the varied range of new 3D printing (3DP) products has convinced businesses that the technology could prove a real game changer.

Companies are increasingly aware that the breadth of 3DP technologies and materials offers solutions for many types of industries, all over the world. However, faced with this huge variety, many businesses lack the knowledge and confidence to identify the right technology, application and use for their needs. In working with clients we have seen that for many, such uncertainty is limiting their ability to quantify the benefits of the technology and incorporate it into their strategic vision. We hope that our new study can provide the insights to help.

The EY's Global 3D printing Report 2016 offers a comprehensive review of current levels of adoption of the technology and of likely future trends. It provides a multi-stakeholder view of the industry, considering both the experience and perspective of companies that have exploited the technology, complemented by case studies, as well as reflecting financial developments on the supplier side. The study incorporates the findings of EY's 3D printing Global Survey, conducted in cooperation with Valid Research. This canvassed the opinions of 900 companies from 12 countries obtaining insights into both current practice and likely future developments. To reflect the variety in applications and use of 3D printing, the survey engaged relevant decision makers from:

Figure 1
3DP surveyed companies



Source: EY

▶ We would like to thank the EY GSA Advisory and TAS teams for their invaluable support in researching and preparing this report. We would like to give special thanks to colleagues Christian Hackober, Andrej Hazke, Sergey Nikonov, Titus Lottig and Tamo Pfeiffer for their contribution.

▶ Different-sized companies: 363 small businesses (with revenue of less than €100m), 373 medium-sized businesses (with revenue between €100m and €1b) and 164 large businesses (with revenue of more than €1b)

▶ Companies from 12 countries: Austria, Belgium, China, Denmark, France, Germany, Holland, South Korea, Sweden, Switzerland, the UK and the US

▶ Businesses from 9 industries: Aerospace, Automotive, Consumer Goods, Electronics, Energy, Logistics and Transportation, Mechanical and Plant Engineering, Wholesale and Retail and other services

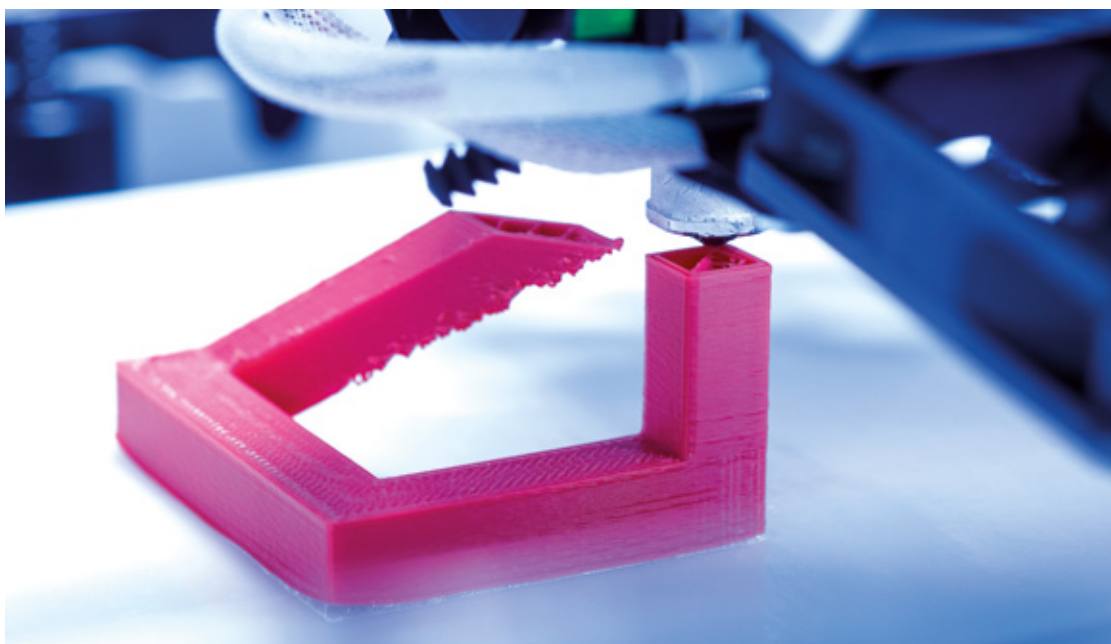
Based on the survey results, case studies and our advisory experience, the study assesses the current and future level of adoption of 3D printing, and the path connecting these two states, in terms of three core topics:

▶ **Maturity:** In what ways do companies currently apply 3D printing? How do companies perceive the 3DP technologies? What levels of maturity in applying 3DP technology have companies reached? What can we learn from companies with high 3D printing maturity?

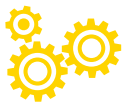
▶ **Models:** What does a company's 3D printing journey look like? How does application of the technology influence companies' strategies, business models, supply chains and operations? What operating models do companies choose and how do they develop their organizations regarding 3DP?

▶ **Motivation:** What benefits can companies expect if they apply 3D printing? What is driving investment in the 3D printing industries? What will be the driving forces in the 3DP industry in the future?

We hope our findings help businesses at all stages of 3D printing maturity to understand and leverage the benefits that this innovative technology can bring.



2. 3D printing - Have we reached the "slope of enlightenment"?



Curiosity about 3D printing has mushroomed in the past five years, both from consumers and businesses. The number of results arising from a web search for "3D printing" and related terms is now six times greater than in 2011.¹ The media fuels this interest by reporting regularly on new examples and individual success stories from companies across almost all industries. Such examples provide convincing evidence that 3D printing has the potential to change companies' business or operating models.

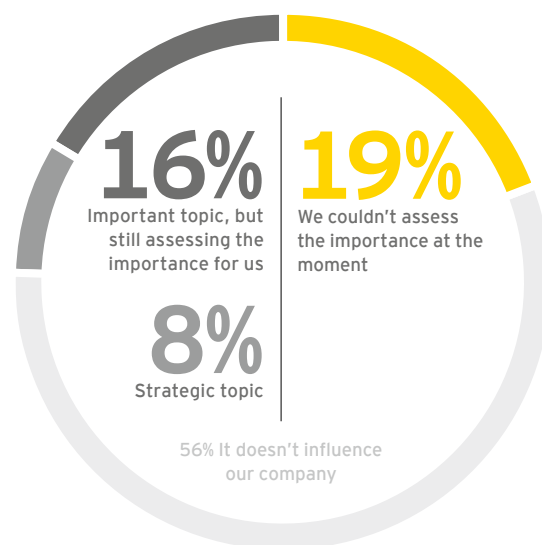
However, until now it has been relatively difficult for either companies or consumers to quantify 3DP's potential. Though great progress has been achieved in the last years, we have perhaps not quite reached what Gartner terms the "slope of enlightenment" in the new technology cycle, where an innovation is becoming increasingly understood and valued.² Available information fills some of the gaps but does not give a full picture of how the technology could be applied. For the companies it is, for example, still not clear as to how widespread or common 3D printing is in different industries and countries. Many companies would like to know which technology and materials their competitors are using and how they have integrated the technology into their business models. This chapter aims to answer such questions.

The first key question is how widely the technology is either well perceived or has actually been adopted. Our experience shows that "industrial" companies, that is, those in manufacturing, logistics, energy and retail, see 3D printing as a decisive success factor and technology that strongly influences their business. Indeed 24% of executives surveyed said that 3DP is a strategic or highly important topic for their company.

Furthermore, 3DP is no longer a test technology reserved for research groups and a limited number of companies. It has become an everyday reality for almost one in four industrial companies. EY's survey results show that 3D printing has grown into a mainstream technology: almost 24% of the companies surveyed have already gained relevant experience of 3DP and a further 12% are considering adopting it.

Chart 1

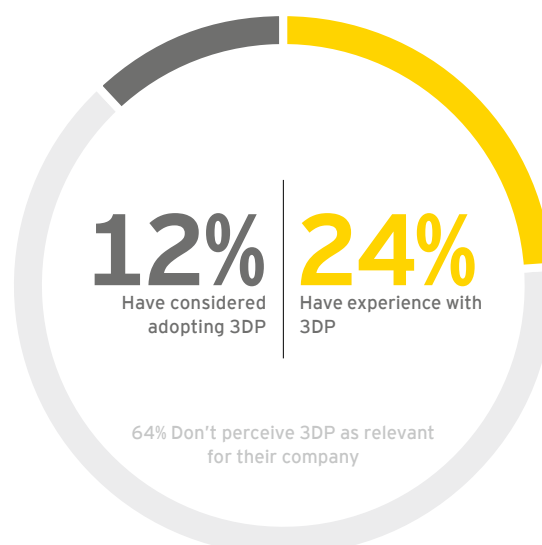
24% of all companies perceive 3DP as a strategic or important topic (%)^{*}



^{*}N=900 companies, EY global 3DP study, April 2016

Chart 2

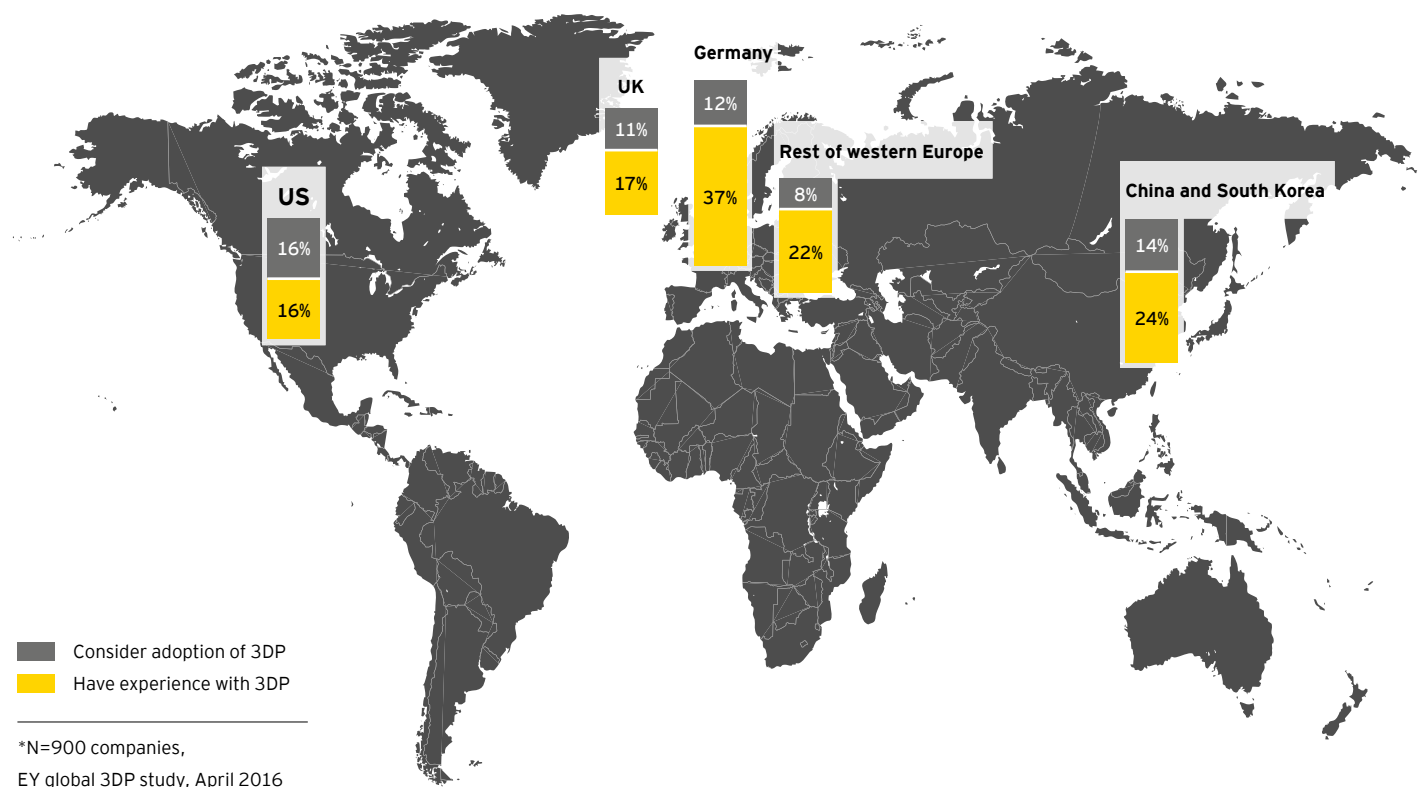
24% of companies have experience with 3DP and a further 12% are considering adopting it (%)^{*}



^{*}N=900 companies, EY global 3DP study, April 2016

Those with experience of 3DP are at different levels of maturity. Certain companies are just beginning to experiment with 3DP; some have integrated it into the operations of certain departments, and others already have a clear vision of how the technology could bring them competitive advantages and possess a clear strategy to achieve this. These include manufacturing companies that apply 3DP for rapid prototyping and the production of higher performing, more efficient tools and others that are already generating a double-digit slice of their revenue with 3D-printed parts.

Chart 3
Current and intended acceptance of 3DP among countries (%)



2. 3D printing - Have we reached the "slope of enlightenment"?

2.1 Additive manufacturing beyond prototyping technology

To many company managers, additive manufacturing still equates to prototyping, the application which first brought it to popular attention. However, the future - and growth potential - of the technology lies in direct manufacturing, that is, the production of consumer products, components and parts for industry, such as tools, machine components and other manufacturing aids.

Developments over the past decade have paved the way for 3D printing's expansion beyond prototyping. Technological advances that enable the manufacture of high-quality products and an array of new ingredients, from metals, ceramic to organic material, have encouraged companies to consider 3D printed parts within their own products. Many are now grasping this opportunity. The EY survey shows that one in three companies with 3D printing experience are already applying the technology for direct manufacturing, whereas 20% are actually producing 3DP end-use components or products. These are predominantly companies in the plastics, automotive, aerospace, medical and pharmaceutical industries. The fact that 30% of companies that are applying the technology for end-use parts come from the plastics industry demonstrates two things:

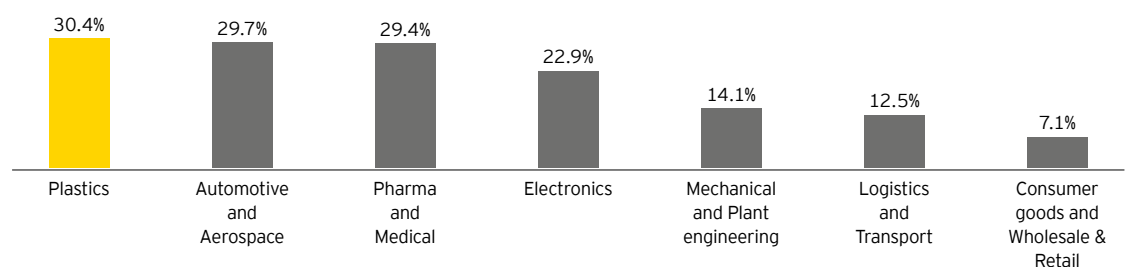
- ▶ Chemical materials manufacturers have started including 3D printable materials in their portfolios.
- ▶ Additive manufacturing is now used alongside injection molding and other traditional technologies in plastic parts production.

The same trend can be observed in the aerospace and automotive industries. The added value that lightweight parts and functionally integrated components bring to aerospace companies has elevated 3D printing from prototyping to serial production. GE, for example, manufactures functionally integrated fuel nozzles for its best-selling product, the LEAP engine³, with which it generates fuel savings of up to US\$1.6m per aircraft per year⁴. The A350 XWB aircraft flies with more than 1,000 3D printed parts⁵ and achieves 25% fuel savings, compared to competitors⁶.

Lightweight and functionally integrated parts are also attractive for automotive manufacturers, especially for sports cars⁷. For example, BMW used additive manufacturing for more than 500 water pump wheels for its racing cars. Furthermore, many automotive companies recognize that 3D printing is a solution for effective production of customized and lot size one parts.

Chart 4

Around one third of the plastics, automotive and aerospace, and pharmaceutical and medical companies that use 3D printing apply it for printing their own end components or products (%)^{*}



^{*}N=214 companies, EY global 3DP study, April 2016

Responding to customer demand

In the medical and pharmaceutical sector, 3D printing is enabling companies to manufacture unique, personalized products cost-effectively. Customer demand for such products explains why one in three sector companies with 3DP experience have started applying the technology for end-use products. Numerous medical and pharmaceutical companies now apply 3DP for producing surgical instruments and personalized implants, which fit perfectly and have unique porous structures that support bone growth.

In March 2016, one of the biggest 3DP systems manufacturers, 3D Systems, opened a “Healthcare Technology Center” for producing 3DP healthcare solutions, including medical devices and implants.⁸ Meanwhile, the US Food and Drug Administration (FDA) has already approved production of the first 3D printed tablet – Aprecia Pharmaceuticals’ SPIRITAM prescription adjunctive therapy for seizures and epilepsy⁹. Aprecia uses 3D printing to make these drugs as it enables the production of a unique porous formulation that disintegrates with a sip of liquid, which is especially important for people with swallowing problems, like its target patients.

As well as using 3DP for end-use products, 17% of all companies with experience of the technology

apply it to directly manufacture tools and machine parts. This trend is mostly evident in the automotive, aerospace and mechanical and plant engineering industries, where 20% of companies with 3DP experience use it in the production of tools or components. For example, such companies directly manufacture injection-molding tools with integrated conformal cooling channels as a way to reduce production time and improve efficiency¹⁰. In addition, 3D printed customized manufacturing aids are often used in manual assembly production, for example at Opel.¹¹

To reach its disruptive peak and deliver its full economic impact, technology must go beyond wide application to become a serial production technology for end-use products. In the context of additive manufacturing, the greatest impact comes when companies start to 3D print their end products and thereby generate a meaningful share of their revenue from them.

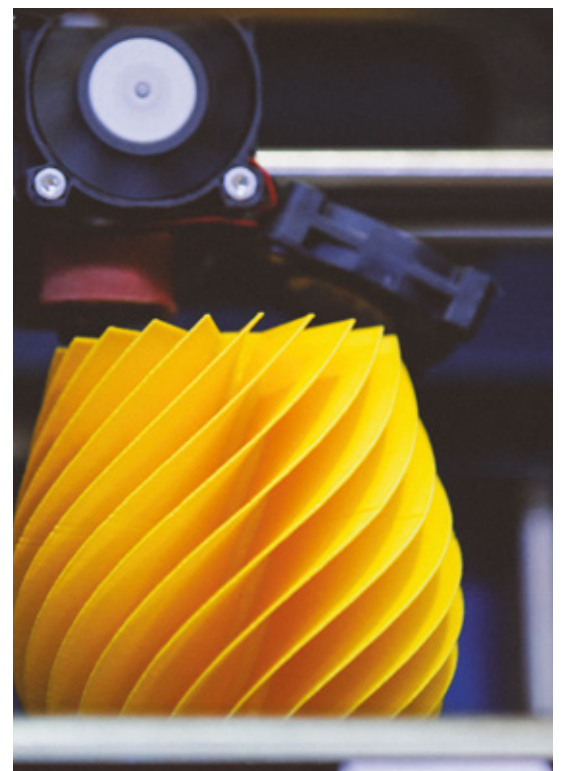
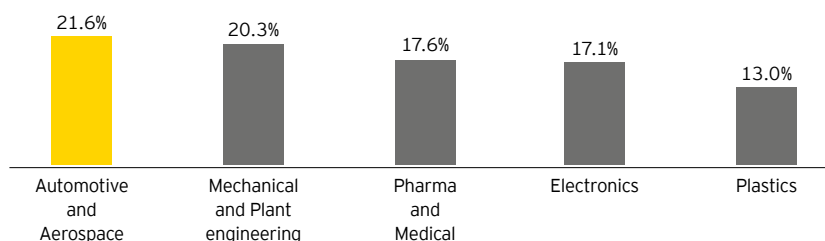


Chart 5
Over 20% of automotive, aerospace and mechanical and plant engineering companies with 3DP experience apply the technology to make tools (%)*



*N=214 companies, EY global 3DP study, April 2016

2. 3D printing - Have we reached the "slope of enlightenment"?

Revenue share generated by 3D printed products

Companies with experience of 3D printing are already generating 2% of their revenue from 3D printed products. We analyzed the 3DP share generated in the various countries, first, as total 3DP revenue as a share of total revenue generated by companies with experience and second, as a simple average of the stated 3DP share, without weighting it with each company's revenue.

Interestingly, the percentage of generated 3DP revenue varies between countries, demonstrating varying levels of application among companies from different geographies. US companies are slow adopters, with only 16% having gained 3D printing experience. However, as shown by the 3DP revenue figure of 8.8% of total revenue, this 16% are realizing the full potential of the technology and applying it for end-use products. It is important to stress that companies with 3DP experience in the US generate on average 7.3% of their revenue with 3DP. The higher total 3DP revenue share occurs because a few large businesses were surveyed, that had a 3DP revenue share of more than 11% of their total revenue. On the other hand, we can observe the opposite situation among Asian companies because most of the large businesses surveyed generate up to just 2% of their revenue with 3DP, while on average the

Asian companies with 3DP experience generate 5.7% of their revenue with 3DP products.

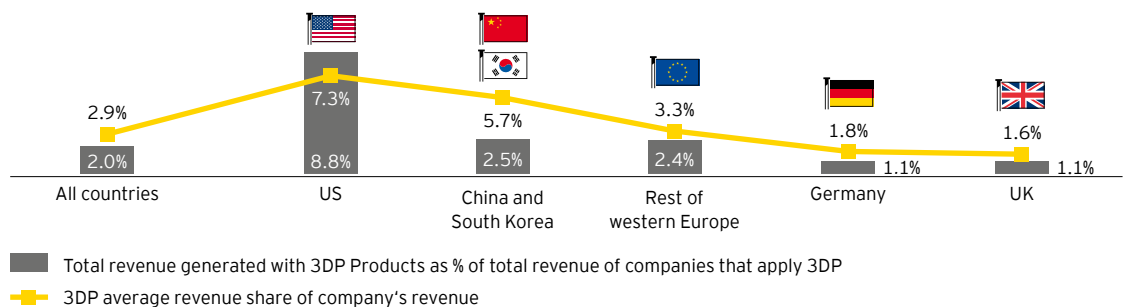
European and Asian companies generally demonstrate different application habits. When considering the revenue share of 3D printed products generated in Germany, China and South Korea as a percentage of the total revenue of companies with 3DP experience against the total revenue of the companies that claimed to generate revenues, a doubling of the share is evident. This demonstrates the conservative approach of German and Asian companies to 3DP: they are quick to test the technology and use it to directly manufacture tools, but are cautious in harnessing it to make end-use products.

Seeking a competitive advantage

3D printing will only become a game changer - and start impacting national and corporate competitiveness - when it is used for serial production. The technology has already found a place in serial production at almost 5% of all companies surveyed. There is no significant variation among companies from different countries but expectations do vary. Thirty-eight percent of companies surveyed expect that additive manufacturing technology will become part of their production processes for end-use items by 2021. German companies are the most

Chart 6

2% of the total revenue of companies with 3DP experience is generated with 3DP products (%)*



*N=214 companies, EY global 3DP/AM study, April 2016

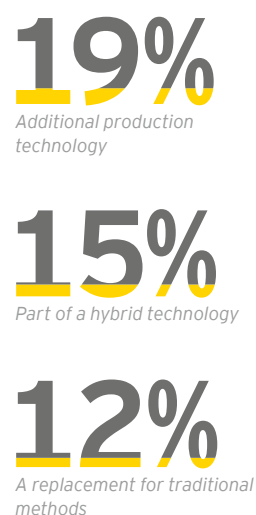
skeptical in this regard, with only one in four viewing 3D printing as a serial production technology. Their caution reflects concerns over issues such as building envelope limitations, product quality and production speed, as well as uncertainty regarding issues such as IP protection and integration into current production and IT systems.

Chinese and South Korean companies are the most proactive in applying the technology to end-use production. One in every two expect to use additive manufacturing to make products by 2021. In China, this conviction is fueled partly by a drive to find new ways to maintain the country's position as global manufacturing leader in the face of rising labor costs. The governments of both countries support the technology's development and have positioned themselves as leading 3D printing nations, seeing it as an opportunity to win a competitive advantage¹².

3D printing can become part of production in one of three ways:

1. Additive manufacturing can be adopted as an additional technology in the existing production process. This is perceived as the most likely scenario, with 19% of companies expecting to apply 3D printing in this way. This approach

Chart 7
3DP will be used in serial production as: (%)*

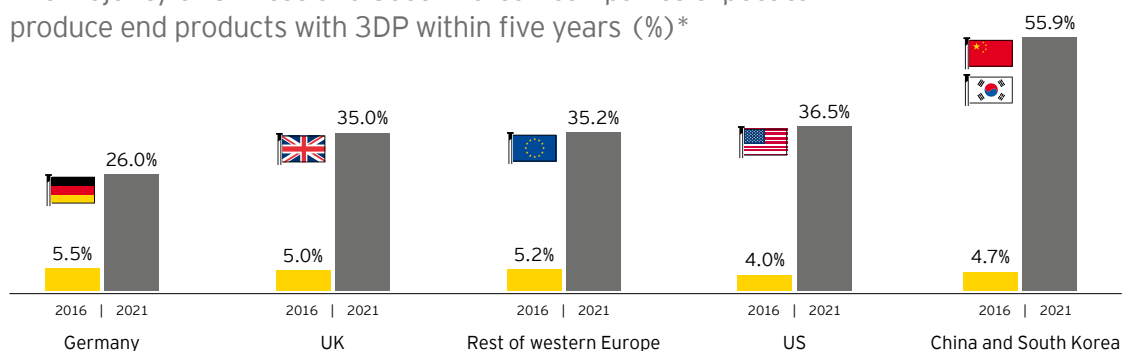


*N=900 companies, EY global 3DP/AM study, April 2016

requires engineering and production managers to weigh up the relative technological and economic benefits of 3DP and traditional technologies in producing specific products.

2. Alternatively, 3DP technologies can be combined with traditional technologies in a form of hybrid technology. Lockheed Martin, for instance, has a system made up of three robotic arms - one for directed energy deposition (also known as metal additive manufacturing), another for optical measuring and a third for traditional milling. No systems provider has yet launched a convincing hybrid solution, which is why Lockheed Martin¹³ and many others have developed their own solutions.
3. In the third scenario, additive manufacturing can replace traditional methods. This would herald the greatest change and disruption in companies. Because of the challenges the technology still faces, over the medium term at least, this is the most unlikely approach. It tends to best suit companies with a small portfolio of highly complex, customizable and/or personalized products. Just 12% of surveyed companies are expecting to replace their current production technology with 3D printing within the next five years.

Chart 8
The majority of Chinese and South Korean companies expect to produce end products with 3DP within five years (%)*



*N=900 companies, EY global 3DP/AM study, April 2016

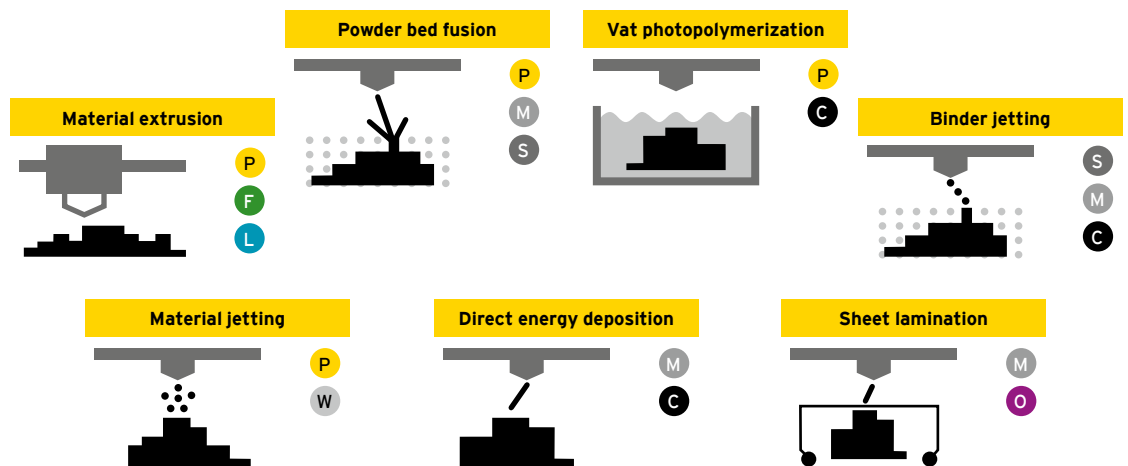
2. 3D printing - Have we reached the "slope of enlightenment"?

2.2 Technologies, materials and the role of metal printing

The 3DP market offers a huge variety of choices. In technology terms, there are seven main sub-technologies (figure 2) and a range of emerging technologies too. 3D-printable materials meanwhile include plastics, high-performing alloys, ceramics, organic material, food and live cells. This variety means there are many types of printing systems, both desktop and professional.

Choosing the most relevant technology and system will, of course, depend on a company's circumstances. Does it need top quality and high precision, or a multi-material or multicolor application? What are the product dimensions and, of course, what is the budget?

Figure 2
3DP sub-technologies



Material key: P=Polymer, M=Metal, O=Organic material, C=Ceramic, S=Sand, L= Live cells, F=Food, W=Wax

Source: EY

Each sub-technology offers different advantages and challenges:

► Material extrusion

Material extrusion systems offer multi-material and multicolor printing of plastics, food or live cells. Because of their relatively favorable price, these systems have contributed largely to making 3DP accessible to many companies and the wider public.

► Vat photopolymerization

For premium products with fine detail and a high-quality surface, vat photopolymerization is the first choice.

► Binder jetting

The most relevant application of binder jetting would be producing casting patterns, raw sintered products or similar large-volume products from sand.

► Powder bed fusion

Powder bed fusion technologies - such as direct metal laser sintering (DMLS), selective laser melting (SLM), electron beam melting (EBM) and selective laser sintering (SLS) - allow companies to print high quality polymer and metal parts. Powder bed fusion technologies heralded the wide acceptance of 3DP as a reliable technology for producing parts that fulfill the

strict standards required in aviation and medicine.

- **Directed energy deposition**

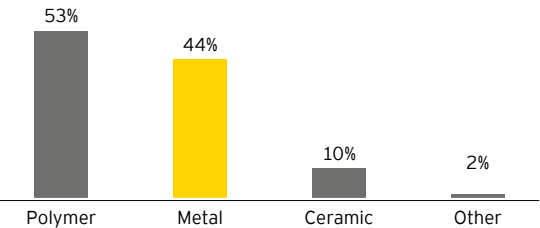
These technologies allow more complex metal printing, allowing much more focused manufacturing with a high degree of accuracy.
- **Material jetting**

These technologies come closest to the commonly known “ink jet printing” as they use small nozzles to deposit droplets of material. They enable relatively fast industrial printing with multiple polymer materials and colors.
- **Sheet lamination**

The process of sheet lamination fuses layers of material and even different metals together with ultrasonic waves. It usually requires extensive post-processing with traditional machining.

In our survey, we asked companies what materials they are currently printing in 3D and about their expectations for the future.

Chart 9
3DP materials used (%)*

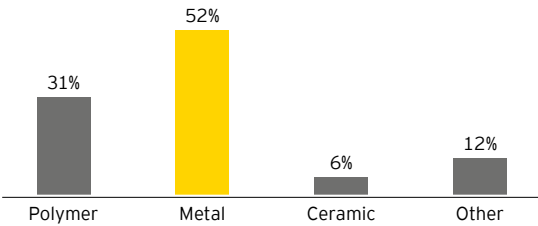


*N=214 companies, EY global 3DP study, April 2016

The results show that, of companies with 3DP experience, more than half (53%) have experience of polymer printing. Almost as many (44%) have experience of metal printing, even though this technology did not begin to win business confidence until much later. Companies choose it because it allows products to be printed from precious metals,

titanium, tool steel, stainless steel and aluminum alloys. Moving forward, more than half of companies (52%) see metal printing as decisive in any decision to adopt 3DP. Metal printing also “opened the door” for additive manufacturing in serial production, especially in industries such as mechanical and plant engineering, where products contain mainly metal components.

Chart 10
Demand for 3DP materials (%)*



*N=900 companies, EY global 3DP study, April 2016

There is also demand for materials other than polymers and metals. Some 6% of companies are interested in printing ceramics, and 12% would like to print other matter such as building materials, pharmaceuticals, food or textiles.

Among companies already using metal 3DP, companies from two industries top the lists : aerospace and automotive companies. 65% of these companies use metal 3DP; this high ratio is due to the huge number of metal components in products from these sectors. Both automotive and aerospace benefit from the production of lightweight components – especially in the aerospace sector, where fuel savings can be huge. There are also a growing number of automotive applications: mainly of functional prototypes, small-batch-size series production, and customized products.



2. 3D printing - Have we reached the "slope of enlightenment"?

When we consider which industries see the ability to print metal as a precondition for integrating 3DP into a company, the picture is fairly similar. Mechanical and plant engineering companies have the highest demand for metal 3DP applications. This industry has a roughly equal call for tool steel and alloys (at least compared to other industries), because of differing product portfolios and applications within the industry. These uses include tools, dies, molds, machine parts and machine components.

In the automotive and aerospace and electronics industries, the demand for standard or high performance alloys is even higher because they are used in the production of end products. However, the interest in tool steel in these industries is much lower. This suggests that their main focus for metal 3DP is on end products, rather than production-related tools or dies.

Emerging technologies also enhance 3DP's appeal. One is continuous liquid interface production (CLIP), a high-speed photopolymerization process developed by Carbon3D¹⁴. Because of its relatively fast printing of products with a high-quality surface, CLIP is set to become part of the operations of companies such as Ford¹⁵ and Johnson & Johnson¹⁶, with which Carbon3D has established partnerships. At least one other company has achieved the same or even better results with

similar technology, as the Australian Gizmo 3D project shows¹⁷.

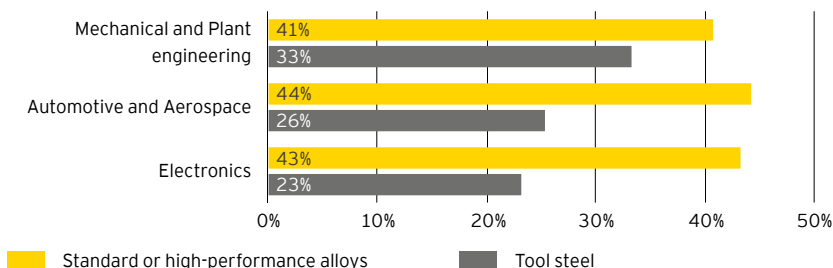
In May 2016, meanwhile, 2D-printer giant HP launched its Jet Fusion 3DP solution - making it one of the first very large companies to compete with existing players like Stratasys and 3D Systems.

What sets HP's printer apart from others is its industrial manufacturing approach, aimed at mass production of end-use products. While there already are industrial polymer 3DP systems, HP says its technology is up to 10 times faster, and delivers parts at half the cost of SLS and fused deposition modeling (FDM) systems, which cost from US\$100,000 to US\$300,000¹⁸. The system is also open to materials from third-party companies, and HP has plans to expand for use with other materials, such as metal and ceramics¹⁹.

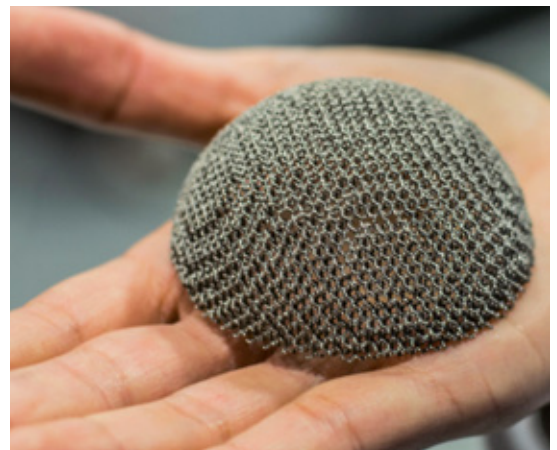
The product launch came two years after HP first announced plans to enter the 3DP market. There are two main reasons for HP's market entry: first, some major 3DP technology patents expire this decade; second, the company sees 3D printing as the natural evolution of its 2D printing business, in which it held a 40% market share in 2013²⁰. Its 3DP printing solution comes after collaboration with partners such as service provider Shapeways²¹ and BASF²².

Chart 11

Demand for metal 3DP: top 3 industries (%)*



*N=900 companies, EY global 3DP study, April 2016



2.3 3DP operating models: is the manufacturer the strongest link in the value chain?

There are many challenges for companies that are considering adopting 3DP in their organization – from investment in systems to organizational structures, capabilities and in-house processes. In this emerging phase, companies have developed different operating models for integrating 3DP.

The main question, though, is: should companies consider high investment in in-house systems and capabilities if they wish to apply 3DP in their organization?

The 3DP market offers a wide choice of system manufacturers and service providers. Generally, 3DP systems can be divided into desktop systems and industrial systems. Desktop systems cost less than \$US5.000, and serve mainly the consumer markets for personal and private use, though companies may also acquire them in the testing phase. Professional industrial systems, meanwhile, can cost anything from \$US5.000 to more than \$US1m. The cost depends on size, but also on technology: generally, metal 3DP systems are

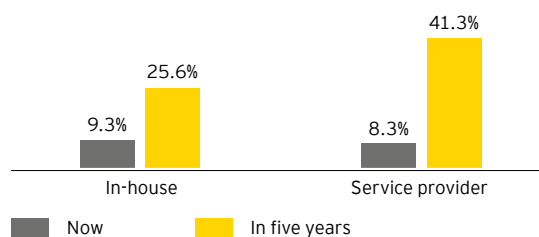
more expensive for technological reasons and have higher associated costs, such as for materials and energy.

Such high costs discourage many companies from investing in industrial-scale professional systems, especially when the business benefit has not been clearly defined. In our survey, around 40% of companies said the high cost of systems was the main barrier to introducing of 3DP. Operating an in-house system, meanwhile, requires internal expertise and capability in product design, additive manufacturing processes and post-production: 28% of companies said the lack of qualified personal or expertise in-house would be the biggest problem when adopting 3DP. So for 3DP to be an established production technology, companies must integrate it into operational and manufacturing processes, not just adopt and deploy IT systems.

But acquiring an in-house system is not the only way to work with 3DP. Companies may use a local 3DP service provider to print components and products, delivering them either to the company or directly to end consumers. There are many advantages of this: service providers may have different systems and technologies, alongside the necessary knowhow and support for product redesign. This type of cooperation is already a growing trend. Large service providers such as Materialise, for example, offer both a broad range of technologies and help with engineering too.

Among the companies we surveyed, acquiring in-house systems and cooperating with service providers are almost equally popular choices. But expectations for the future are different. One in four companies expect to have 3DP in-house within five years, but 41% expect to co-operate with specialist 3DP providers. Considering that, by 2021, 38% of companies expect to apply additive manufacturing in the serial production of end-use products, this suggests that companies are expecting to build their own 3DP production facilities, but at the same time are seriously considering the option of using specialist partners.

Chart 12
In-house systems or cooperation with 3DP service providers: now and in 5 years (%)*



*N=900 companies, EY global 3DP study, April 2016



2. 3D printing - Have we reached the "slope of enlightenment"?

Localized production and plant location

Since one of the main advantages of additive manufacturing is on-demand production close to the customer, this means an option would also be to develop an operating model based on contract manufacturing - using local 3DP locations, with different in-house technologies and relevant production expertise.

In the future, this may impact where plants are located. Because of the ability to produce highly customized product portfolios with fewer production steps and no changeover, 3DP has been seen as an opportunity to restore manufacturing back to Western countries. There could be many different kinds of impacts: on the one hand, costs can be reduced and competitiveness increased; on the other, current locations may not be needed because products will be produced by local 3DP hubs, and crucial value-added processes can be insourced. But as there are still many unanswered questions related to product IP protection, companies will tend to find a compromise solution in their operating model. Joint ventures between companies and additive manufacturing specialists (whether systems manufacturers or service providers) at dedicated local 3DP production sites will give companies direct control over production processes and access to the necessary expertise.

In our global survey, 43% of companies expect 3DP to have a strong impact on the location of plants.

The impact on the plant locations can be diverse - from reducing costs and becoming more competitive with 3DP, over no needing current locations since the products will be produced by local 3D printing hubs, to insourcing back of the crucial value added processes. Because of the short and less effort-intensive value chain companies even perceive additive manufacturing as a chance to re-shore the manufacturing back to western countries. This expectation is highest in the UK, with 66% anticipating this change; this compares to 46% in China and South Korea. Meanwhile, 16% of companies see 3DP as a chance to increase operational efficiency and thereby reduce costs. This expectation is highest in Germany (21%), where one in five companies think 3DP will herald an improvement in operations.

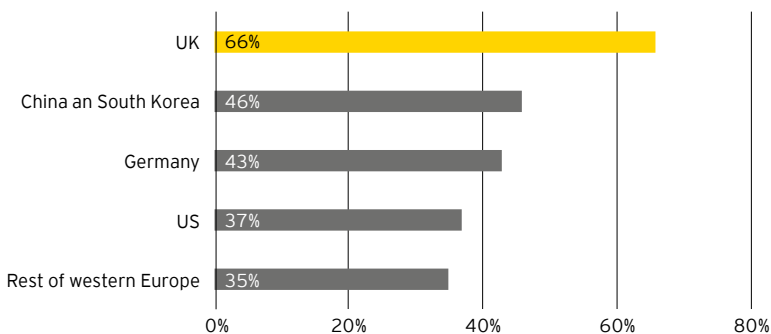
Almost 17% of companies, meanwhile, see in 3DP a chance to return important processes to the business. This opinion is shared by 19% of organizations in the logistics and transportation sector: printing close to customers will affect long-distance transportation, so logistics companies will need to find new value-added processes, perhaps by combining their core business with 3DP services.

In our survey, some 15% with regard to companies say that, in future, products will be made by specialized subcontractors close to customers. Such a change is anticipated most by electronics companies (22%), many of which currently rely strongly on subcontracting manufacturing to low-wage countries, rather than close to the end customer.

These expected changes with regard to plant location and the operating model raise important questions. Is it really important to have in-house manufacturing? And who is the irreplaceable player in the value chain: the owner of the digital product design, or the product manufacturer?

Chart 13

Almost 43% of all companies expect 3DP to impact plant locations (%)*







*N=900 companies, EY global 3DP study, April 2016

2.4 3DP maturity levels: from testing to strategic implementation

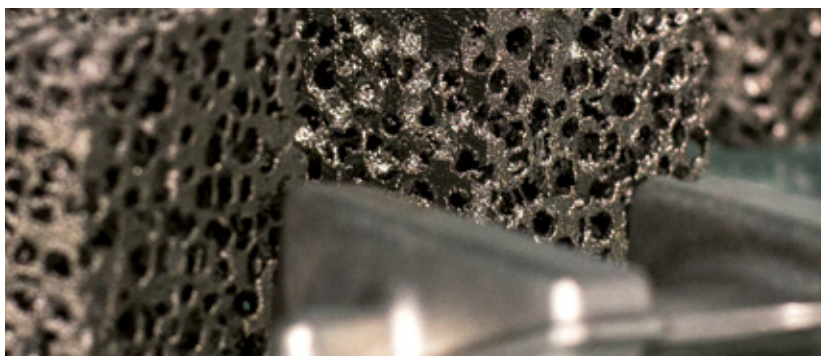
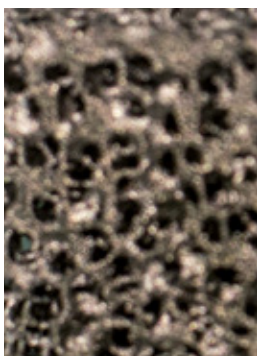
Through our research and work with clients, we have observed wide variations in how different companies and industries apply 3DP. While certain first movers have a clear strategic direction – along with established structures and processes with measurable benefits – most companies struggle to understand how the technology is relevant to their

company. Reflecting these variations, we have developed a 3DP maturity model, which ranks each company according to one of four levels. The model assesses a company’s maturity in four areas: strategic direction; integration of 3DP into organization and processes; technological enablement, and measurable value (see figure 3).

Figure 3
3PD maturity model

Maturity level	Strategic direction 	Organization and processes 	Technology enablement 	Value and performance management 
4 Strategic application across company	<ul style="list-style-type: none"> ▶ Application of 3DP embedded in company's strategy ▶ C-level sponsorship 	<ul style="list-style-type: none"> ▶ 3DP embedded in relevant operational areas with clear organization and processes 	<ul style="list-style-type: none"> ▶ Own or joint ventures with 3DP production locations ▶ Own or joint 3DP research centers 	<ul style="list-style-type: none"> ▶ Embedded measurement of how applying 3DP improves efficiency
3 Application in "champion" departments	<ul style="list-style-type: none"> ▶ Clear direction on application of 3DP in a certain department 	<ul style="list-style-type: none"> ▶ "Champion" departments have integrated 3DP into operations ▶ First cross-functional teams 	<ul style="list-style-type: none"> ▶ Own systems from relevant technology ▶ Established collaborations 	<ul style="list-style-type: none"> ▶ Measurable results within specific departments or areas of application
2 Experimenting and testing	<ul style="list-style-type: none"> ▶ Department leaders start to invest, test and understand the technology 	<ul style="list-style-type: none"> ▶ Teams of enthusiasts test the 3DP technology ▶ No structured processes for application of 3DP 	<ul style="list-style-type: none"> ▶ Testing different technologies with service provider, research groups or own cheap systems 	<ul style="list-style-type: none"> ▶ First own use cases with measurable results
1 No experience	<ul style="list-style-type: none"> ▶ Leadership has no or low awareness about 3DP and application in the company 	<ul style="list-style-type: none"> ▶ Possibly, first evaluation and consideration of possible form of 3DP application 	<ul style="list-style-type: none"> ▶ Possibly first considerations of form of application (own system, cooperation) 	<ul style="list-style-type: none"> ▶ No own experience. Possibly, review of experience from other companies

Source: EY



2. 3D printing - Have we reached the "slope of enlightenment"?

Our research shows that most companies (76%) have no experience with 3DP (maturity level 1). Nevertheless, 12% out of these companies are evaluating the technology, and considering starting to test or apply it.

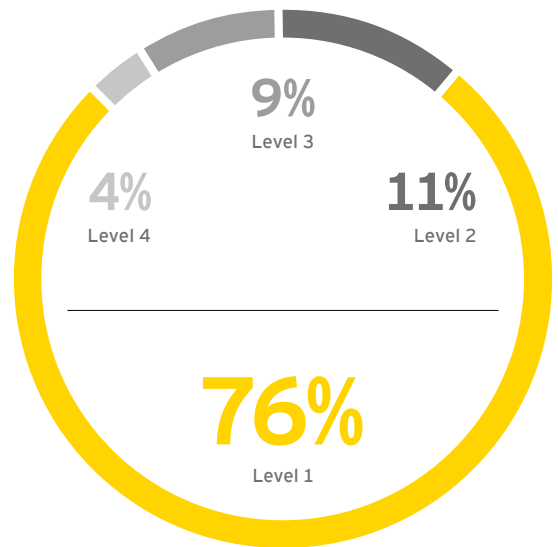
Of companies with experience, most are still experimenting with 3DP and trying to identify how it could be best applied to them - as well as which sub-technology and application model is right for their organization (maturity level 2). This is understandable, considering that interest in additive manufacturing only escalated when 3DP patents began expiring and printing systems became more affordable. This group makes up 11% of the total.

At a further 9% of companies, 3DP is an integral part of operations in one or more "champion" departments (maturity level 3).

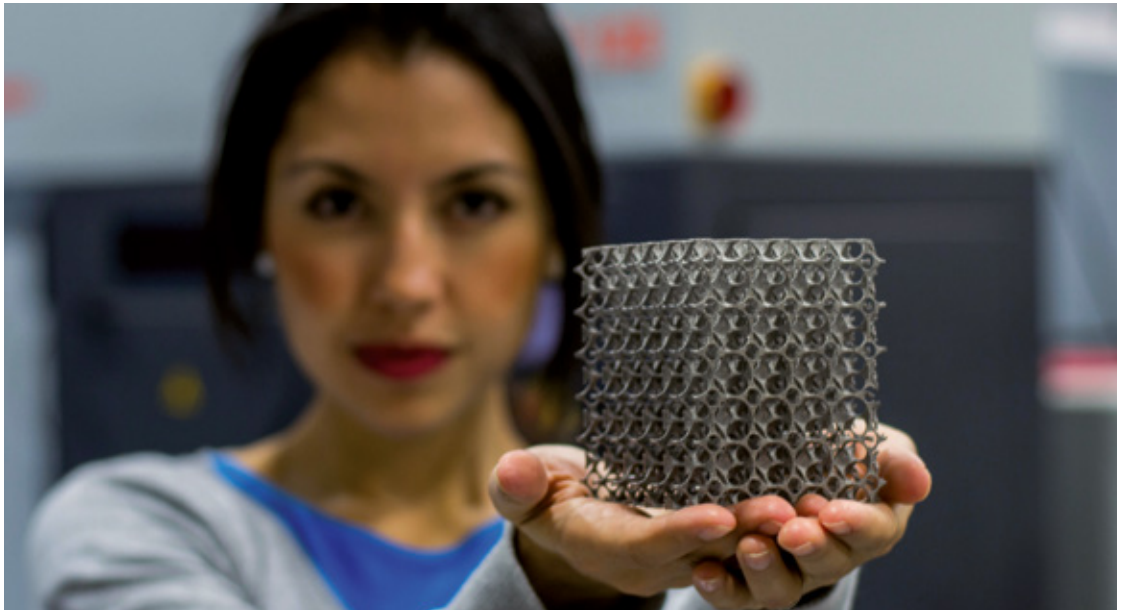
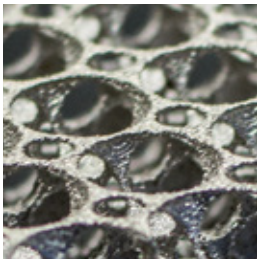
Finally, the first movers in 3DP have a clear strategic direction (maturity level 4). These companies have evolved most, not only because of their advanced use of the technology but also in the way they have integrated it internally. They make up just 4% of all companies surveyed.

Chart 14

Global 3DP maturity level (%)*



*N=900 companies, EY global 3DP study, April 2016



2.4.1 Companies with no 3DP experience - reasons and expected changes

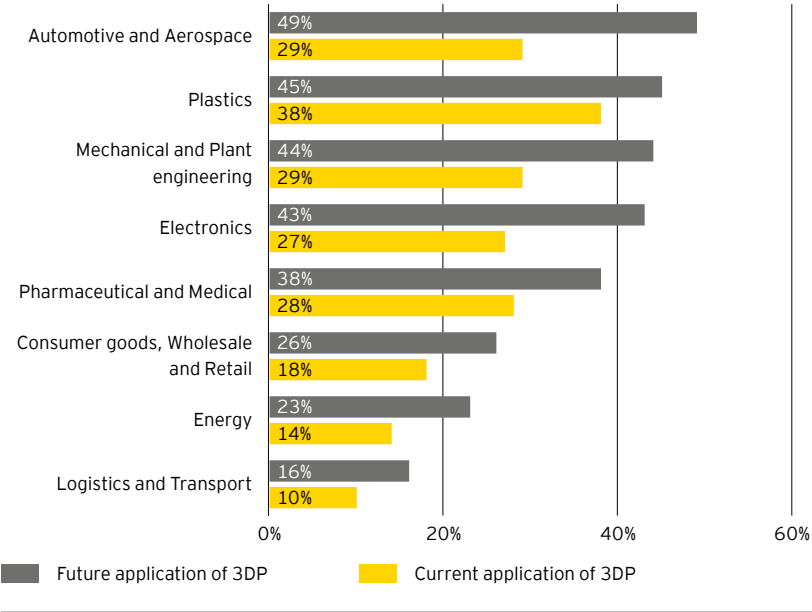
Although early 3DP technologies were developed in 1987²³, there are still many companies who have never applied them in any form. We consider these to be in the group with the lowest maturity: level 1.

At these companies, the leadership either has limited awareness about the development of 3DP, or does not understand how it is relevant to their organization. At such businesses two main groups can be identified: those that believe 3DP has no relevance for them and those considering its application. In the second group, companies are usually reviewing best practice cases from other businesses, and evaluating how they can start to test the technology. In this way, companies aim to identify cases of use among their products and supply chain, along with the expected benefits, the appropriate sub-technology to apply, and whether to invest in their own systems or to work with

partners, such as research groups, universities or service providers.

This interest means we are likely to see a wave of further adoption of 3DP. Our survey shows this will mostly affect the automotive, aerospace, plant and mechanical engineering industries and electronics companies. For example, if companies implement their intended 3DP adoption, about half (49%) of automotive original equipment manufacturers (OEMs) or component suppliers will likely use 3DP to directly manufacture car parts, in order to achieve operational efficiencies. The 3D printing of end components can help companies address challenges such as demand for customization, continued improvement, and lightweight products.

Chart 15
Industries that apply 3DP today and will apply it in the future, if the intended adoption is implemented (%)



*N=900 companies, EY global 3DP study, April 2016

2. 3D printing - Have we reached the "slope of enlightenment"?

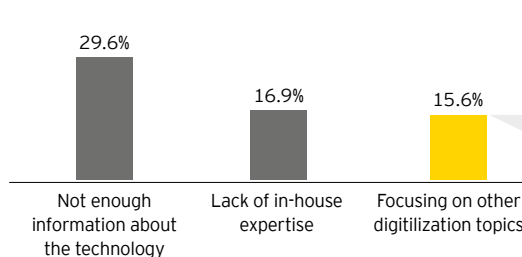
Why do some companies have no 3DP experience?

There are several reasons why companies may not have considered 3DP. These include a lack of information, limited awareness about the technology, and a shortage of in-house skills. A lack of information is a common problem. Of companies with no experience, almost one-third of managers say there is not enough information about technological advances and the related challenges. Such inadequate knowledge causes skepticism about the capabilities of modern systems - regarding part sizes, materials, and the quality of 3DP products.

A shortage of in-house competence and qualified personnel makes it hard for managers to recognize the benefits of 3DP and to prioritize it on their digitalization agenda. Our survey shows that of all companies without experience of 3DP, 15.6% prioritize other Industry 4.0 technologies more highly. In Germany, almost 28% of companies without 3DP experience neglect it because of other Industry 4.0 topics. Yet additive manufacturing can complement other Industry 4.0 technologies: combining robot technology with 3DP, for example, enables companies to overcome the space limitations of most 3DP systems - and to implement the large-scale 3D printing of metal parts.

Chart 16

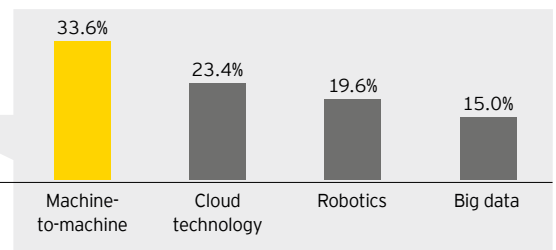
Reasons for no 3DP experience (%)*



*N=686 companies, EY global 3DP study, April 2016

Chart 17

Relevant Industry 4.0 topics for companies without 3DP experience (%)*



*N=107 companies, EY global 3DP study, April 2016

2.4.2 From testing to strategic implementation

Our research shows that companies at maturity levels 2, 3 and 4 share common characteristics:

Maturity level 2: Experimenting and testing

When companies are taking their first major step toward 3DP, they generally focus on gaining experience with the technology. Enthusiasts in specific departments start to experiment and test 3DP sub-technologies to improve operations or to redesign products and components. These projects

will become their first successful 3DP use cases, achieving their earliest measurable results. Such use cases will pave the way for further integration of 3DP since they show how it can affect performance.

Companies at this testing stage may start to cooperate with different service providers or research groups. They may also acquire their own systems: our survey shows that 32% of all companies in this phase have in-house systems.

Maturity level 3: Champion departments

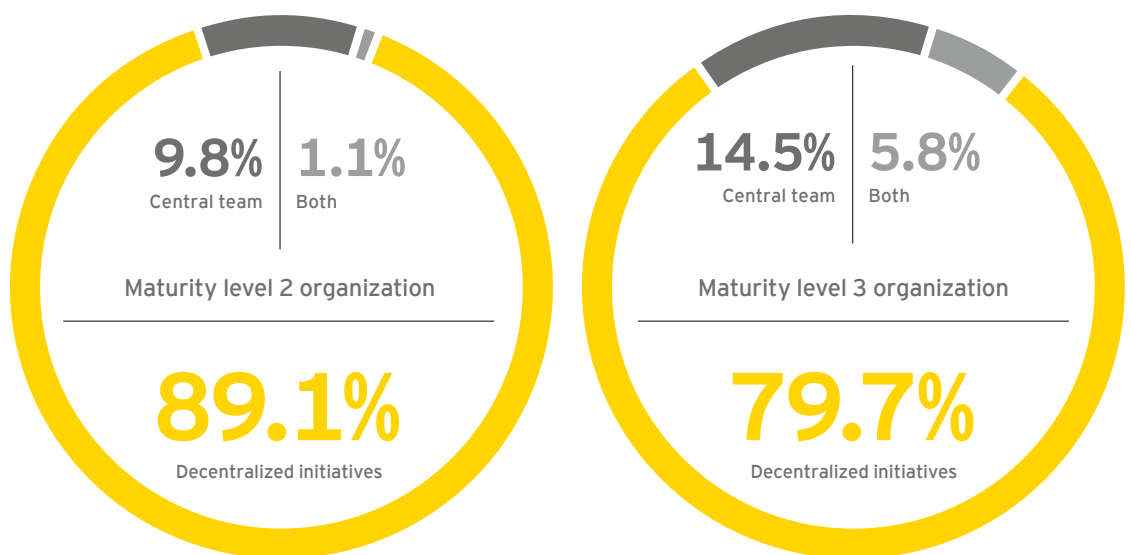
Once a company has recognized the potential of 3DP, at maturity level 3, it is likely to establish “champion” departments. Such departments incorporate the technology in their functional strategies. The benefits of 3DP are now clear and consistently measurable; application areas are defined, and the company has enabled its own systems or has linked up with service or knowledge partners. Division leaders, as the main sponsors,

have a clear perspective of how to use the technology for their own operations.

As the technology emerges from the testing phase, it becomes more strategically important and starts to be coordinated centrally. Whereas the 3DP activity of maturity level 2 companies consists of almost 90% decentralized initiatives, this falls to just under 80% at level 3.

Chart 18

Central team vs. decentralized initiatives: types of 3DP application (%)*



*N=214 companies, EY global 3DP study, April 2016

Audi champions 3DP

In Audi’s “champion” toolmaking division, 3DP enables state-of-the-art toolmaking. Leaders recognize how the “smart factory” is changing toolmaking, and aim to use new methods to

develop more precise and flexible tools. Audi is also examining how to apply 3DP to the production of complex parts, with the goal of applying 3D metal printing to serial production²⁴.

2. 3D printing - Have we reached the "slope of enlightenment"?

Maturity level 4: Strategically targeted application

At maturity level 4, 3DP is central to corporate strategy. All companies that use the technology on a larger scale - including GE Aviation, Airbus, Boeing, Rolls Royce and Lockheed Martin - have their 3DP initiatives mostly sponsored by C-level members.

In companies who consider 3DP to be strategically important, our survey shows that the main sponsor is the CTO 46% of the time. This is typical for emerging technologies: although a company may have a clear vision for applying 3DP, it may not be so mature that it can transfer ownership of the technology to operations.

Within all maturity level 4 companies, however, the technology is strategically embedded in company operations - where it brings significant benefit, accompanied by clear organization and processes. The most mature companies have also identified the sub-technologies and 3DP systems they should buy, or which service provider to work with. They often have their own research centers and dedicated divisions who implement and apply the technology across different business functions. They track their results as they move forward which helps them to further drive usage of 3DP.

Companies at a high maturity level are more likely than others to have a central team involved with 3DP - reflecting their more strategic approach.

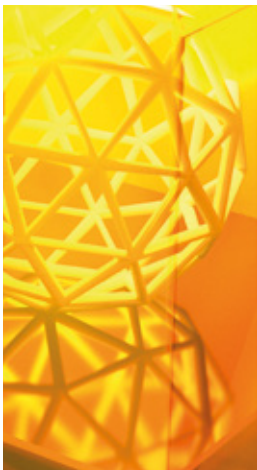
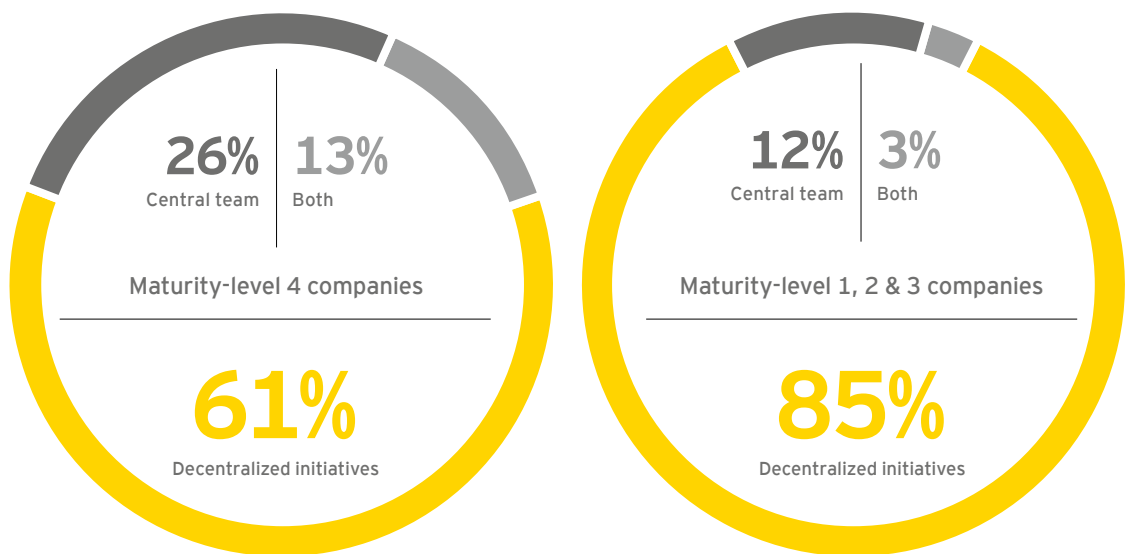


Chart 19
Central teams driving 3DP (%)*



*N=214 companies, EY global 3DP study, April 2016

Developing a digital factory

APWorks, a subsidiary of Airbus, is dedicated to all aspects of industrial 3DP, from materials to design and from testing to series production - not only for Airbus' sector-specific applications, but for applications in other industries, too.

Once Airbus had tested 3DP, it founded the company in 2013 to support engineering across Airbus Group and offer consulting. But its business quickly evolved: it has redesigned existing parts for Airbus, for example, such as cabin partitions. APWorks' revenue grew from

€300,000 in its first year to €2,8 million last year²⁵. Ever since, it has worked with research facilities and software specialist Autodesk²⁶ to help develop Airbus's key "digital factory" concept, which also includes 3DP.

Airbus' innovation division also has an additive layer manufacturing (ALM) section, led by John Meyer, the ALM roadmap leader²⁷. According to him, the section connects engineers and developers with technological 3DP experts to find specific solutions.

2. 3D printing - Have we reached the "slope of enlightenment"?

2.5 3DP in the company: barriers and challenges

Although 24% of companies we surveyed have experience of additive manufacturing, there are still many questions to answer - and challenges to face - if 3DP is to be accepted as a standard production technology or adopted by more companies. Based on our survey and our client experience, we believe these issues can be divided into three main groups:

- ▶ High prices and investment
- ▶ Technological limitations
- ▶ Business challenges

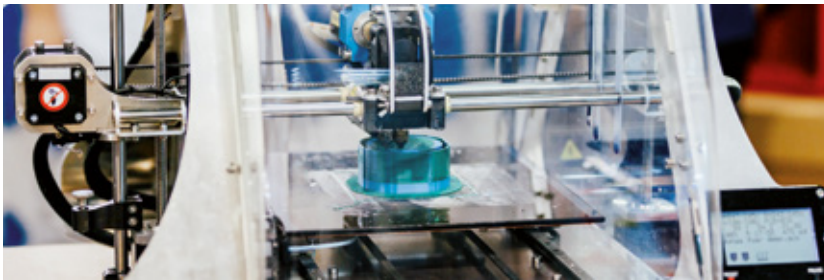
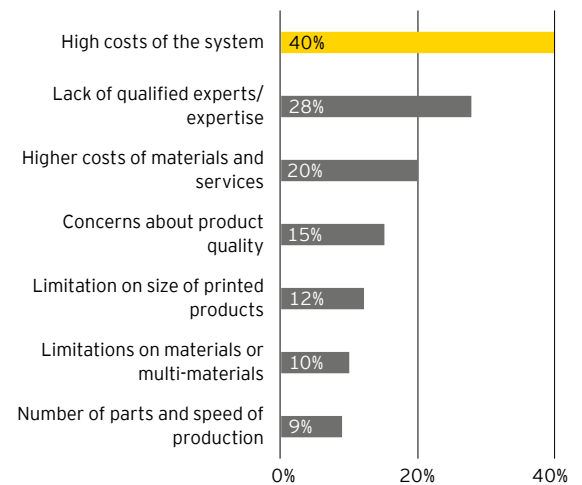


Chart 20

What are the hurdles when implementing 3DP? (%)*



*N=900 companies, EY global 3DP study, April 2016

High prices and investment

Price of 3DP systems

In order to apply 3DP to end-use products, companies require reliable production systems. Most industrial 3DP systems can offer the quality potential clients expect, but they cost more than they want to pay. In our survey, the high price of 3DP systems is the most commonly cited barrier to adopting or extending the technology, cited by 40% of companies - rising to 43% of small firms, for whom resources are more limited.

Metal printing systems, in particular, can command high prices: with some costing more than €1m each. In machinery and plant engineering, metal printing technologies are a decisive factor when extending the use of 3DP; perhaps for this reason, industrial companies perceive price to be a barrier to implementing 3DP.

As expected, Chinese and South Korean companies also see price as the main barrier, with 56% of companies citing it as an issue.

Price of materials and related services

The operational costs of 3DP are also high, with the outlay for printing materials much higher than for traditional materials. Polymers, for example, cost 20 to 100 times more for 3DP than for their injection molding equivalents²⁸. One in five companies expect to see a reduction of the operating costs before considering applying 3DP widely. The prices of materials are currently also high because many systems providers sell machines that can operate only with the materials they provide.

Technological limitations

Build envelope and product size

A company's acceptance of 3DP will depend on how many of its products can be produced with 3DP technologies. Most technologies, though, offer standard systems with limited building envelopes, making 3DP applicable mainly to smaller parts. This is true for almost all technologies, but it is a particular issue for powder bed fusion – a widely applied sub-technology for metal printing – where the biggest building envelope of standard machines²⁹ for metal printing is 800mm by 400mm by 500mm. Of course, it is possible to customize machines for customers, but this is more expensive.

In our survey, limitations on product size were cited as a barrier by more than 12% of companies, mostly from industries that make large products, such as machinery and plant engineering or automotive and aerospace. This is why efforts to develop new technologies or adjust current technologies to print large products – such as big area additive manufacturing (BAAM)³⁰ or mammoth stereolithography³¹ – are keenly anticipated by the industry.

Limitations on materials and multi-materials

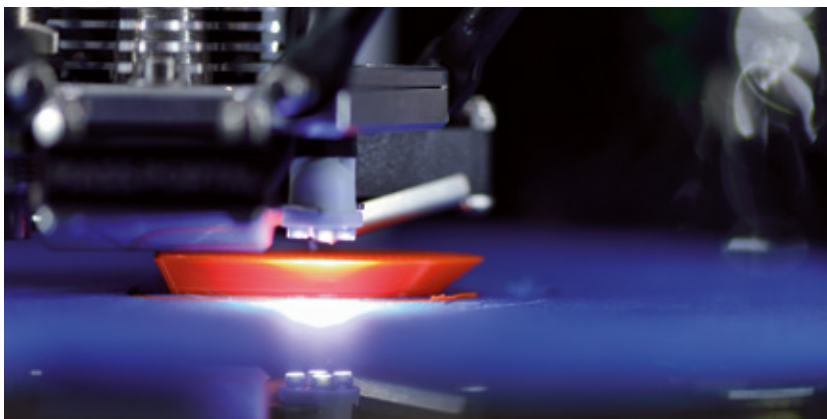
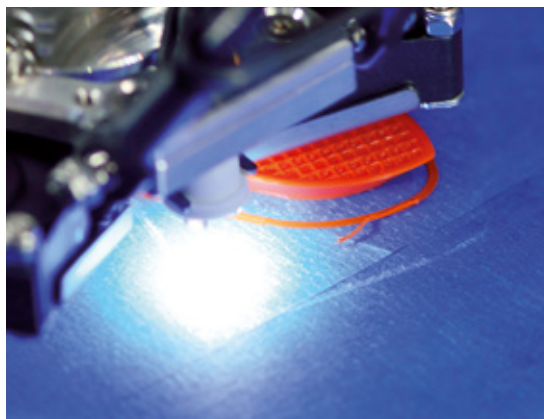
While there are systems that allow the printing of multiple polymers and almost all metals, multi-material printing is limited to materials within a single material “family”. Material extrusion and

material jetting allow the combination of different polymers and multi-color printing; sheet lamination technologies, meanwhile, make multi-metal 3D-printed products possible. But in the medium term, the functional integration of parts for serial production will demand technologies that offer multi-material combinations. 10% of companies we surveyed, mainly from the automotive and electronics industries, cite this as a current barrier.

Concerns about product quality

If 3DP is to be applied to end-use products, product quality needs to meet both specific standards and customer expectations. For 15% of companies we surveyed – coming mainly from the energy, consumer goods and automotive industries – quality concerns are a factor. These concerns are understandable. Depending on layer thickness, a 3D-printed polymer or metal object could have a rough surface, so additional post-processing will be needed in order to assure the expected surface quality.

3DP can also change the material properties of products. The layering process causes natural anisotropies, or directional dependencies – which means that the properties of the material are not evenly distributed. With metal printing, a product might meet all quality demands despite a slight anisotropy – but not if the 3D-printed part has to be heat-treated³².



2. 3D printing - Have we reached the "slope of enlightenment"?

Business challenges

Lack of in-house expertise

Introducing 3DP in-house will create a need for many kinds of additive manufacturing experts in the company. Product engineers will need to change their way of designing to establish processes driven by the product's added value. Technology experts will also be required; they will need to be familiar with 3DP in industrial engineering, production, production planning, maintenance and purchasing processes. But the availability of 3DP expertise is limited since, as a new technology, it is not sufficiently covered in schools and universities.

For 28% of the companies we surveyed, gaining relevant expertise in-house is a barrier to the sustainable application of 3DP. This lack of expertise is perceived differently between nations. While in China and South Korea, almost 48% see the lack of expertise as a barrier, it is a problem for 30% in the UK, 27% in the US, 21% in the rest of Western Europe and 18% in Germany.

In order to overcome this barrier in the short term, companies have started cooperating with specialized service providers because, as well as offering access to different technologies, they also cover related activities throughout the supply chain.

Integration into the operational status quo

Introducing additive manufacturing into serial production requires the integration of 3DP systems into existing structures and systems. If operations are to be effective, it is important that 3DP is included in operational processes, and vertically and horizontally integrated into IT infrastructure. This is especially vital in this era of connected production.

Intellectual property issues

3DP technologies also raise the issue of patent infringement. Anybody with a 3D scanning device, for example, could copy the design of a company's product and "print" it out at home. This could be especially significant for after-sales and spare parts industries, where suppliers offer the products of original equipment manufacturers.

As the value of the digital product, rather than the physical one, increases, this issue will become more relevant - and is a question to which companies would like a clear answer before widely adopting 3DP. Currently there is no specific legislation addressing 3DP infringements.



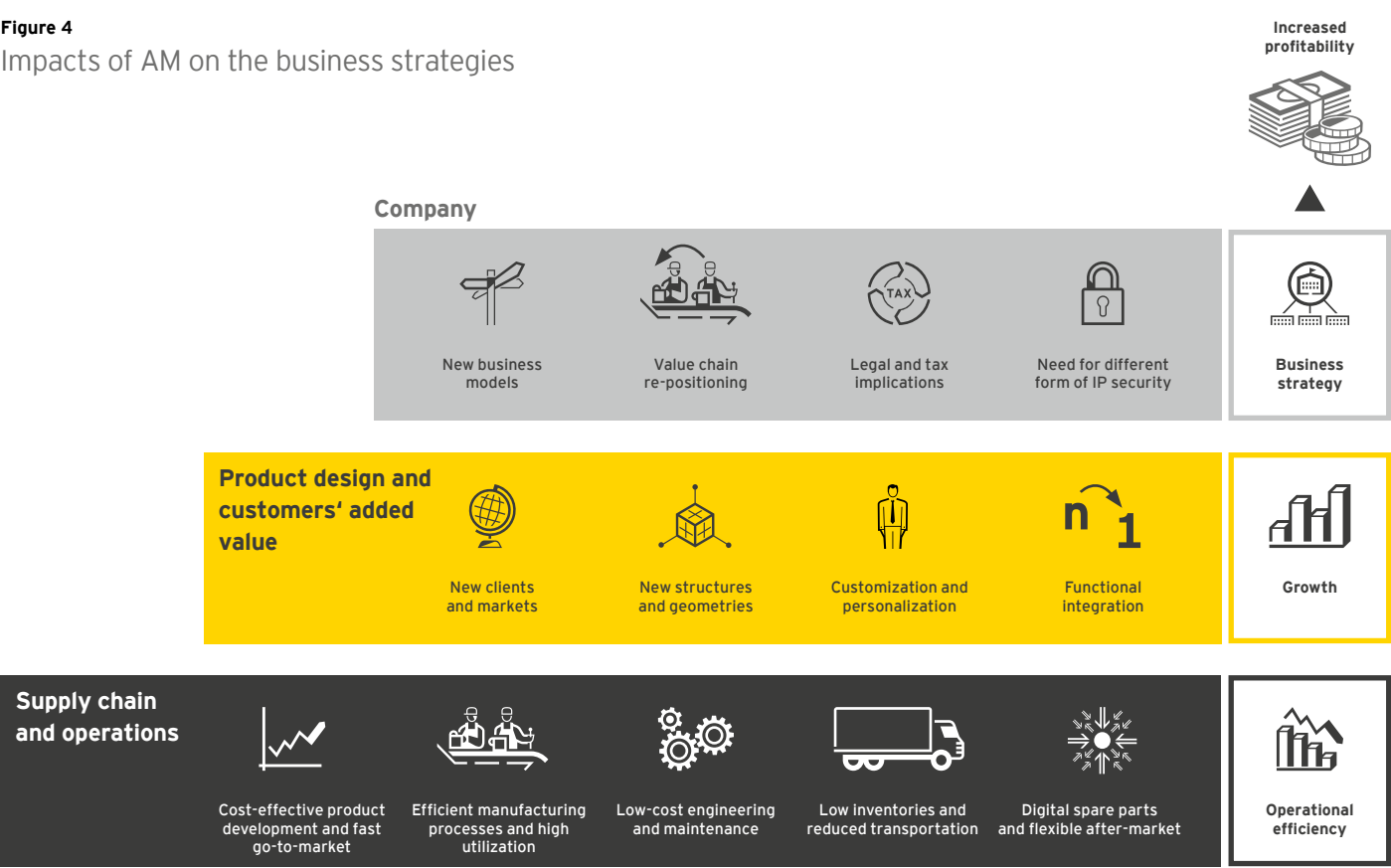
3. From optimization to reinvention - how 3DP can benefit business



3DP already has an influence on many industries but, even for early adopters, understanding the benefits of the technology is crucial for deciding to start applying it.

3DP can help a company to gain a competitive advantage, to improve its position in the value chain, to achieve growth, and to increase the efficiency of its supply chain and operations. These benefits may be understood on three levels: efficiency, growth and transformational.

Figure 4
Impacts of AM on the business strategies



Source: EY

Efficiency benefits

Through targeted application of 3DP in specific areas of the supply chain and operations, businesses can seek to improve their performance. In this context, 3DP can be considered as an efficiency strategy. The technology could, for example, be used to create prototypes in product development, to reduce time to market and cut development costs. Or it might be used to directly manufacture tools

that allow “conformal cooling” in injection molds, reducing cycle times and in turn making manufacturing more efficient.

This strategy is less risky than other options, since it requires no revision of the end product, only a change in operations. Of companies with 3DP experience, 21% say that optimizing the supply chain and operations has been its greatest benefit.

3. From optimization to reinvention – how 3DP can benefit business

But targeted applications are just the first step in optimizing the supply chain and operations. By redesigning products, businesses can create new supply chains and operate more efficiently. With a 3DP-feasible design, for example, companies can manufacture products closer to the point of demand, which increases responsiveness and ease of delivery while decreasing the costs of inventory, transportation and logistics.

3DP creates the flexibility to manufacture products according to the “lot size one” principle – that is, individually – without tools or changeovers, while maintaining production capacity. Engineering departments, meanwhile, can design and produce special and customizable machine parts, independent of suppliers. Last but not least, 3DP enables companies to rethink their after-sales and spare parts strategy – to establish a new approach with increased responsiveness and lower costs.

Growth benefits

The greatest benefits come when 3DP is applied as a direct manufacturing technology, to create end products and components. This enables companies to optimize product design, gain additional customer value, create new products or improve existing ones. This opens new revenue sources and markets, so can be seen as a growth strategy.

The growth approach reaches its full potential when companies design customized or complex products with, for example, bionic or internally complex structures. New product designs can improve quality and functionality while adding value for the customer. In our survey, almost 83% of companies who had already adopted 3DP saw the greatest benefit in the potential to design better-quality products, to develop complex products that cannot be produced with other technology, or to offer better customized products.

These new products will also require new supply chain and operational processes, so businesses also gain efficiency benefits.

Transformational benefits

As well as offering efficiency and growth benefits, 3DP offers companies the chance to revolutionize their business – creating new business models, with unique product portfolios and operations models to back them up. It creates the opportunity to design a new, global, digital business and operational model. In this way, 3DP becomes the main enabler as companies strengthen their position in the value chain, because value will transfer from the manufactured product to digital product design. In this way, 3DP will be much more than just a means of production – it becomes the keystone on which a business can build a competitive advantage.

Expected impact in the next five years

Our global 3DP survey reflects the cross-industry trend toward adoption of 3DP. 46% of all respondents believe their business will benefit from 3DP in the next five years – including the delivery of a competitive advantage through efficiency, growth strategies, and even new business models.

Chart 21

Will 3DP offer advantages for you? (%)*



*N=900 companies, EY global 3DP study, April 2016

One in four companies specifically expect to gain a competitive advantage by adopting 3DP. Most optimistic in this regard are mechanical and plant engineering companies (32%), followed by the plastics industry (27%). These two groups of companies are not only users of 3DP: their current business, systems and materials are in direct competition with 3DP producers. In plastics production, advanced additive manufacturing technologies offer a cost-effective customizable alternative to traditional technologies such as injection molding. But these companies have recognized 3DP's potential and have started adjusting. For example, German injection molding manufacturer Arburg³³ offers its customers the Freeformer additive system, enabling customers to produce multi-variant, small-volume batches from standard granulate, as well as individualizing high-volume plastic parts.

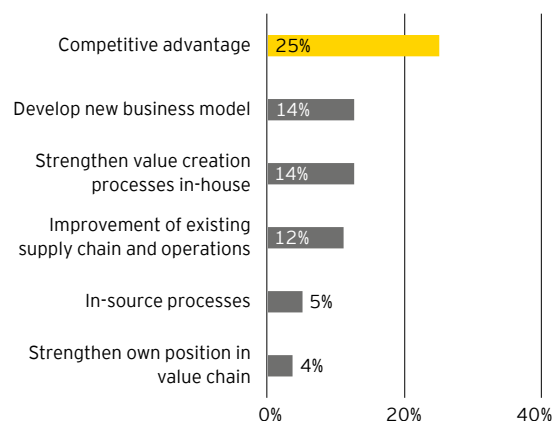
According to our global survey, almost 14% of all companies believe they will advance their business

model thanks to 3DP - rising to 21% of the automotive and aerospace companies. Using 3DP, the automotive business - already strongly localized - will take just-in-sequence (JIS) production to the next level. This will influence the network of suppliers and partners of original equipment manufacturers (OEMs), and drastically change today's complex automotive supply chain.

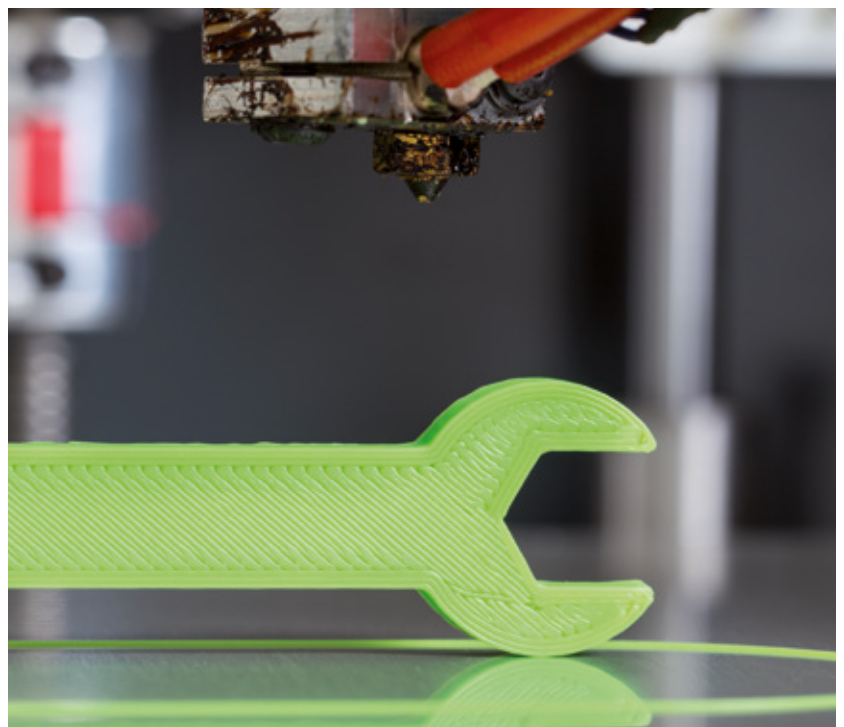
Supporting this, 18% of automotive and aerospace companies, more than any other sector, expect to be able to keep and strengthen decisive value-creation processes in-house. In the short term, this suggests that dependence on suppliers for product and machine part prototypes and tools will fall. In the long term, it implies that value creation will happen at companies who create a digital product, rather than a physical one.

Chart 22

What advantages do you expect from 3DP in the next five years? (%)*



*N=900 companies, EY global 3DP study, April 2016



3. From optimization to reinvention – how 3DP can benefit business

3.1 3DP product redesign as a growth strategy

3DP can add particular value when developing new products, as mentioned above. In our global survey, we identified three main ways in which the technology can benefit product innovation: via improved quality and value, with easier customization, and in enabling complexity.

Quality and value added: the technology helps companies design better quality products – for example, by combining functional parts that suffer less abrasion. In our survey, we found that 44% of companies across all industries could improve product quality with 3DP.

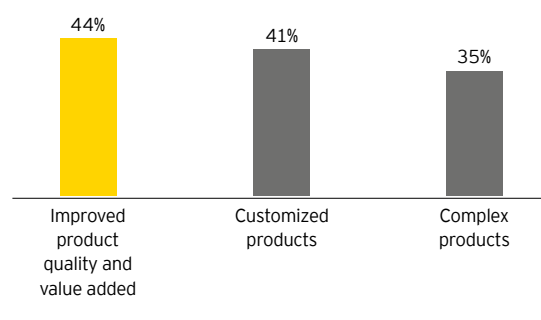
Customization: additive manufacturing makes it easier to personalize products, at a time when customers in almost every market and industry are demanding greater customization.

Complexity: the 3DP “building” process allows for unique structures and geometries – enabling the development of products that were once too expensive to make, or not feasible at all. Before

industrial-scale 3DP production, engineers needed to take into account how manufacturing processes worked. As products are now built up layer-by-layer more complex elements, such as overhanging features, can be introduced.

Chart 23

What is the main benefit of 3DP product redesign? (%)*



*N=214 companies, EY global 3DP study, April 2016

3.1.1 Customization and personalization of products

The 3DP advantage: cost-efficient and fast customization

Mass customization is a cross-industry trend. Settled, closely-correlated markets drive commodification which, in turn, fuels customer demand for individualized products. This presents clear and manifold challenges, as well as opportunities, and the supply chain must adapt to enable the cost-effective delivery of varied products.

Traditional mass production technologies require expensive tooling, while small lot-size production invariably leads to inefficiencies. Companies that produce many bespoke products incur high tool expenses and have to balance the demands of short change over times, low inventories and fast delivery. 3DP-based manufacturing, on the other hand, neither requires tooling, nor does it impose the pressure of minimum batch sizes. With 3DP,

any sequence of different products can be produced. Traditional manufacturing-based customization challenges companies on two levels: they need to produce both customized end-use products and the customized equipment (tools, dies, grippers and other production parts and aids) needed to make them.

3DP, meanwhile, enables the design and cost-effective production of unique products in line with customer needs. German company Schunk's individualized gripper product is a good example of industrial 3DP customization. Schunk, which offers gripper arms for industrial production lines, created an online tool in collaboration with service provider Materialise³⁴. Schunk's clients can now design and order customized, 3D printed grippers by uploading the computer file of the part to be gripped. The gripper is then produced and delivered within one

week. This is a good illustration of how 3DP-enabled individualization can incur no high complementary costs, with single part costs increasing in a linear way, instead of being bound to batch sizes, such as for example, in the injection molding industry.

With 3DP, companies can now involve customers in the creation of individual products. Although a manufacturing company will still produce the basic parts, exterior design can be personalized by the customer. In the electronics industry, for instance, headphone producers - including the well-known brand V-MODA - apply 3D printing to deliver customized products.³⁵

In another example, Philips offered a limited batch of 125 personalized shavers, to mark its 125th anniversary.³⁶ Customers could change the color and dimensions of the shaver housing which was then produced with a powder bed fusion additive manufacturing system by Shapeways' 3DP service.

Picture 1
Philips customizable shaver

Unique personal products

As well as enabling customers to change the look



Source: Philips

of their products, companies can now let them personalize functionality by incorporating unique personal features. Shoe producers such as Nike³⁷ and New Balance³⁸ already use 3DP for customized sole parts for professional athletes or in limited editions. In doing so they aim to improve the customer experience, with higher comfort and better performance. The start-up Wiiv shows that even shoe insoles can be 3D printed with little effort³⁹. Customers use a smartphone app to scan their feet, with the insoles costing around US\$75. This enables customers to make all their shoes more comfortable, at a cheaper price than conventional medical insoles.

In the medical sector, personalized products can offer two-way benefits: companies gain an advantage through efficient manufacturing while patients receive personalized products that work better. Implants such as the Concept Laser titanium spine implant⁴⁰ combine multiple advantages. For example, the human body accepts titanium implants with a higher surface porosity faster than usual, so reducing risk. Phonak hearing aids, meanwhile, come with personalized housing, adjusted to each patient's ear. More than 10 million people already use these hearing aids, most without realizing they are 3DP⁴¹. Dental applications are also becoming more widespread, with systems manufacturers like EOS offering dedicated and certified materials for crowns, bridges and orthodontic applications⁴².

While medical 3DP applications have been used for many years, the pharmaceutical industry is now moving into personalized drugs. Above, we discussed the case of Aprelia, a company that 3D prints approved drugs. Even greater benefits will come with personalized medicine which can be adapted to every single patient. This could ultimately eliminate off-the-shelf products, deliver higher value to end-users and make pharmaceuticals production more efficient. In 2015, a proof of concept study was released to show that 3D printing is capable of calculating "dosages according to patients' biological and clinical parameters instead of using pre-determined dosages".⁴³

3. From optimization to reinvention – how 3DP can benefit business

3.1.2 Creating more complex, higher quality products

3D printing enables the manufacture of products that were technically impossible before. The technology has brought many innovative constructions to life, such as internal structures, functionally integrated parts and completely new external geometries.

3DP-enabled internal structures

The building process of 3DP enables freedom of design; it can even integrate internal structures under the previously inaccessible surfaces of parts. One example, already widely applied, is that of cooling channels for injection molding tools. Most of these tools need active cooling and, of course, the better the cooling the faster the machine produces parts. Traditional manufacturing technologies such

as drilling and milling are limited in the way they can create cooling channels. But flow analysis can help development teams find the optimum solution which can then be created using 3DP – resulting in “conformal cooling” of the tool, ultimately reducing cycle times.

Functionally integrated products

As well as improving existing features such as internal structures, 3DP enables manufacturers to combine parts for integrated functionality. Due to the design freedom the technology offers, parts that previously needed to be assembled from multiple parts can be constructed as a single unit. In addition, new functions can be added to existing parts. The functional integration of parts helps improve product quality and product features. Furthermore, by combining the production and assembly stages into one step, companies can save costs and time.

Picture 2

LEAP engine fuel nozzle



▶ Leap engine fuel nozzle – integrating 20 parts into one, enabling a 5 times longer product lifetime and expected fuel cost savings of up to US\$1.6m per airline each year.

GE Aviation, for instance, is utilizing 3DP to manufacture the fuel nozzle tips for its new LEAP jet engine⁴⁴, produced by its joint venture CFM International. Whereas the former nozzle was made up of 20 parts⁴⁵, the new design has just one – the product itself. The 3DP redesign has also heightened performance as durability has increased by a factor of five and temperature resistance has improved. This has delivered significant added value to customers, including an expected fuel cost saving of up to US\$1.6m per airline each year. GE has already received many customer orders because of the improved product’s fuel savings.

New geometries

3DP frees engineers and developers from product design restrictions. The technology allows the creation of many more types of structures – and their adjustment to support the optimal flow of forces. It also enables more lightweight structures as, unlike traditional manufacturing technologies, 3DP needs no unnecessary materials, such as casting. Internal geometries and the product surface can also be adjusted to specific needs, be it a large porous surface or a sandwich structure.

Source: GE Aviation

Increasingly, companies are even developing bionic structures that copy nature, for example, bone structures for an optimal lightweight product. Such light structures can improve performance and

reduce costs, both via lower material outlay and through reduced follow-up charges, such as fuel savings in the aerospace industry.

A metal partition for the Airbus A320

In the aerospace industry, weight is a crucial factor since it determines fuel consumption and thus CO₂ emissions. So for Airbus, creating a lighter cabin partition through 3DP could save hundreds of thousands of tons of CO₂ per year.

Through its "bionics network", Airbus has connected bionics institutions and 3D printing experts worldwide to develop and

reinvent a range of products based on nature. In the case of the A320 partition, the experts from Airbus Group subsidiary APWorks, Autodest and The Living, tried many design variants - ending up with a version that mimics bone and cell structures. It saves 30kg of weight compared to traditional design, a 45% reduction.⁴⁶

These numbers may not seem that revolutionary - but if the new design was introduced in entire cabin and every A320 aircraft it would save up to 465,000 tons of CO₂ emissions annually. The part is already being tested and will have its first flight in 2016.



Source: The Living

Picture 3
Airbus 3D printed partition

Picture 4
Assembly parts of the partition after 3D process



Source: The Living

Conclusion

The design freedom that 3DP brings means the question is no longer "What can be produced?" but rather "What do customers want?". This creates a related challenge for engineers since they should now ask, not "Which components should I design and assemble to make this product work?", but rather "What would the optimal functionality in 3DP look like?" With additive manufacturing, products can be created that deliver significant added value

to customers and influence their buying decisions. Therefore, the products designed for 3D printing can become an important new source of customers and growth. Furthermore, once the new level of 3DP-enabled quality becomes the standard that customers expect, it has the power to change the business and industry - exactly as the hearing aid sector converted to 100% additive manufacturing in less than 500 days⁴⁷.

3. From optimization to reinvention - how 3DP can benefit business

3.2 3DP as an efficiency strategy and its influence on the supply chain

Applying 3DP in a business can improve supply chain and operations (SC&O), and even lift operations to a new level of efficiency. There are three main ways in which 3DP can affect operations:



Of companies with 3DP experience, 21% say that optimizing the supply chain and operations has been its greatest benefit.

► **3D-printed prototypes of products, tools or machine parts.** 3DP can help improve operations in the product development and product ramp-up phases. In section 3.2.1 and 3.2.3, we show how 3D-printed prototypes of products, tools or machine parts can help qualitatively improve product development and industrial engineering processes, while making them more cost-effective.

► **Direct manufacturing of tools, machine parts and manufacturing aids.** 3DP can be used to create new tools, molds, dies or machine parts with improved performance features - for example, conformal cooling channels in mold inserts - which can help to improve traditional manufacturing processes as discussed in section 3.2.2 and 3.2.3. And with fast, direct in-house manufacturing of one-time machine parts for special machines or manufacturing aids, ancillary

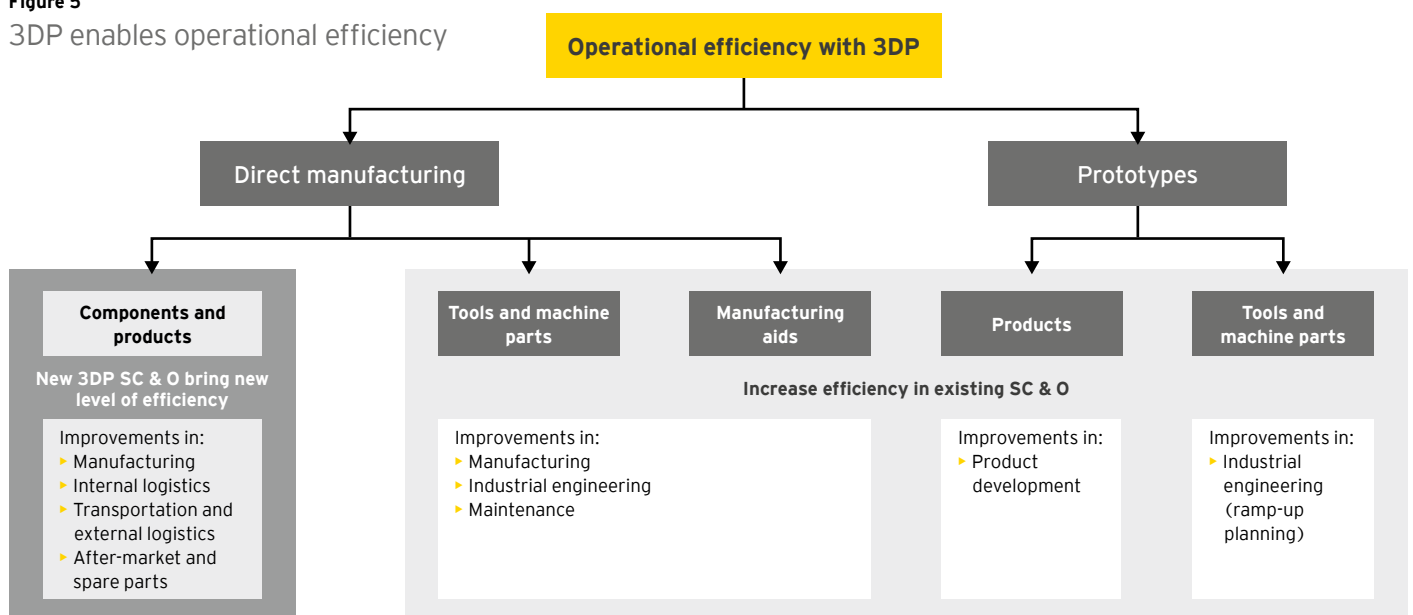
tooling and delivery costs can be eliminated, and lead times reduced.

► **Direct manufacturing of end-use products or components.** When 3DP is used to redesign end-use products, supply chain and operations are transformed. Generally speaking, these newly redesigned products do not only add extra value for customers, but also operational areas such as manufacturing, logistics and after-sales processes derive high benefits. The 3DP value chain also offers the company a chance to rethink its operational model: for example, can localized production of serial or spare parts, by specialist 3DP contract manufacturers, improve a company's performance?

In the next sections, we will assess how each of these areas can affect operational efficiency.

Figure 5

3DP enables operational efficiency



Source: EY

3.2.1 Cost-effective product development and swift go-to-market

Product development processes and challenges

Modern product development offers many challenges. To gain a better understanding of these, product development needs to be seen as one part of an entire process: product lifecycle management (PLM).

Markets are changing quickly, with some - such as the electronics, medical and automotive industries - changing much faster than others. Such change reflects customer demand for innovation, lower prices and individualized products - which, especially in these industries, tends to make innovation cycles shorter and means products need to be more customizable. The medical industry, for example, is facing innovation cycles as short as 18 to 24 months, and a huge demand for individualized products such as dental crowns, hearing aids and titanium implants.

Addressing these external influences is a difficult challenge for R&D and engineering departments, since it requires lean and flexible processes.

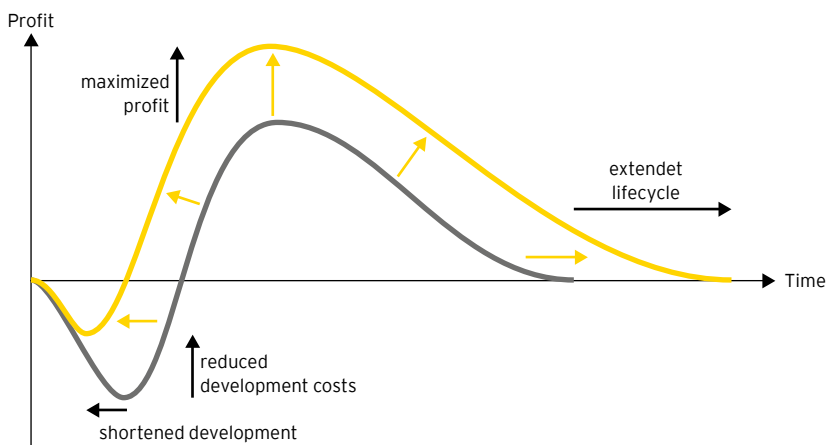
Our PLM optimization model (figure 6) shows that, to maximize profit, businesses need to address

development times; this leads to lower costs, by enabling faster time-to-market. Companies can use technology to reach this goal and thus maintain control of costs.

Solving challenges with 3DP

Estimating development costs and time is a particularly important task for businesses. Since such processes are not linear, they are hard to calculate. Businesses need to use creativity, apply trial and error, and find a way to keep track of progress. However, a Harvard Business School study⁴⁸ offers a way forward. Researchers compared 391 development teams and found the most successful and efficient team was the one with the greatest number of, and quickest, iterations - which enabled the deepest learning during the development process. After finding out the problem they had to solve, the successful teams made many design iterations swiftly, assisted by digital methods and rapid prototyping. This suggests that the sooner prototypes are available, the shorter the product development process is, and the quicker profit grows.

Figure 6
Product lifecycle management optimization model



Source: EY



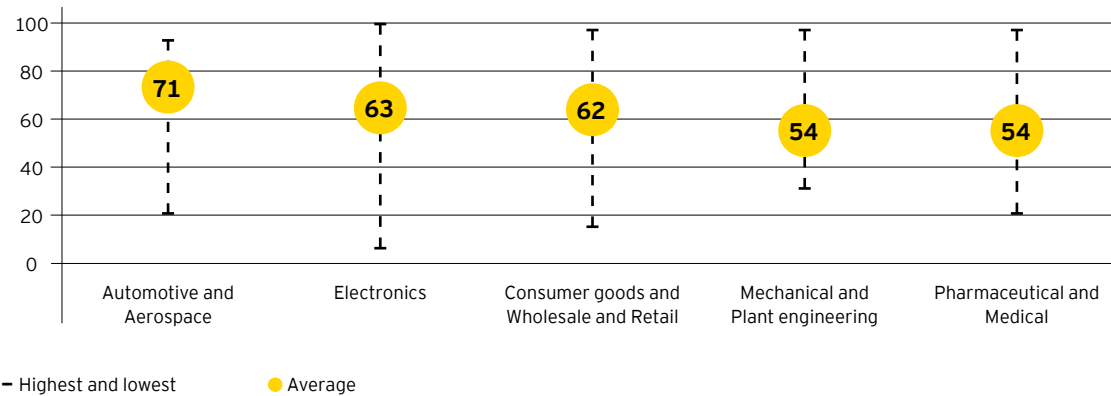
3. From optimization to reinvention - how 3DP can benefit business

84%
of all companies
applying 3DP use it for
product development

Most companies already know that fast prototyping is key to product development: our global research shows that 84% of all companies which apply 3DP use it for product development. DePuy Spine, a Johnson & Johnson company that develops medical instruments, is one of them. In its first year of owning a 3DP system, the company evaluated more than 2,000 prototypes⁴⁹, including a plate bender tool used in spinal operations. The prototypes were all produced with an EOS metal system - and with a dramatically shorter development time. DePuy Spine Staff Team Leader Peter Ostiguy says the greatest benefit of using 3DP was the capacity to print multiple iterations of a prototype within days, as the digital process did not incur more costs for design variants.

3DP can enable prototypes to be printed within hours, or overnight. Rapid prototyping enables production to take place in-house, which reduces dependence on suppliers and lead times. Depending on part complexity, size and material, traditional prototyping is very time-consuming and can take weeks or even months. As ready access enables more iteration cycles, 3DP not only speeds up the product development process; it also helps improve the results. Our analysis of 57 case studies from different industries showed that rapid prototyping helps reduce the average prototyping time by 63%.

Chart 24
Prototyping time reduction with 3DP (%)*



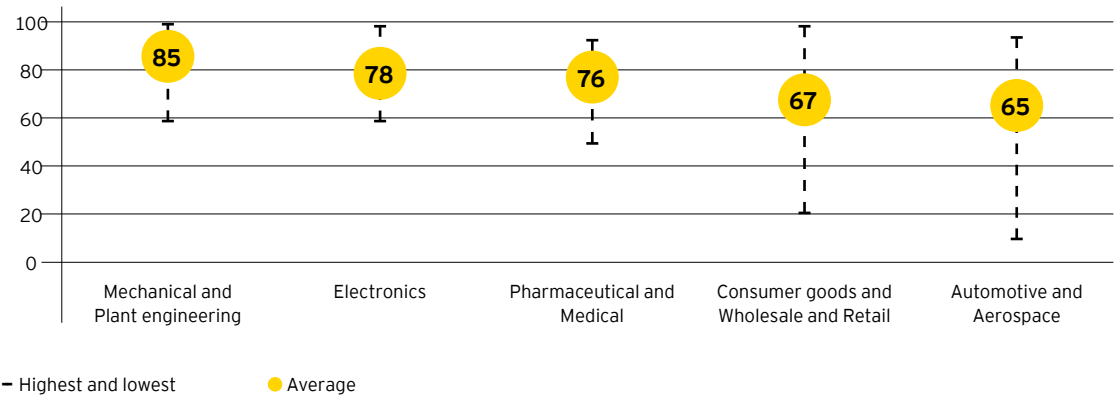
*N=57 companies, EY global 3DP study, April 2016

As well as enabling time-efficient development of new products, 3DP can also help reduce prototype costs. Traditionally, the largest cost factor is tooling, and since most design iterations require new tools and dies, costs can quickly become too high. Additionally, production at suppliers is related to logistics and other prototype-related costs. So rapid prototyping in-house can help reduce development costs significantly.

With materials continuing to improve, industrial 3DP systems can produce very high quality parts. Prototypes can be made of plastics, metals or sand and wax to be used for casting; some sub-

technologies also enable full-color models. In most cases 3DP materials are strong enough not only to serve as a visual evaluation of design iterations, but also for functional testing.

Chart 25
 Prototyping costs reduction with 3DP (%)*



*N=57 companies, EY global 3DP study, April 2016

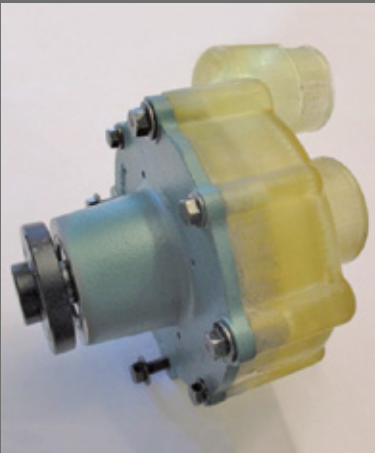
3DP accelerates development at Volvo Construction Equipment

When Volvo Construction Equipment decided to cut development times for large engine projects from 36 to 24 months, and to reduce overall costs, engineers needed ways to save time and money.

So they used 3DP to produce for example a transparent, water pump housing prototype - which had such good properties that it could be used for functional testing under water pressure.

The benefits for Volvo Construction Equipment were 90% time savings compared to traditional prototyping, and a total cost reduction of 92% ⁵⁰, mostly because tooling costs were eliminated. The company even said it was considering using 3DP for small batch sizes in direct manufacturing because the quality of the parts was so good.

Picture 5
 3D printed transparent water pump housing



Source: Stratasys

3. From optimization to reinvention – how 3DP can benefit business

3DP as an integral part of the organization

Within organizations, 3DP can be guided by a central team or it can exist as a separate department initiative. Our global survey shows that in 80% of companies with 3DP experience, application of the technology is decentralized; in almost 40% of these, it is part of the research and development (R&D) team. This is because companies start using 3DP for prototypes in the product development phase since it is less likely to cause a risk to operations. As a company's use of additive manufacturing matures, however, the time and cost benefits in product development drive the application of 3DP into direct manufacturing.

When considering how companies expect to benefit most from 3DP in the next five years, product development is at the top of the list. According to our survey, just over 25% of companies say they expect to see advantages in this area. Interestingly, the industry most likely to expect product development benefits is the mechanical and plant engineering industry (more than 35%), a sector that already benefits most from prototyping cost reductions, according to our use case research; this was followed by automotive and aerospace (33%) and plastics (30%). These results are due to several key factors. First, automotive companies and suppliers of plastics to the electronics industry are each facing constantly decreasing product lifecycles, with phasing in of new products; in this

environment, fast product development can be a competitive advantage. Meanwhile, mechanical and plant engineering companies can use metal 3D printing to speed up the production and testing of functional prototypes, allowing more iteration cycles without additional tooling costs.

Finally, all companies rate 3DP's product development advantages highest, not only because of these benefits, but because the technology allows faster response to market demands, helping increase competitiveness and the potential for innovation.

Chart 26

The role of R&D in the decentralized use of 3DP (%)*

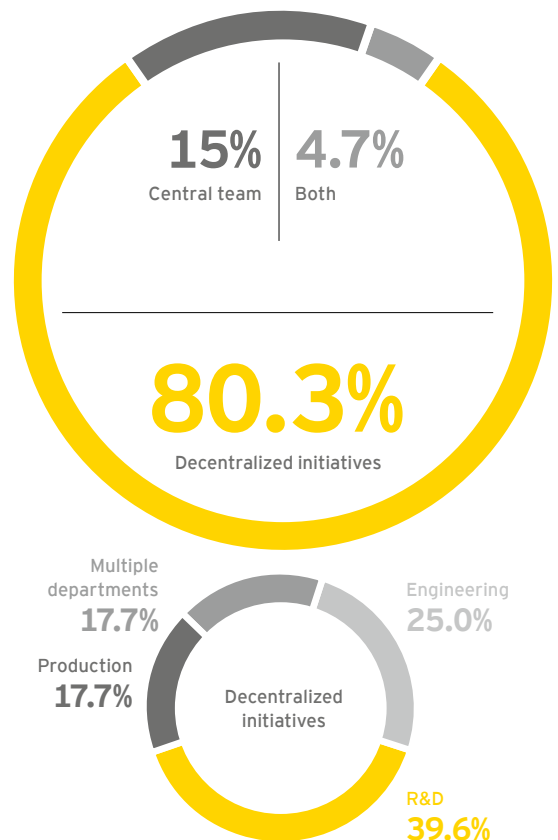
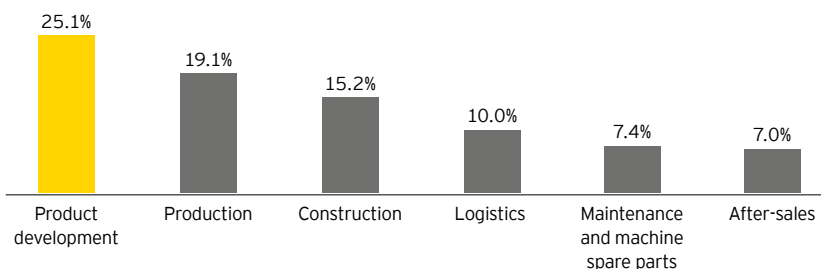


Chart 27

Advantages companies expect to experience in five years from using 3DP (%)*



*N=900 companies, EY global 3DP study, April 2016

*N=214 companies, EY global 3DP study, April 2016

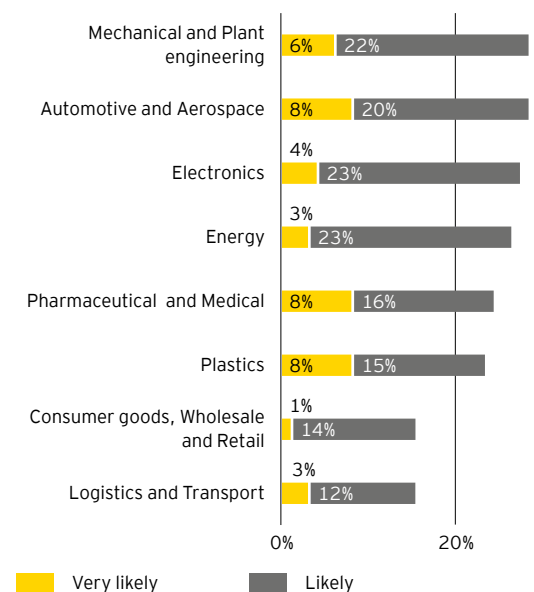
3.2.2 Unlocking the potential for operational excellence in manufacturing

In the past three decades companies have applied different approaches to operational excellence - including lean manufacturing, Six Sigma, and total productive maintenance (TPM) - in order to achieve cost-effective operations. As companies face rising pressures on costs, they need an efficient manufacturing process that minimizes waste and loss. Lean manufacturing principles, for example, strive to achieve a highly flexible, "one-piece-flow" production process, using minimum inventory, since products are produced when and where they are needed by customers, in the right quantity, quality and sequence. 3DP supports these principles, helping establish efficient and flexible manufacturing processes on three levels:

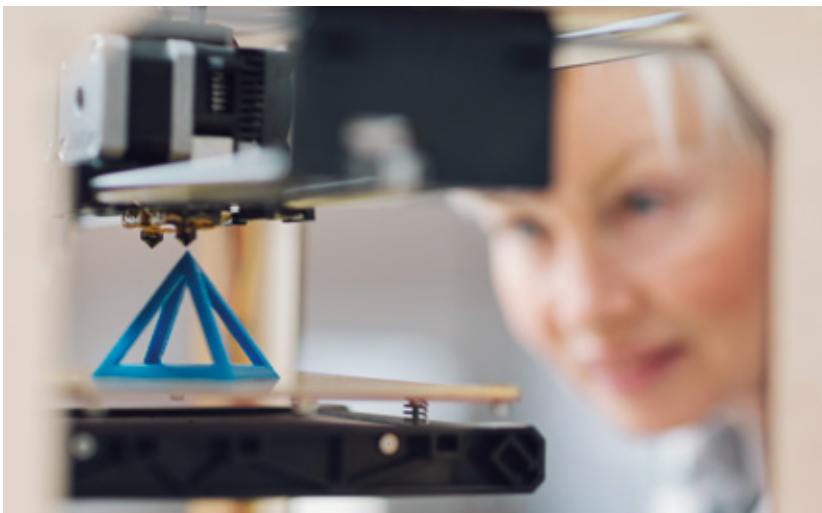
1. 3DP achieves efficiencies within the existing manufacturing process, by improving the performance of tools, dies and manufacturing aids.
2. Existing products can be transformed into 3D-printed products, with the aim of creating more efficient manufacturing and operation processes.
3. Functional integration of multiple components into a single component results in a new, more efficient, manufacturing flow.

As our survey shows, companies expect to realize production efficiencies using 3DP. When asked how likely they are to gain an efficiency advantage in production with 3DP in the next five years, 6% of companies said it was very likely and a further 18% said it was likely. Figures vary from industry to industry: companies in mechanical and plant engineering, aerospace, automotive, electronics and energy tend to have higher expectations in this regard. In the next sections we will cover the potential for efficient manufacturing, paying attention to the potential in these industries.

Chart 28
3DP/AM for increasing the efficiency in production in 5 years (%)*



*N=900 companies, EY global 3DP study, April 2016



3. From optimization to reinvention – how 3DP can benefit business

3.2.2.1 3DP achieves efficiencies within existing manufacturing

In this scenario, the end product and its value stream stay the same; companies simply improve the manufacturing process, by designing 3D-printed molds, tools, dies or manufacturing aids.

One of the most common applications of 3DP is to improve injection-molding processes by redesigning molds and mold inserts. 3DP enables molds to be designed with integrated conformal

cooling channels that enable better fluid flow. This leads to shorter production cycle times; the ultimate quality of plastic parts is also improved, contributing to a better product for the end-user. 3D printing of molds benefits industries that use injection molding; these include not only technology manufacturing industries such as automotive and electronics, but also industries such as consumer goods, where blow molding is commonly used.

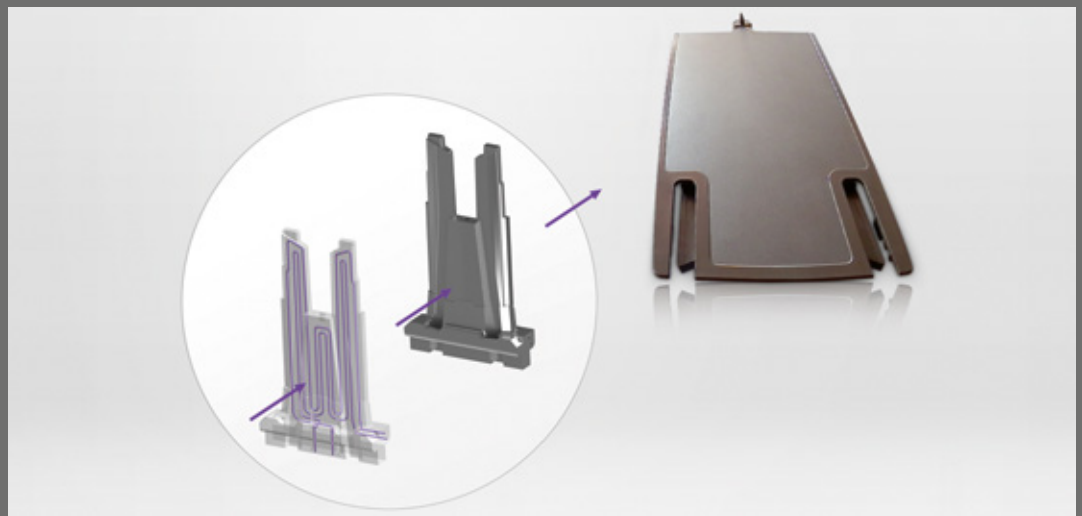
Case study: Magna improves injection molding output with 3D-printed tools

In the automotive industry, tools are very expensive and must meet high quality standards because their design and performance strongly influence the quality of plastic injection-molded parts. The more evenly and efficiently a plastic part is cooled, the faster the process and the better the results. Czech 3DP service provider Innomia helps automotive suppliers like Magna to meet this challenge by offering 3DP services such as repair, prototyping and tooling for injection molds.

When creating plastic components for an armrest, Magna formerly used a complex process in which uneven temperature distribution led to tool corrosion. Using 3DP, Innomia was able to include internal cooling channels closer to the surface of the mold insert, which resulted in more conformal cooling. This cut the cycle time of the injection molding process for the part by 17%, while at the same time increasing the quality⁵¹. The corrosion problems were eliminated and maintenance intervals extended by five-to-six weeks.

Picture 6

3D printed tool for conformal cooling



Source: Innomia, Magna; EOS

A major challenge for manufacturers is reducing periods of downtime – from unplanned stoppages, such as for breakdown repairs, to planned downtime, such as for tool changeover or maintenance. Using 3DP can help companies design and produce higher-performing tools which operate for longer – and thus reduce downtime.

One example of such a tool is an insert drill, used for drilling coolant holes, made by German company Mapal. Previously, technological restrictions meant drills could not be made with a diameter of less than 13mm. But by 3D-printing parts, Mapal was able to widen its product range to 8 to 32.75mm.⁵² Industrial clients using the drill now benefit from higher productivity because of its optimized internal cooling channels.

3D-printed manufacturing aids can also increase the productivity of assembly processes in a cost-effective way. These processes are most productive when strictly standardized cycle times are achieved at assembly lines. 3D-printed aids such as jigs, fixtures and shadow boards can help ensure processes are completed in the allotted time. The increased range of end-user customized products is reflected in the number of manufacturing aids that can be rapidly and cost-effectively 3D-printed. This application for 3DP is commonly used among automotive original equipment manufacturers such as BMW⁵³ and Opel⁵⁴.

3.2.2.2 3DP value stream raises manufacturing efficiency to the next level

In the second industrial revolution, Henry Ford's assembly line concept represented revolutionary thinking about how to assemble complex, multi-component products quickly. Since then manufacturers have designed products while considering how they could be most efficiently assembled. But what would product design – and manufacturing – be like if no assembly was needed?

3DP represents a paradigm change as a product containing many components can now be produced in one step without assembly. The traditional value stream is characterized by multiple production stages and intermediate storage of semi-finished products, which together result in long lead times. The ideal 3DP value stream is shorter and faster, because multiple stages are combined into one production step. This means there is no need for intermediate inventory or intra-logistical transport and handling. While a casting-based production process, for example, requires several stages that can take weeks in all (including the manufacture of core halves, the production of half-molds, mold assembly, and casting), the production of sophisticated cast parts can occur in a single step

with additive manufacturing. Similarly, in the traditional manufacture of plastic or metal modular products, separate components will be pre-produced, made, pre-assembled and assembled; with 3DP, this could be reduced to the production of one part. Lockheed Martin, for example, applies metal 3DP to end-use products such as spacecraft fuel tanks: reducing lead times from 18 to 20 months to two weeks⁵⁵. In addition, traditional technologies such as turning or milling can result in waste, because the product is cut out of a block of material. With 3DP, only the material needed is applied, in the case of filament – or, with powder layers, the processed non-melted material is reusable.

That said, although the ideal 3DP value stream is almost waste-free, state-of-the-art additive manufacturing technology is associated with certain operational losses. Production rates are still relatively low and production processes involve non-value-added activities, such as the pre-warming of material or post-processing. Nevertheless, for certain product groups, applying 3DP will still be more efficient than traditional manufacturing.

3. From optimization to reinvention – how 3DP can benefit business

When 3DP is introduced as an additional production technology, companies may consider developing more effective production control processes. For product groups with low volume and high variety that are usually made to order, production with 3DP is a cost-effective alternative. The advantage of

tool-free 3DP production is that there are no labor-intensive and time-consuming changeover processes, and tool-related costs are eliminated. Different orders can also be built one after another without delay – or even at the same time, if more than one object can fit in the machine's building area.

Festo saves 40% per part with 3DP

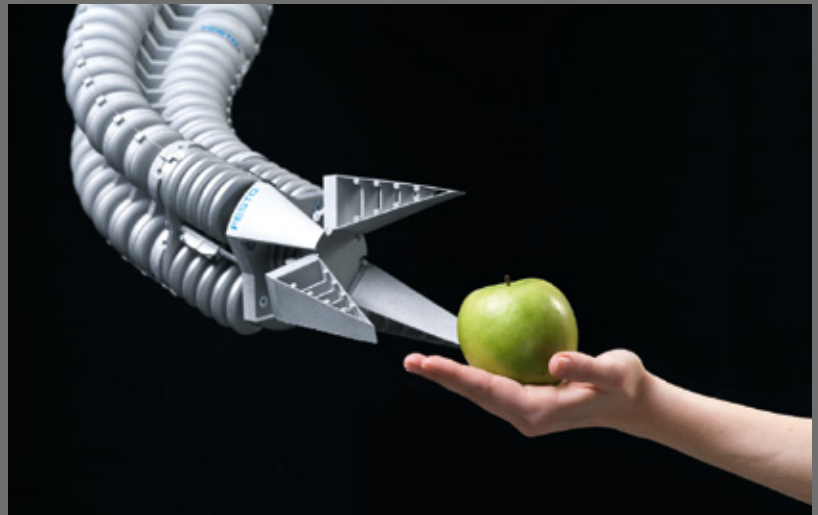
German automation technology specialist Festo developed a bionic design for an adaptive gripper, imitating the structure of a fish fin. To produce the gripper, and the high-tech arm – or “bionic handling assistant” – which controls it, Festo used selective laser sintering (SLS) machines from EOS.

The 3DP process enabled one-piece manufacturing

of the gripper, including all parts and joints, saving 80% on weight compared to traditional metal grippers⁵⁶.

According to the company, on one 12,000-piece order from a client, it was able to save 40% of the cost per part. Production time for the whole job was also reduced by almost 88% compared to conventional manufacturing methods.

Picture 7
3D printed arm and gripper



Source: Festo; EOS

As a first step, 3DP-based production requires a product to be redesigned for additive manufacturing. Companies can either “copy” the current design – for example, a cast part – to a 3D-printable standard tessellation language (STL) file; or they can create a new, functionally integrated design for the modular product. Redesigning for additive manufacturing means changing the end product and its value

stream; this tends to bring benefits in the form of higher operational excellence, but is riskier than targeting efficiencies by using 3D-printed tools or molds.

3.2.3 Low-cost engineering and maintenance

3DP can help businesses overcome challenges, and increase efficiency, in industrial engineering and maintenance.

For example, companies often experience problems with product ramp-ups, production of special machine parts and customized machine parts for custom end-use products, and repairs. Increased customization is having a particular knock-on effect on the manufacturing process: special or custom machine parts are usually produced in small batches, or even as “lot size one”. As with the repair of single machine parts, these small batches are expensive to manufacture using traditional methods, since they require tooling and long lead times.

3DP, however, helps companies to control these costs since the technology requires no tooling, enables flexible adjustments to custom parts in the development phase, and allows fast direct manufacturing and the cost-effective repair of, for example, metal tools.

In our global study, we found that 44% of all companies now applying 3DP use it for the direct manufacturing or prototyping of tools or machine parts. This signals a recognition of 3DP’s potential for tools and machine parts, as it helps establish flexible, fast and cost-effective engineering and maintenance processes in all phases of the product lifecycle.

Efficient industrial engineering with 3D printing

In engineering, companies may incur costs in three main areas:

1. Prototypes of machine parts, dies and tools

Shortened product lifecycles and intensive ramp-ups of new products can put operations under pressure. To ensure that standard operating procedures (SOPs) are successful, companies perform test runs with prototypes of new machine parts. With common manufacturing methods, such as milling, prototypes can be expensive – and it often takes weeks

until they are produced and delivered by external suppliers.

3DP, on the other hand, enables companies to reduce time and costs, allowing for flexible design iterations thanks to digital manufacturing. Stratasys, for example, showcased this potential when it created blow molds for a client who, looking to test a new bottle design, decided to 3D-print the mold. The plastic mold prototype was tested until it was able to withstand the high processing temperature during blow molding. Compared to traditional methods, 3DP turned out to be 50% to 75% faster. The company was also able to cut the cost of the prototype by 50% to 60%⁵⁷.


2. Direct manufacturing of special machine parts

Similar to machine part prototypes, parts for special machines are often “lot size one” and would traditionally require expensive tooling and a long lead time. Due to their low volume, they are particularly suitable for additive manufacturing. These parts also have higher quality requirements, since they are end-use parts.

German 3DP systems manufacturer EOS, for example, showcased this capability with the rotor of a small washing unit. It shrunk the original 32 parts to just three⁵⁸, and delivered the part quicker and more cheaply than with traditional manufacturing methods.

3. Customized machine parts, tools and manufacturing aids

Special client requests for one-off parts can also take time and money to deliver. In such cases, 3DP’s flexibility again comes into its own because it is possible to use the technology to print custom machine parts, tools or manufacturing aids. With 3DP, design changes to existing end-user products (or custom products) can be easily made and transferred into production, because digital workflows enable machine parts to be adjusted in accordance with the new custom feature.


44%
of companies now applying
3DP use it for printing
end-use tools or machine
parts or their prototypes

3. From optimization to reinvention – how 3DP can benefit business

Kuhn-Stoff creates efficient custom parts with 3DP

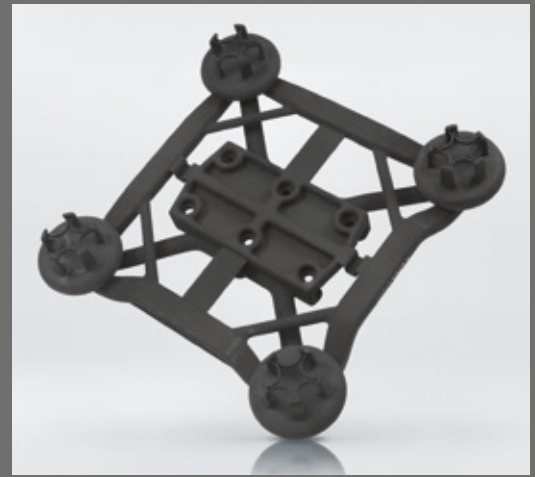
German company Kuhn-Stoff was asked by a client to create an industrial gripper. Working with EOS, Kuhn-Stoff constructed a gripper that was about 80% lighter than a previous model and consisted of just three parts instead of 21⁵⁹.

This “lot size one” order led to a range of efficiency advantages. It cost 50% less to make and reduced manufacturing time by 81%, with savings in material and production costs, assembly time and special tooling. The additive manufacturing also offers flexibility for spare parts printing or design change.

Source: Kuhn-Stoff; EOS

Picture 8

Printed gripper element



3DP allows for new maintenance approaches

Additive manufacturing also offers a way to repair expensive metal tools that wear during production, instead of having to throw them away. In many cases

a 3DP repair is more attractive in terms of cost and logistical effort than creating a new spare part – even if companies cooperate with a service provider.

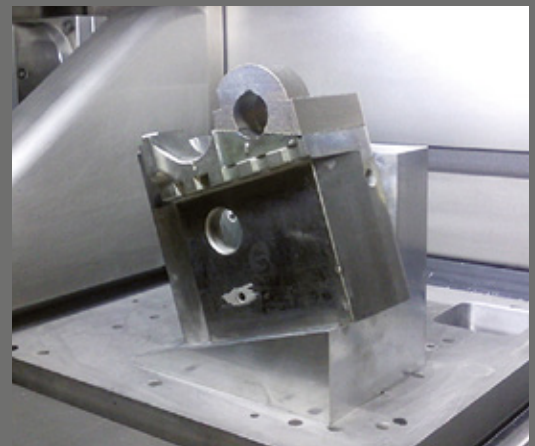
Innomia uses 3D printing to refurbish worn parts

To repair tools for its injection molding machines, service provider Innomia uses a powder bed fusion system⁶⁰. The company can refurbish damaged tools, and even implement design changes at the same time: it cuts off a piece of the part, creates an even surface, then “melts” the new or repaired part on top. Depending on the material and part, this can require heat treatment in post-processing.

Source: Innomia

Picture 9

Refurbishment of injection molding tool with 3D printer



In our 3DP survey, 25% of companies said they were “likely” or “very likely” to use 3DP for producing tools and machine parts within the next five years. Flexibility - in the cost-effective and swift manufacture of machine parts and spare parts - is the main advantage to business. 3DP enables companies to react fast and speed up their SOP, while experiencing shorter downtimes due to faster access to parts. Companies in plastics, automotive, aerospace and mechanical and plant engineering, in particular, are most likely to use 3DP for this purpose. This reflects our own experience with clients in these industries.

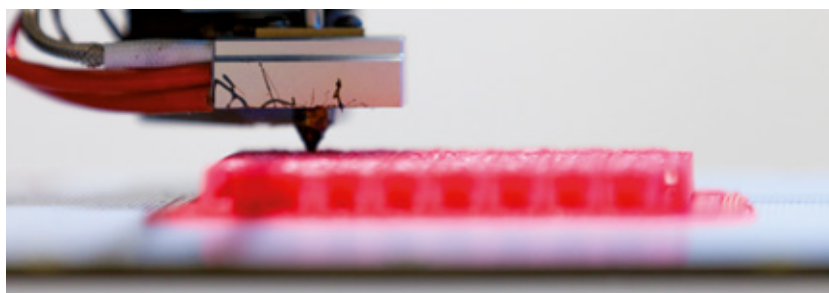
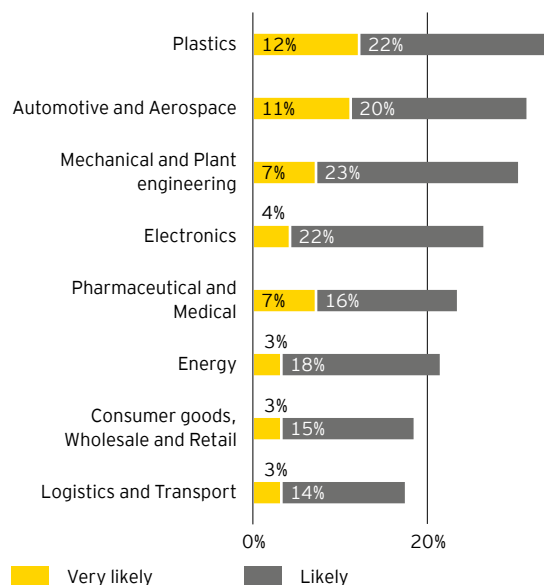


Chart 29

3DP/AM for construction and production of tools and machine parts in 5 years (%)*



*N=900 companies, EY global 3DP study, April 2016

3.2.4 Are transportation and warehouses still relevant in a 3DP world?

3DP is affecting all industries in different ways; the logistics sector, however, is experiencing particular disruption. The impacts are two-way: manufacturers will be able to 3D print products closer to their customers, on demand, so reducing logistics costs. This will influence the entire logistics and transportation industry, requiring it to adjust its business models. As 3DP technology advances swiftly, many global logistics players are considering its impact and how it will influence their future approach.

Our global research shows that 10% of all logistics and transportation companies already have experience of additive manufacturing. Although this ratio might seem high, it is much lower than in other industries: 38% of companies in the plastics

industry, including injection molding as part of it, have similar experience. This reflects the fact that the technology's impact on many other industries currently is much higher; however, logistics and transportation companies will be affected greatly as the 3DP technologies advance further.

In addition to the 10% of logistics and transportation companies that already apply 3DP, another 5% are considering using it. However, 19% say that they would not employ the technology due to a lack of information: this again shows that many companies are unaware of the advantages that 3DP offers for their business.

3. From optimization to reinvention – how 3DP can benefit business

3.2.4.1 How 3DP impacts manufacturing logistics

Manufacturing closer to customers

Being a digital technology, additive manufacturing allows for cost-effective, decentralized production closer to customers. In addition, the reduced transportation required enables companies to offer more flexible and more reliable deliveries.

The technology can be harnessed in different ways: companies can produce parts at their own 3DP sites or work with service providers or systems manufacturers. A future business model for companies with slim margins could be to arrange specific product manufacturing closer to the client. They could then choose a service provider or manufacturer to directly manufacture the order and deliver it to the end-user or client. Such options have many benefits but they do require investment, which is why many future business models will rely on partnerships with manufacturing companies. In our state of the art of the technology section 2.3 we discuss this potential: whereas today 8% of all companies with additive manufacturing experience cooperate with service providers, this number will climb to more than 41% by 2021.

Lower transport volumes via decentralized manufacturing

The trend of positioning manufacturing sites closer to customers, referred to above, will transform the transport industry over the long term. But the mass production of smaller parts and prototyping will actually be affected in the near future. Currently the direct manufacturing costs for 3DP metal parts are higher than those when the parts are manufactured by using traditional methods. The full cost savings occur on a supply chain level and are only achieved by combining, for example, several manufacturing steps and optimizing logistics. That is, by decentralizing 3DP sites so they are more cost-efficient, and using more flexible transportation. Our global survey shows that almost 15% of all companies believe that 3DP will lead them to contract out the printing of end products within the next five years.

Digital storage will reduce logistics handling and physical storage

As 3DP technologies are digitally-based, products can be printed on demand. This reduces the need

for extensive product inventories. Similarly, manufacturing companies will no longer need to stock molds, dies, tools and physical design models to provide customers with spare parts throughout the product lifecycle. 3DP enables manufacturers to become independent, making physical storage redundant and enabling the fast and effortless production of spare parts. Digital computer models can be additively manufactured anywhere, they are not tied to a geographic location.

The huge potential this represents can be seen with Airbus A300/310 airplanes. Airbus expects the planes to require spare parts until 2050 and, by 2014, was already storing 3.5 million parts⁶¹. This required storage space and tied up a great deal of capital. Today, Airbus is in the process of estimating which parts can be 3D printed in order to save storage and costs.

Furthermore, traditionally, inventories extend beyond necessary spare parts to include all kinds of products. Manufacturing companies often have minimum batch sizes in series production due to supplier conditions and technical restrictions. 3DP means that handling processes and storage can be reduced to an absolute minimum. Parts optimization can, in turn, lead to less assembly and thus reduced handling of interim inventory; storage capacity can also shrink since production capacity can be adjusted to meet customer demand.

Less waste means less logistics effort

Building 3DP systems produces little if any waste. With 3DP technologies such as material extrusion, only the material needed is applied. Furthermore, most of the unused material in the various processes, such as in powder or liquid photopolymer-based manufacturing, can be reused or recycled. Systems manufacturer EOS's material management system, for instance, enables leftover powder to be reused⁶². This means less materials are used for manufacturing; an advantage complemented by the fact that, as many 3DP products can be optimized geometrically, resources can be reduced even further. This impacts logistics: less material use ultimately leads to lower inventories and transport volumes.

3.2.4.2 How logistics companies can remain competitive

It is difficult to predict exactly how 3DP will change future logistics processes. However, as 3DP is having manifold impacts on the sector, the industry's responses to the challenge are likely to be similarly diverse. Freight companies around the world are already preparing for 3DP and the threat caused to their core business from lower shipping volumes. For instance, like many national postal services, global transportation and logistics provider, UPS, has also invested in 3DP⁶³. To stay competitive, as

more service providers emerge, the company now offers related services in their stores.

In estimating the potential of 3DP in our global study, we found that almost 16% of all logistics and transportation companies are aware of the advantages that additive manufacturing will bring to their business within the next five years. Worldwide urbanization is continuously increasing, meaning that most current and future customers will live in cities. This will lead to higher transport costs since regulatory fees and tolls are also steadily increasing, especially in cities. It is important to save transport costs by siting distribution hubs closer to customers. Such hubs mean that last-mile logistics will become ever more important.

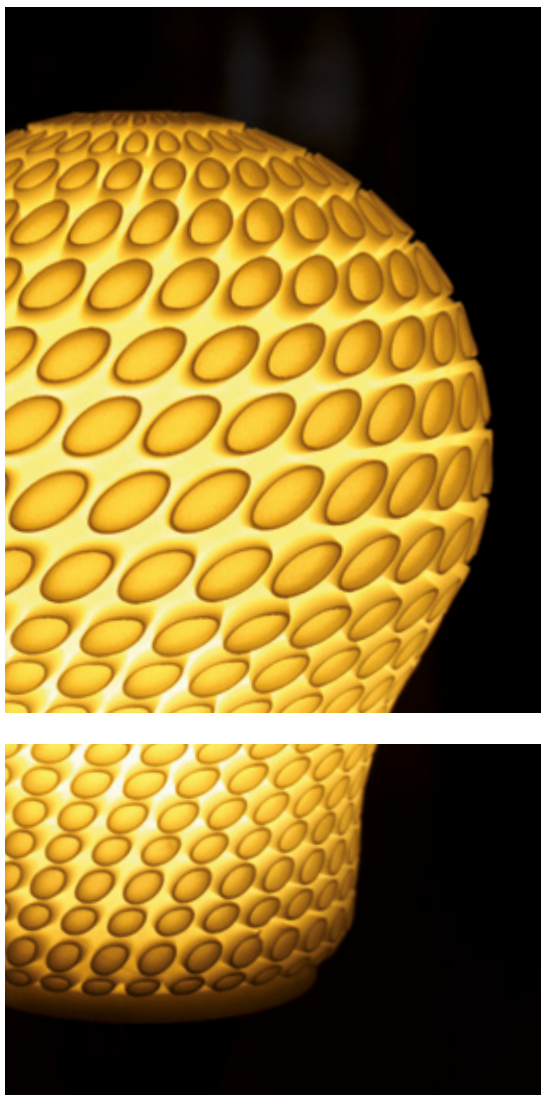
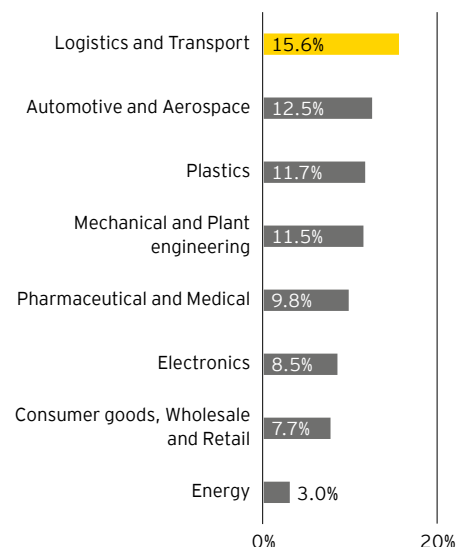


Chart 30

Industries that expect reduced inventories and lower logistics and transportation costs in the next five years with 3DP (%)*



*N=900 companies, EY global 3DP study, April 2016

3. From optimization to reinvention – how 3DP can benefit business

Logistics companies have the unique opportunity to offer both 3DP services and shipping. If they exploit this opportunity, it will give them a clear advantage over current 3DP service providers. In the future, competition will increase in the industries traditionally served by manufacturing companies with complex supply chains. The automotive industry, for example, with its slim margins, may be particularly attracted to cheaper suppliers close to their customers.

The impact that the combination of product with delivery could have and the need for transportation companies to rethink their business model because of this, was demonstrated by Deutsche Post's dramatic reduction in transport volumes in Munich.

This decline was caused by an Amazon pilot project in the city, involving the retailer managing its own deliveries with several subcontractors⁶⁴. Other postal services and transport companies around the globe have made provision for such aggressive strategies. La Poste⁶⁵ in France, the British Royal Mail⁶⁶, UPS⁶⁷, TNT⁶⁸ and many more have started to consider offering 3D printing, either in-house or in cooperation with systems manufacturers and service providers. In 2015 UPS, for example, teamed up with the service provider Fast Radius to provide customers with same-day delivery of 3D printing orders⁶⁹.

Case study: UPS embraces 3DP to stay competitive

UPS has adapted its business model and formed new partnerships to harness the potential of 3DP, as the global logistics industry experiences stagnating transport rates. In 2015, a combination of over-capacity and declining volumes in sea freight caused sector underutilization. The air cargo industry was also faced with a glut of capacity, as new wide-body airplanes entered the market. To manage such changes

logistics and transport companies need to position themselves strategically along new logistic chains. UPS, for one, has developed several approaches. It now works as a 3DP service provider, cooperates with other providers and has positioned its own or partner facilities at logistic key points.

Picture 10

UPS airport with Fast Radius (Former CloudDDM) containers



Source: Fast Radius

The company:

- ▶ Has teamed up with service provider Fast Radius to provide customers with same-day delivery of 3DP orders⁷⁰. UPS integrated the 100-3DP machines facility into its "world port" airport in Louisville, Kentucky
- ▶ Is offering a 3DP service with its own systems in more than 60 stores in the US⁷¹
- ▶ Cooperates with German software provider SAP to manage its 3DP services⁷². According to UPS, the service will go beyond novelty items and prototyping to aim at cost-effective series production and fast parts delivery
- ▶ Has partnered with service provider Materialise⁷³. UPS' logistics software is connected to Materialise's to ensure that all parts the service provider 3D prints reach the customer on time and in full

3.2.4.3 How 3DP will affect wholesale and retail

Wholesale and retail companies are under growing pressure from the new business models and growth strategies of competitors and disruptors. 3DP is not unknown in the industry: 18% of surveyed wholesalers and retailers have already gained experience of the technology, while another 8% are considering its application. Office supply retailer Staples⁷⁴, for instance, is introducing 3DP - as part of a range of new products and services - to help stay competitive in the face of changing workplace behavior and online competition.

Moreover, e-commerce has transformed the consumer goods and retail industries. It is an essential distribution channel, due to the surge in online consumption. It also goes hand in hand

with omni-channel growth strategies that enable companies to reach their clients via multiple, interconnected channels. Such strategies often lead to higher vertical integration and, as online retail has shown, to the shift of shipping costs on to those clients who want faster delivery. If same-day delivery is not to prove prohibitively expensive, products must be close to the customer. Having products in a digital warehouse and printing them when needed, close to customers, is the winning combination. 3D printing enables companies to adjust their strategies in line with the new competitive realities. Amazon, for instance, is constantly looking for new methods for handling its last-mile logistics, including drones⁷⁵ and trucks with 3D printers on board that build parts as they are being delivered⁷⁶. Additive manufacturing will undoubtedly stay on the executive agenda: 17% of wholesale and retail companies surveyed expect to gain a competitive advantage by using 3DP within five years.

Conclusion

3DP is already having a significant impact on almost every industry, with inevitable knock-on effects between different sectors. Manufacturing companies are mainly experiencing changes around internal logistics, like handling and storage, while they strive to remain competitive by offering greater flexibility and more reliable delivery. On the other hand, logistics and transportation companies can benefit too. 3DP allows them to develop new business models, such as partnerships with additive manufacturing service providers, and more cost-effective delivery. What is more, all other industries can learn from these practices and adopt similar or new models to stay competitive. The example of Amazon's approaches for its last-mile logistics shows that companies need to think out of the box and use the full potential of 3DP.



3. From optimization to reinvention – how 3DP can benefit business

3.2.5 3DP for superior and flexible after-market performance

In a globalized world, where customers can source goods from almost anywhere, profit margins are under constant pressure. Companies in a huge range of industries – including machinery, automotive, consumer goods, aviation, mining, power and utilities, oil and gas, and medical technology – face tough competition from global rivals.

One way to meet this challenge is to provide customers with excellent after-market service, including spare part provision, throughout the lifecycle of products and services.

This focus can help increase margins: the after-sales market promises much better margins than that for primary products. In automotive after-market, for example, a 30% margin can be achieved on spare parts⁷⁷; in the machinery industry, margins on spare parts and service can be as high as 56%⁷⁸.

Furthermore, after-sales activity can help set a company apart from competitors. If a business provides effective after-sales and spare part support, it can help convince customers of the value of its product – as it can be repaired and used for longer.

In some cases, there is even a regulatory obligation to offer spare parts for a significant period of time – making after-market activity a necessity.

There are, therefore, many potential opportunities from delivering after-sales support effectively – but making it work can be complex and challenging.

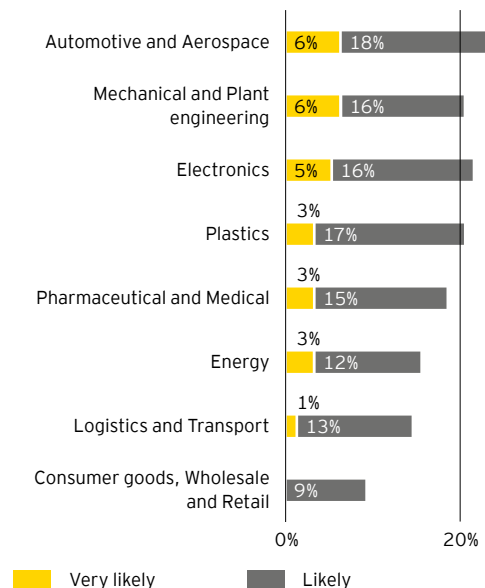
How 3DP addresses after-sales challenges

When delivering after-market services, a rapid response is vital. If a product fails, customers expect spare parts and service quickly, on site. To meet these expectations, businesses need to keep an inventory of spare parts close to the customer – or at least the relevant tools and dies, along with free production capacity. This can be expensive, which is why many companies are considering alternative approaches based on 3DP.

Our global survey shows that this topic is on many companies' agenda. Generally, in total 18% of all surveyed companies think that use of 3DP for spare parts is likely or very likely within 5 years. In total, 24% of aerospace and automotive companies think it is likely or very likely that they will use 3DP for spare parts in the next five years – as do 22% of companies in machinery and plant engineering, for many of which after-market is a crucial part of their business, representing a significant revenue source.

Chart 31

Likelihood that company will use 3DP for spare parts (after-sales) within the next five years (%)^{*}

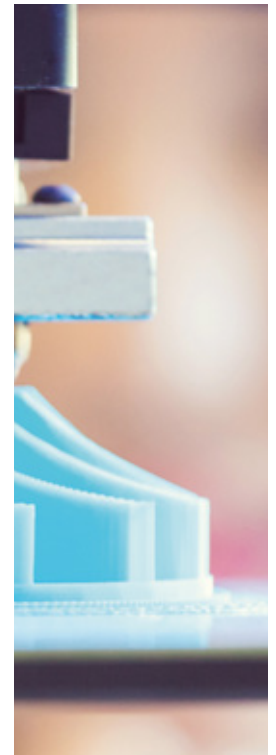
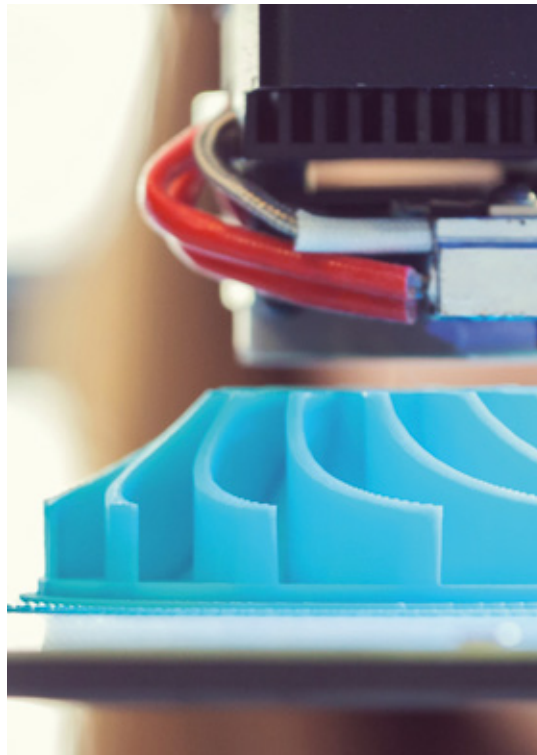


^{*}N=900 companies, EY global 3DP/AM study, April 2016

All these industries share three main challenges:

- ▶ **High numbers of components.** Many contemporary products consist of thousands of parts, often produced by many different suppliers over several supply chain stages. For example, compact cars consist of over 25,000 parts, more than 70% of which are not produced by the original equipment manufacturer itself⁷⁹. So it can be difficult to manage and ensure spare part availability along the supply chain over the lifecycle of a product.
- ▶ **Product variety.** The variety of products has increased significantly as a result of rising customization, resulting in lower average lot sizes. Innovation cycles have also shortened substantially, even as the average lifespan of products has increased. We expect these trends to continue.
- ▶ **Regulatory obligation and costs.** In some cases, there is a regulatory requirement to provide spare parts for a long time after the actual product sale. Generally speaking, the higher the value of a product, the longer spare parts have to be provided. Airbus, for example, stocks a broad variety of spare parts for each aircraft type sold as long as there are five in service somewhere in the world. This leads to a massive stock inventory⁸⁰. In such cases, some spare parts may never even be needed and, when they become obsolete, are expensive to dispose of. So, besides the obvious charges attached to after-sales activities - such as storage, handling, shipping and tied-up working capital - there are other costs that are more difficult to quantify, such as the risk of obsolescence of spare parts in stock. Even so, these costs need to be balanced against the potential loss of after-sales business or goodwill that can result from items being out of stock - as this could lead to warranty claims, or allow a competitor to differentiate itself by keeping more after-sales stock.

3DP offers an ideal way to address these challenges. For example, the technology enables companies to redesign complex, multi-part components and print them as one part - reducing complexity and overcoming glitches in the supply chain that could affect after-sales support. Because spare parts exist as digital information, companies can also consider having a "cloud-based warehouse" - making parts available for 3D printing, near to the customer, without needing them to be produced and stored at several stages of the supply chain.



3. From optimization to reinvention – how 3DP can benefit business

3DP also makes it possible to produce low volumes of sophisticated spare parts on demand. But while most metal parts can be 3D-printed, how will 3D-printed spare parts revolutionize the industry?

Additive manufacturing boosts customer satisfaction by its capacity for low volumes. For example, truck and bus manufacturer MAN is experimenting with 3DP spare parts for low-run items, which could reduce the lead time for spare part delivery from two to three weeks to just one⁸³. If a company can produce low-volume parts on demand, it does not have to keep all potential spare parts in stock at local warehouses near the customer, as it can produce parts when and where they are needed. This enables a business to create a supply of parts for its product throughout its useful life, without having to worry about disposal

of obsolete parts. And by extending the time over which parts are available, it can offer a broader variety of even rarely-used spare parts that it might not currently keep in stock.

New after-sales business models

Additive manufacturing also creates new business models in after-sales. For example, companies have the opportunity to outsource their after-sales services, or to create different supply chains for them. The technology could enable new after-sales service providers to enter the market, such as for example, digital spare parts company Kazzata⁸⁴. Its value proposition is to deliver spare parts to customers quickly, by printing them locally via a proposed worldwide network of 3DP facilities and a cloud-based digital warehouse.

For Siemens, 3DP means 90% shorter lead times for industrial repairs

Replacing burner tips for Siemens' industrial gas turbines is traditionally a time-consuming and cost-intensive process. When a burner tip wears out, the turbine can be down for up to nine months – and spare burner tips are expensive too.

But at a new 3DP center in Sweden, Siemens is using 3DP to reduce the time to market for replacement burner tips, keeping turbines in use longer – while improving burner tip design in the process.

Siemens achieves this by removing the worn-out burner tip, 3D-printing the missing part, and then welding it back on to the burner. This reduces the lead time to a repair by as much as 90% – from 44 weeks down to 4 weeks. As a result, the turbines can be connected quicker to the grid⁸¹ faster.

The 3DP approach also makes it possible to change the geometry of the burner tip at each repair, optimizing the performance of the turbine. Depending on the gas used, this can mean up to 60% less fuel consumption and 50% lower gas emissions⁸² when turbines are in use.

Siemens, meanwhile, does not need to keep expensive burner tips in stock, but produces them on demand near to its customers.

Picture 11

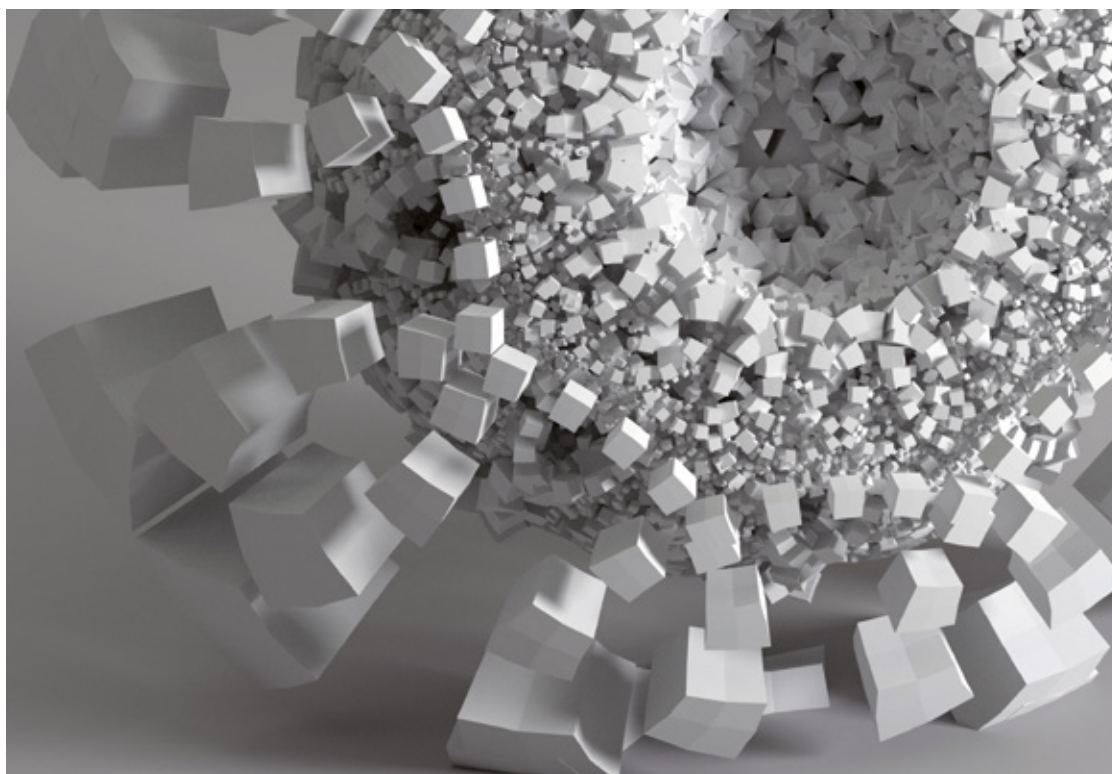
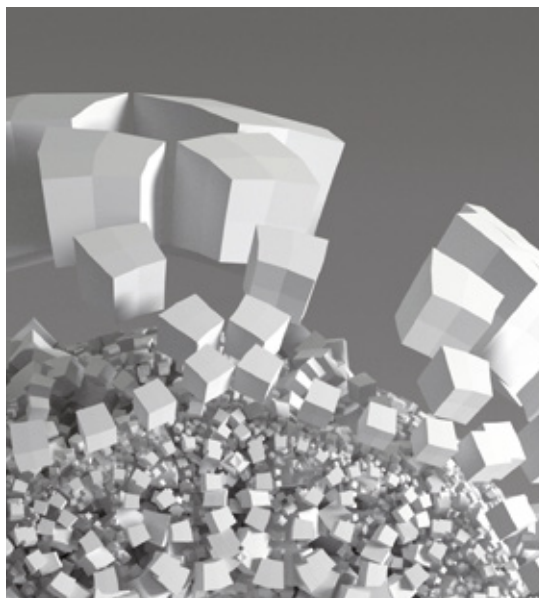
Customized EOS system for refurbishments



Source: Siemens; EOS

Machinery company Caterpillar provides another example of how 3DP can enable an efficient after-market approach. Faced with a need for a fuel filter base - a metal spare part that had previously been manufactured through casting - the company simply 3D-printed it instead, without making design changes⁸⁵, which allowed the minimum order numbers to be reduced.

For a manufacturing company, moving from providing manuals and diagnostics online to delivering the digital information to print spare parts does not seem too great a step. It would even be possible for a company to form an alliance with a 3DP service provider or system manufacturer, set up a digital warehouse, and consolidate spare part production data for its supply chain network.



4. 3DP: Trends, developments and challenges



Ever since additive manufacturing emerged roughly three decades ago, research facilities and industrial companies have been driving its development. The first applications were dedicated to prototyping but now, with seven main sub-technologies available (see section 2.2), 3DP has proved mature enough for manufacturing purposes. This move toward direct manufacturing was the key step which accelerated the technology's development.

The additive manufacturing sector which has now established itself specializes more and more in series production-grade 3D printing. Systems manufacturers, material suppliers, software developers, 3D scanning/reverse engineering companies, 3DP service providers and consulting companies all offer products and services to industrial clients and, on a smaller scale, to private consumers.

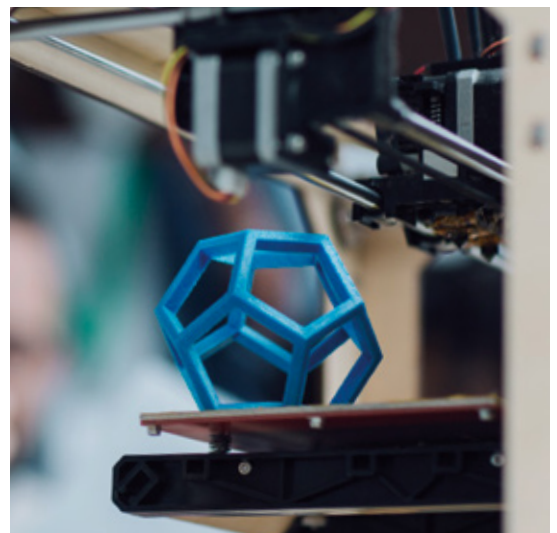
The largest market share belongs to systems manufacturers like Stratasys, 3D Systems and EOS. These three companies account for about 70%⁸⁶ of the total 3DP systems market. Whereas Stratasys and 3D Systems specialize mostly in polymer printing, EOS offers polymer and metal systems, with the latter technology experiencing substantial growth in the past four years due to its industrial relevance. As discussed in previous sections, companies on the demand side see an increased need for fast, reliable and cost-effective metal printing solutions; it will be interesting to see how this shapes the further development of the industry.

With its high number of different players, the industry structure can seem to reflect the variety present in the technologies and materials. But when considered in terms of market share, the picture narrows. Most 3DP companies belong to industrial investors in the same sector, as our M&A analysis shows (section 4.2). Moreover, M&A activities have been declining since 2013. Such facts indicate that the market is consolidating more and more.

However, many start-ups, in all the above-mentioned areas, have entered the market over the last few years, offering new sub-technologies, materials

and software. Big non-3DP specialists, such as Adobe, Autodesk, Dassault Systemes SA, DMG Mori AG (formerly Gildemeister AG), Hexagon AG and Konika Minolta may also be interested in investing in the sector⁸⁷. HP's entry into the market, as a major player offering new technology, services and solutions, could also revolutionize the sector. Which begs the question: could Xerox and other competitors follow?

Historically, 3DP systems and related services have caused a steep increase in additive manufacturing's market volume, with a yearly growth rate of 28% from 2011 to 2015⁸⁸. The latest developments show that, although the industry is still growing, the revenues and margins of systems manufacturers are declining. Meanwhile, revenues are rising for service providers, whose main business consists of delivering ready-to-use prototypes and products, as well as engineering and 3DP consulting services. The relatively high price of industrial 3DP systems is the main reason why companies have used external providers rather than acquiring own 3D printing systems. Another advantage of using external service providers is that it allows clients to use different manufacturing technologies, while saving substantial capital expenditure on machines and materials. This picture could alter rapidly if systems prices change over the next year.

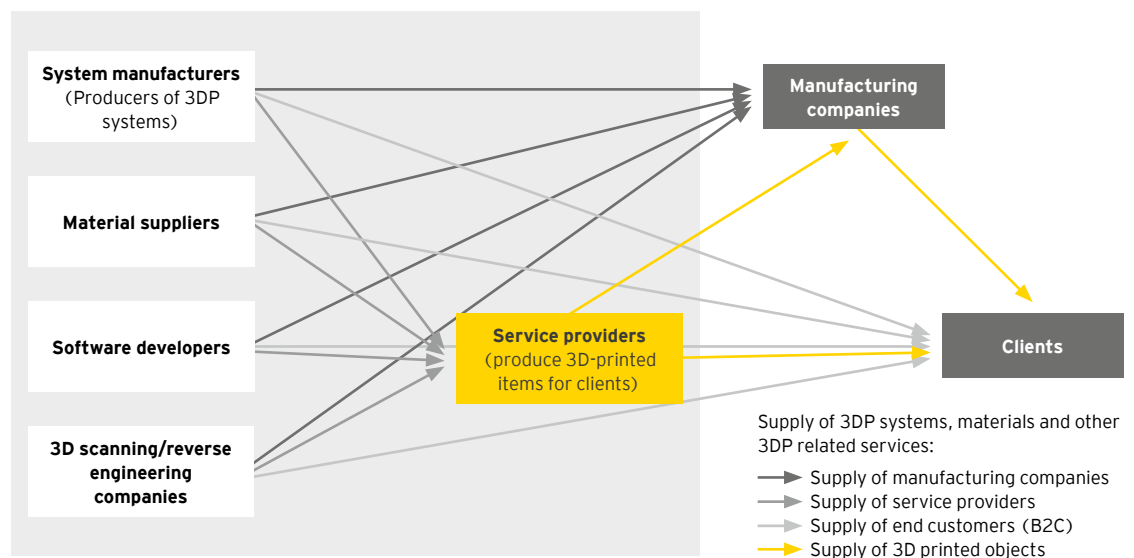


4.1 What does the 3DP industry look like?

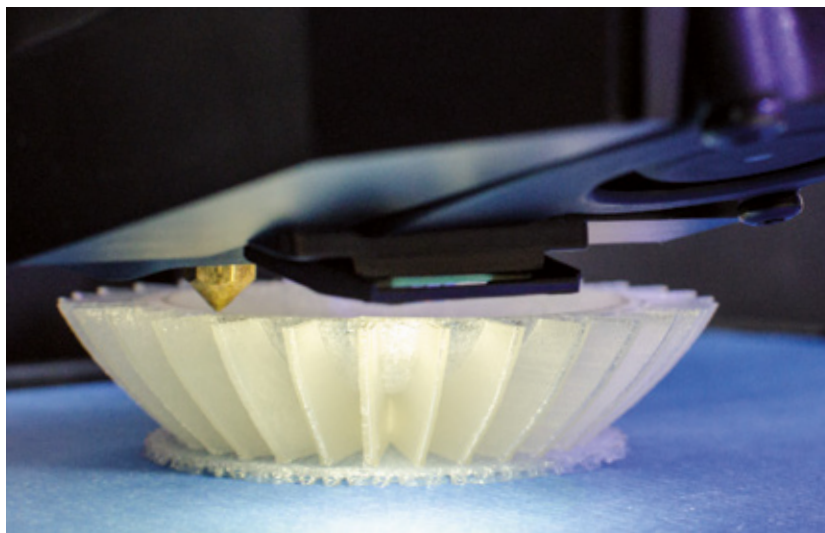
The fast-growing 3DP industry is divided into two sides: clients and suppliers. Suppliers include systems manufacturers, material suppliers, software developers and 3D scanning/reverse

engineering companies. Clients range from industrial manufacturing companies to private individuals.

Figure 7
Overview of the 3DP value chain



Source: EY



Systems manufacturers

3DP systems manufacturers develop systems and (sub-) technologies for the additive manufacturing market. They represent the largest group of players, with the highest supplier market share. The most important systems manufacturers include Stratasys, 3D Systems, EOS, Concept Laser, SLM Solutions, ExOne and Ultimaker. Such companies usually offer related software, materials, engineering, consulting and other services.

Systems manufacturers establish business-to-business relations with other suppliers, which can include systems, materials and consulting services too. Many systems manufacturers cooperate with partners to offer individual solutions, such as customized systems or software.

4. 3DP: Trends, developments and challenges

The sector also offers systems for clients - mostly professional systems for manufacturing companies, which are their largest customers, but also smaller desktop systems for private users.

Material suppliers

Material suppliers develop and produce materials for 3DP. They usually have knowledge of materials science, heat treatment and sintering processes. Their products range from polymers to metals. While polymer products usually consist of filaments, metal products can be made of powders or wires.

While there is a large base of private users that require filaments for desktop systems, the more complex and expensive products are metal powders for service providers and manufacturing companies. As 3DP is applied to more industrial uses, the potential for high-tech metal materials increases.

Software developers

3DP software suppliers are large traditional software companies, alongside some specialist 3DP service providers.

Siemens, for instance, extended its PLM NX software to include an NX Hybrid manufacturing module for 3DP hybrid manufacturing technologies⁸⁹; and HP's new 3DP systems will be driven by Siemens additive manufacturing software⁹⁰. Other players such as Autodesk⁹¹,

Dassault Systèmes⁹² and Adobe⁹³ have also entered the market, and 3DP service providers such as Materialise⁹⁴ also offer solutions.

Software developers mostly serve systems manufacturers and service providers. Nevertheless, some 3D design and PLM solutions are for the industrial client sector too.

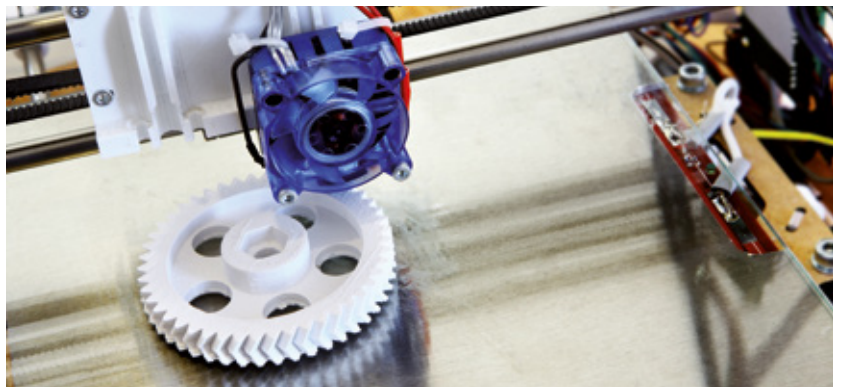
3D scanning/reverse engineering companies

The small group of reverse engineering/3D scanning companies create 3DP designs from existing structures or products, for example in the architecture, automotive or mechanical engineering industries. The service is used mainly for testing or verification purposes, whether for industrial companies or smaller private-user applications.

Many systems manufacturers offer their own solutions; some dedicated and established companies existed prior to the development of 3DP.

Service providers

3DP service providers represent the group of companies that deliver ready-to-use 3D printed prototypes and products, as well as engineering and 3DP consulting. They belong to the next stage of the value chain, since they are both clients of the previously mentioned suppliers and also supply industrial companies or other clients.



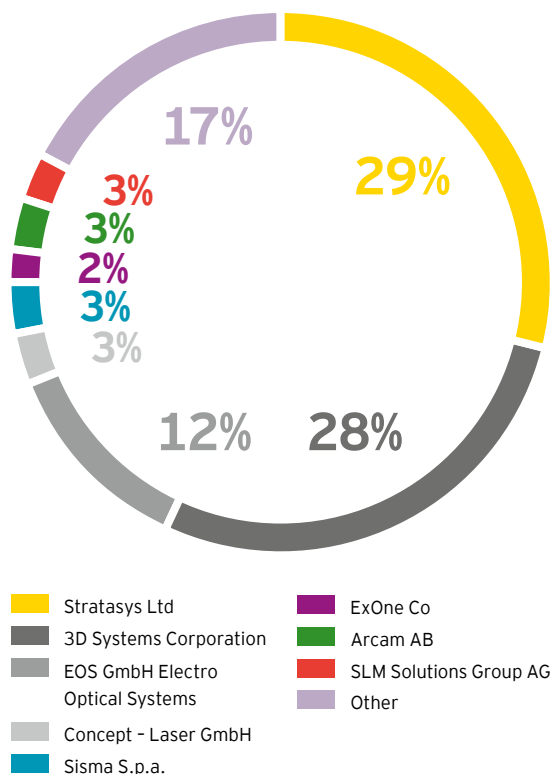
4.1.1 Market share

As a result of acquisitions and partnerships, the 3DP sector has reached a level of consolidation among both systems manufacturers and service providers. This process is ongoing.

Although the number of players is high, just a few companies account for much of the market. In 3DP systems, Stratasys, 3D Systems and EOS accounted for about 70% of market share in 2015⁹⁵. Similarly, the market for service providers is led by two players: Materialise⁹⁶ and Proto Labs (for which 3DP accounts for around 10% of revenue). Nevertheless, the service providers market is characterized by a high number of small service providers and start-ups.

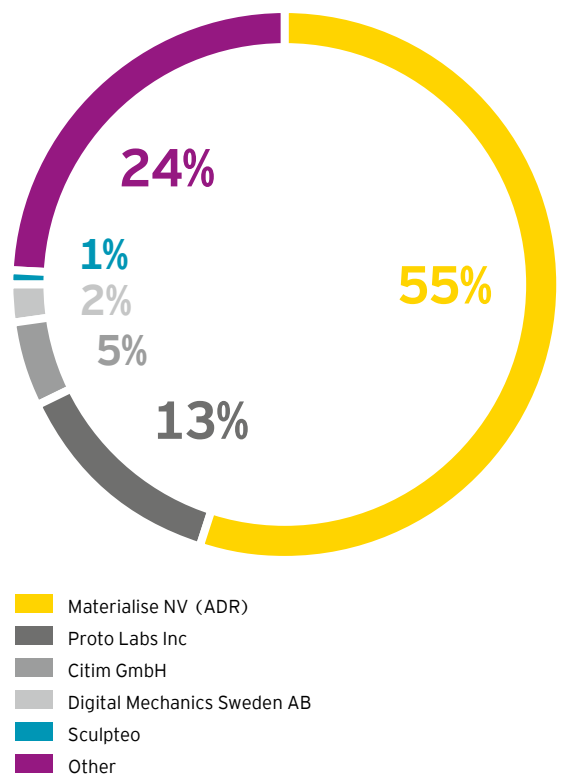
In 2015, systems manufacturers accounted for about 55% of the total 3DP market, while service providers represented about 25%. However, most 3DP systems manufacturers have recognized the potential of 3DP services and are offering these too, accounting for 20% to 30% of their total revenues. Stratasys and 3D Systems, for example, have recently acquired 3DP service providers to broaden their portfolios: in 2014, Stratasys acquired Solid Concepts and 3D Systems acquired Medical Modeling. The effect of these acquisitions was not taken into consideration in the study, as entire company revenues were allocated to the companies' primary fields of business.

Chart 32
Market share of 3DP system manufacturers based on sales, FY15



Source: EY

Chart 33
Market share of 3DP service providers based on sales, FY15



Source: EY

4. 3DP: Trends, developments and challenges

4.2 M&A analysis

Since the wave of consolidation mentioned above, M&A activity has fallen in the industry. In terms of transaction volumes, 3DP M&As show a clear decline over the past two years (down 12% from 2013 to 2015). In each of the years from 2013 to 2015, most acquisitions were made by industrial investors - that is, other direct competitors or new 3DP market entrants.

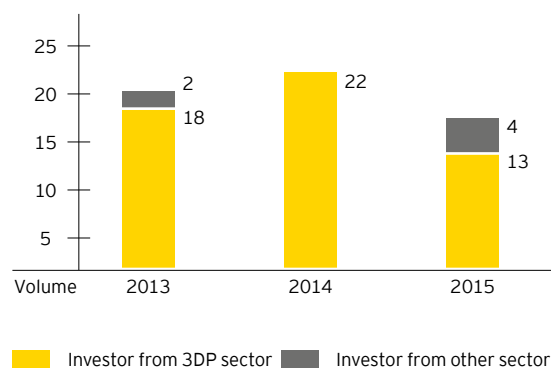
In 2015, more than 76% of industrial investors were already in the 3DP business, reflecting the strong consolidation pressure in the market. Large players, especially, made a high number of add-on acquisitions: Stratasys made 10 acquisitions from 2013 to 2015, while 3D Systems made 22 over the same period.

Most financial investors in the 3DP industry are venture capital funds which focus on new start-ups. In 2015 more than 42% of the financial investors were providers of venture capital, followed by other investors such as family offices and pension funds. Private equity funds accounted for only 14% of all financial investor transactions in 3DP; this

very low share could be due to the absence of relevant targets, as they are either too small (covered by venture capital providers) or too expensive due to the interest of strategic industrial investors.

Chart 35

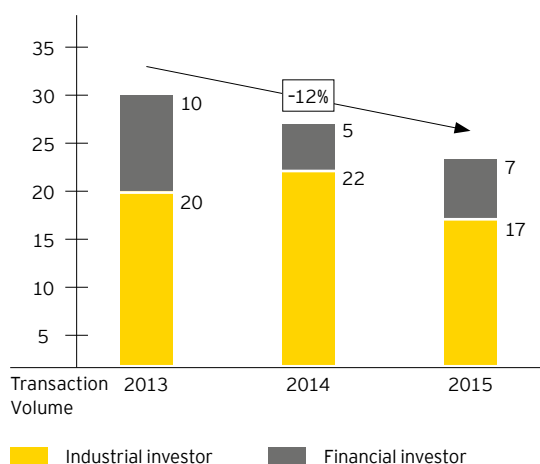
Types of industrial investors in 3DP-related transactions



Source: EY

Chart 34

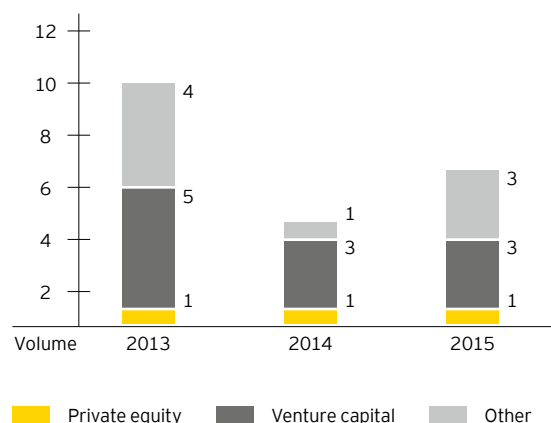
Volume of 3DP-related transactions



Source: EY

Chart 36

Types of financial investors in 3DP-related transactions



Source: EY⁹⁷

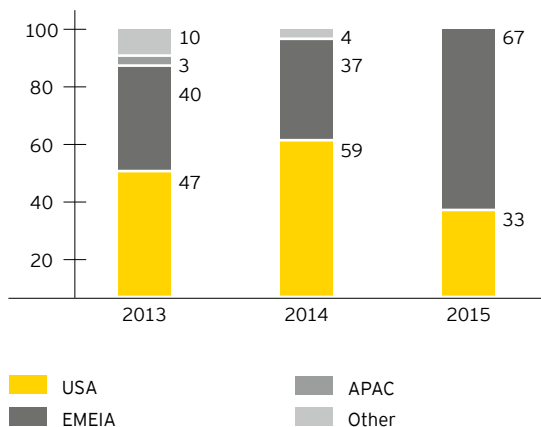
Geographical spread of M&As

Recent M&A transactions were mainly concentrated on Europe and the US. Indeed, the fall in the total number of transactions (chart 37) was mainly caused by a smaller number of transactions in the US. By contrast, the number of transactions in Europe, the Middle East, India and Africa (EMEIA) increased slightly which could indicate that European competitors are offering interesting product portfolios and technologies that could suit the add-on strategies of established companies.

Perhaps surprisingly, Asia Pacific (APAC) still shows low levels of M&A activity in 3DP. This could be because this kind of manufacturing technology is not yet fully established in the region. But it does mean that there are great opportunities for additional growth. China, in particular, is supporting the development of the domestic 3DP industry via various initiatives; its National Additive Manufacturing Industry Promotion Plan aims to establish two or three internationally competitive companies by 2016.

Chart 37

Geographic background of target companies in 3DP-related transactions (based on number of transactions)

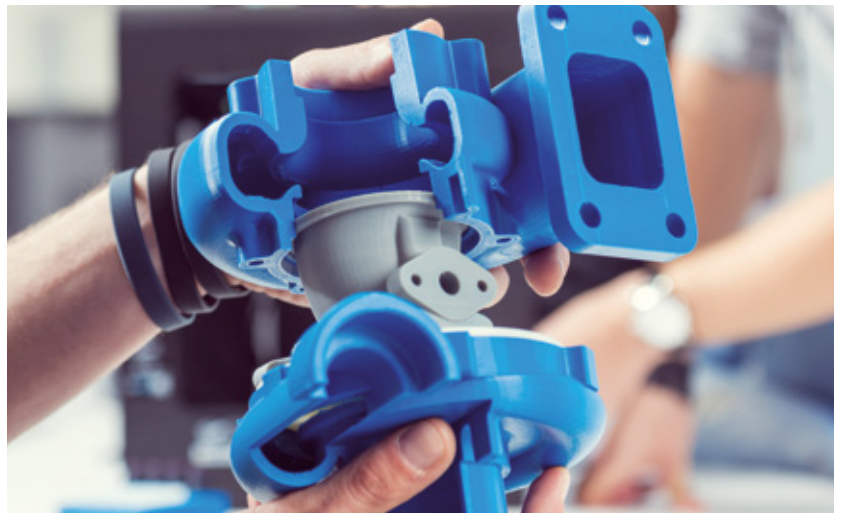


Source: EY

We believe the consolidation trend will continue, as large systems manufacturers adopt new technologies by acquiring smaller, specialized players. This development will probably intensify following the rebound in 3D printer demand that is expected in 2016.⁹⁸

New technologies and applications could also lead to as yet unknown disruptive impacts. For example, a reduction in 3DP production times, along with the design of new products, may expand the application range of additive manufacturing products.

Global technology firms could also disrupt the 3DP industry by entering the market. The arrival of HP, for example, was eagerly anticipated, as the company has pledged to introduce a superior technology and has the resources and R&D capabilities to pursue an aggressive entry strategy. This could help bring the 3DP industry to a new level of maturity, resulting in additional M&A activity. For example, there are market rumors that HP plans to buy Stratasys. Such a deal could provide opportunities for HP, as Stratasys has the established sales and distribution network that it currently lacks.⁹⁹



4. 3DP: Trends, developments and challenges

4.3 Development of the industry

Demand for 3DP systems and related services has sparked a steep increase in additive manufacturing market volumes, from US\$1.5b in 2011 to US\$4.2b in 2015, an annual growth rate of 28%¹⁰⁰.

However, figures show a recent decline in year-on-year revenue growth for large 3DP systems manufacturers. Stratasys' revenues fell by 7.22% between 2014 and 2015, while 3D Systems' revenues grew by just 2.53%. In the same period, pure 3DP service providers still showed high growth rates: these include Proto Labs, increasing 3DP revenue by 168%¹⁰¹, and Materialise, up by 25%, as well as relatively small 3DP system manufacturers such as Voxeljet, growing by 48%, and Arcam, rising by 70%.

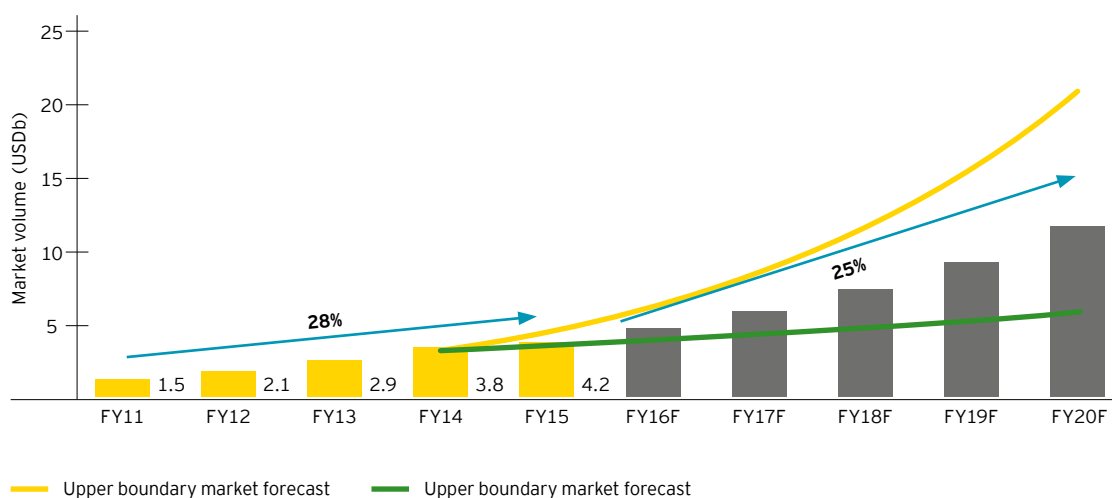
One reason for the strong ongoing growth of the smaller players could be their focus on metal-based 3DP technologies. This technology is gaining market share, contributing to the high growth rates of manufacturers. Besides Arcam, other metal systems manufacturers, such as EOS, SLM Solutions, and Concept Laser, also benefit from the growing demand for metal-based 3DP systems.

They recorded remarkable growth in the last year: EOS grew by 53%, SLM Solutions by 97% and Concept Laser by 54%.

Furthermore, the establishment of 3DP within the manufacturing industry has resulted in high revenues for service providers, as their main business consists of delivering ready-to-use prototypes and products as well as 3DP engineering and consulting services. (The biggest advantage of using external service providers is that it allows clients to use different manufacturing technologies, as well as to save on capital expenditure for machines and materials.)

We expect that the impressive annual growth of 28% over the past four years will continue, and estimate that the 3DP market will grow by about 25% annually until 2020 - resulting in a total market value that year of US\$12.1b. This estimate takes into account historical data and analyst consensus reports, as well as the different types of company and varying maturity levels within the industry. For example, the more mature players in the systems manufacturing market, such as

Chart 38
3DP market



Source: EY¹⁰²

Stratasys and 3D Systems, are expected to grow at a lower level; younger entrants, on the other hand, are likely to continue growing at their historical rate as they will gain customers by introducing new technologies. Service providers are also expected to grow at a lower level, as these businesses have become mature.

Based on the 2015 financial year performance, other market studies for the 3DP industry show widely different annual growth rates and overall market sizes. They range from approximately 10% growth from 2014 to 2018, which represents an overall market value of US\$5b in 2018 (shown as the lower boundary in the graph), to a 34% yearly growth rate, accounting for an overall market value of more than US\$20b in 2019 (shown as the upper boundary in the graph). However, it is important to consider that the underlying data might not be identical as some forecasts use slightly different selection criteria.

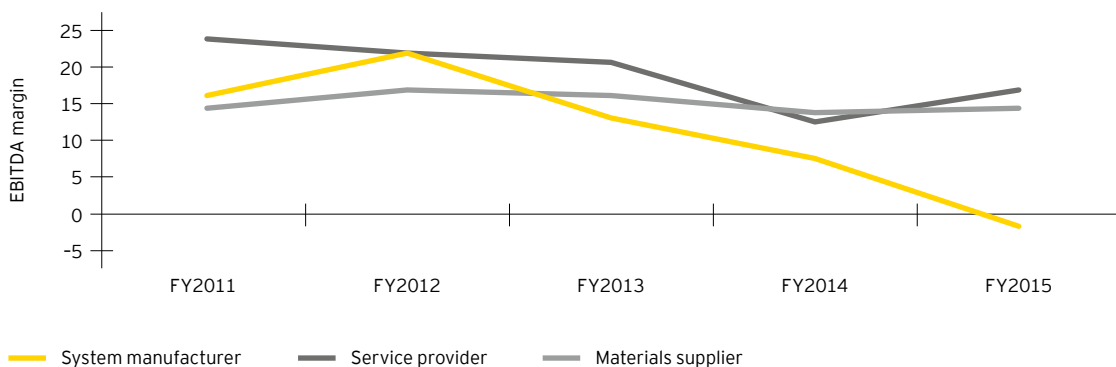
The historically strong rise in 3DP industry revenues has not been accompanied by higher profitability across the whole sector. In the 2015 financial year, the average earnings before interest, taxes, depreciation and amortization (EBITDA) margin for system manufacturers was -2%, compared to 14% for materials suppliers and 17% for service providers.

The average margin for system manufacturers declined from 2012 to 2015. There may be two key reasons for this:

- ▶ The ratio of consumer business for the larger systems manufacturers increased, leading to lower margins
- ▶ Increasing market saturation may have forced systems manufacturers to reduce prices, while overheads remained at the same level
- ▶ As suggested above, large systems manufacturers suffered particularly in the 2015 financial year
- ▶ There has been a slight increase in margin for materials suppliers. This could reflect two different developments:
 - ▶ A drop in the oil price in October 2014 lowered the cost of raw materials, temporarily improving the average EBITDA margin (before price adjustments took effect)

The introduction of new technologies could have increased demand for higher margin products, such as metal powder, as reflected in the development of the service provider margin.

Chart 39
Average EBITDA margin, 2011 to 2015 financial years



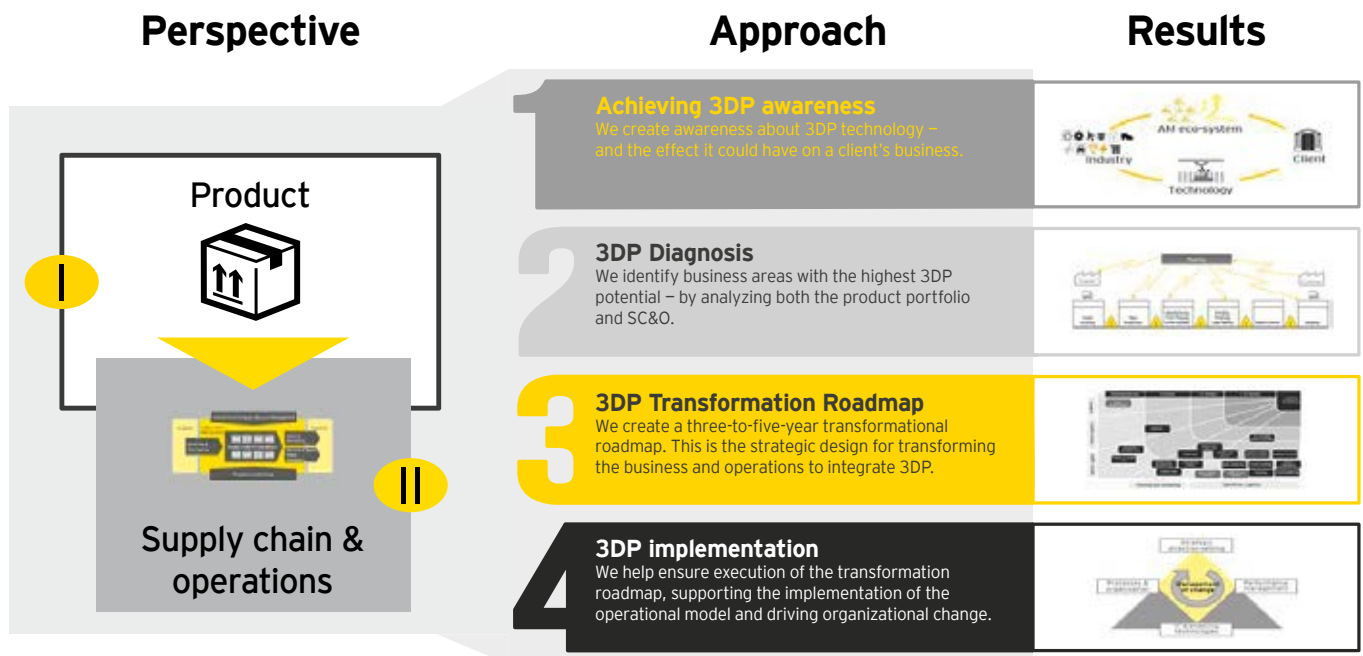
Source: EY



Companies with no experience of 3DP often struggle to understand whether, and how, they can benefit from the technology. Businesses that have gained their first experiences, meanwhile, are often looking for ways to unlock the potential of 3DP for their entire organization.

While there is no single proven approach, we have observed that the most efficient strategies focus on adding value to customers through 3DP and on improving operations.

Figure 8
EY's 4-phase approach to 3DP



Source: EY

5. How EY supports companies on their 3DP journey



Our approach is based on two elements:

- ▶ **Product design** – considering how functionally integrated products, new product geometries or customized and personalized features can deliver added value for customers
- ▶ **Supply chain and operations** – from specific, targeted improvements to bringing a new level of efficiency to the company throughout the 3DP value chain

EY supports companies in identifying the business impacts and benefits that 3DP can bring. We accompany and support our clients on their 3DP journey, based on a four-phase approach:

1. Creating organizational awareness around 3D printing. In this first phase, we raise the level of our clients' awareness, especially those unfamiliar with the latest state-of-the-art technology. Our aim is to enable companies to work with us to together identify 3DP potential.

2. Performing a 3DP diagnosis. During the second phase, we identify where to apply 3DP, finding use cases which will bring the highest added value.

Analysis is the starting point of a diagnosis: it enables us to achieve a common understanding about a company's strategy, business models, product portfolio and efficiency challenges in supply chain and operations (SC&O). By understanding the product portfolio and core competences, we help to define which 3DP product redesigns will bring the highest added value for clients. As part of our operational excellence analysis, we identify areas with the highest current losses and the greatest optimization potential.

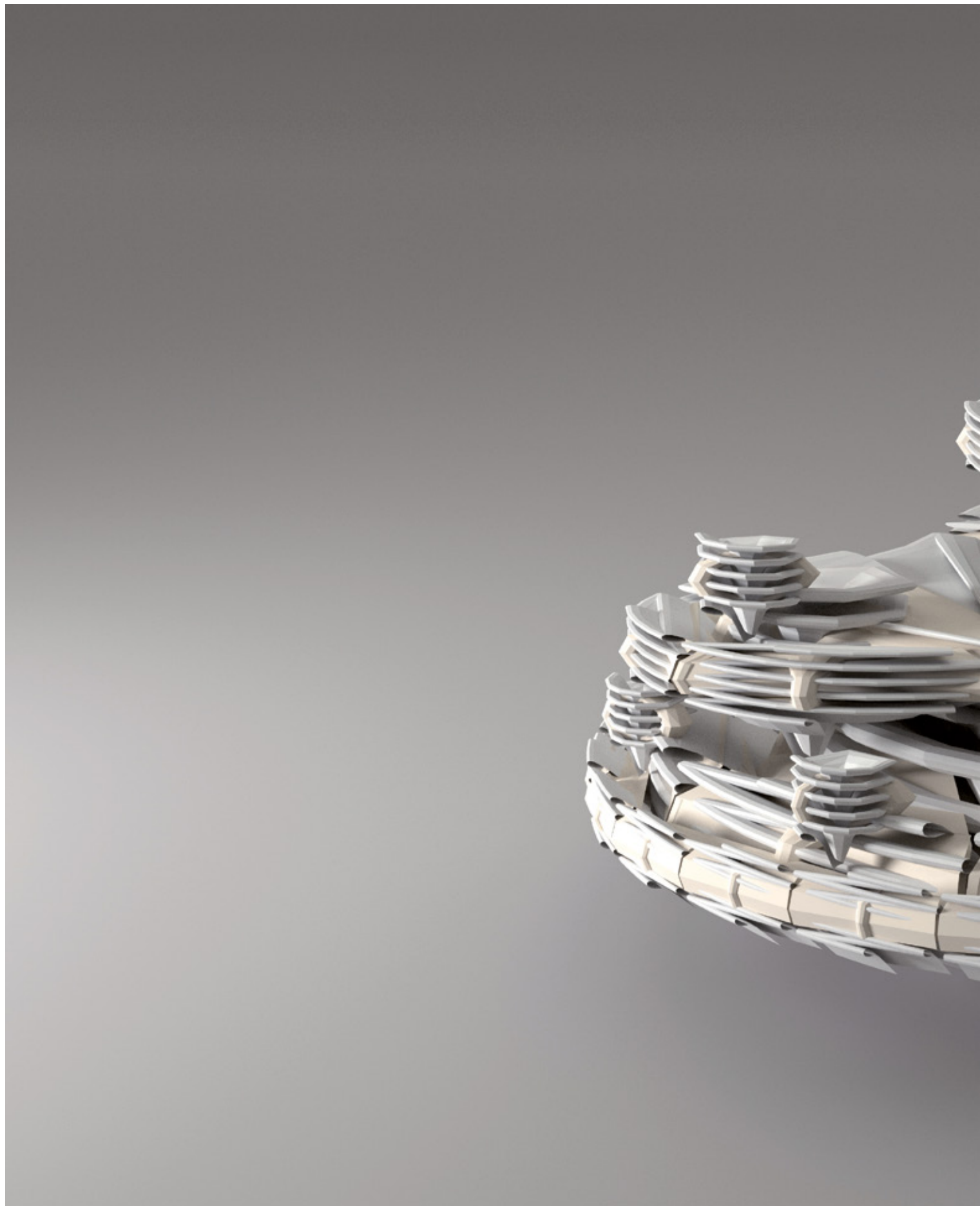
Based on a company's current operational performance and its vision for future development – and with the help of an

advanced "3DP analytics tool" – we select the relevant product groups and operational areas on which to focus. By analyzing printability and added value, we then "cluster" the relevant product groups that can benefit from redesigning with 3DP. We estimate the impact of various 3DP applications and calculate the business case for areas with the highest potential. This quantification of impact is particularly important. It can help to both justify the comparatively high investment and demonstrate the impact the technology will have on the customer and value chain.

3. Developing a transformation roadmap. In the third phase, we consolidate, prioritize, and build a three-to-five-year transformational roadmap. This roadmap provides the strategic and business design needed to transform business and operations to enable successful integration of 3DP. It highlights areas where the company intends to apply additive manufacturing, based on potential business impact.

Within the business design, the plan will define the operating model to help ensure the roadmap is implemented successfully. This model includes recommendations on partners and providers, required capabilities, and organizational design. Since achieving success with the appropriate operational model may require non-organic growth, we will consult with clients about potential mergers, acquisitions or the founding of joint ventures.

4. Implementing the transformation roadmap. We support clients as they put 3DP into practice. We help to ensure execution of the transformation roadmap, support clients in implementing the operating model, and drive organizational change. We consult with clients on implementing the organization, systems and processes that will enable sustainable integration of 3DP.





Authors

**Dr Andreas Müller**

Partner, GSA Advisory
New Business Leader

Ernst & Young GmbH
Wirtschaftsprüfungsgesellschaft
Willy-Brandt-Platz 5
68161 Mannheim

Phone +49 160 939 18800
a.mueller@de.ey.com

**Stefana Karevska**

Manager, GSA Advisory
3D Printing Expert

Ernst & Young GmbH
Wirtschaftsprüfungsgesellschaft
Willy-Brandt-Platz 5
68161 Mannheim

Phone +49 172 707 9525
stefana.karevska@de.ey.com

Contributors



Dr Robert Wienken

Partner, GSA TAS
Private Equity Leader

Ernst & Young GmbH
Wirtschaftsprüfungsgesellschaft
Mergenthalerallee 3-5
65760 Eschborn/Frankfurt am Main

Phone +49 160 939 25367
robert.wienken@de.ey.com



Dr Christoph Kilger

Partner, GSA Advisory
SC&O and Industry 4.0 Leader

Ernst & Young GmbH
Wirtschaftsprüfungsgesellschaft
Heinrich-Böcking-Strasse 6-8
66121 Saarbrücken

Phone +49 160 939 18355
christoph.kilger@de.ey.com



Footnotes

- 1 Google Trends, search term "3D printing", as of 05-01-2016
- 2 Gartner Hype Cycle, www.gartner.com/technology/research/methodologies/hype-cycle.jsp, accessed 23 May, 2016
- 3 T. Kellner, "World's First Plant to Print Jet Engine Nozzles in Mass Production", GE Reports, 2014
- 4 T. Kellner, "Fit to print: New plant will assemble the world's first passenger engine with 3D printed fuel nozzles, next-gen materials", GE Reports, 2014
- 5 "Airbus produzierte über 1.000 Bauteile für den A350 im 3D-Druckverfahren" <http://www.stratasys.com/de/industrien/luft-und-raumfahrt-und-verteidigung/airbus>, Stratasys, accessed 01 June 2016
- 6 A35 XWB Family, <http://www.airbus.com/aircraftfamilies/passengeraircraft/a350xwbfamily/>, accessed 01 June 2016
- 7 "Renntechnik aus dem 3D-Drucker: BMW fertigt Wasserpumpenrad für DTM-Rennwagen in additivem Fertigungsverfahren", <https://www.press.bmwgroup.com/deutschland/article/detail/T0215062DE/renntechnik-aus-dem-3d-drucker:-bmw-fertigt-wasserpumpenrad-fuer-dtm-rennwagen-in-additivem-fertigungsverfahren?language=de>, press release, accessed 27 May 2016
- 8 "3D Systems Announces Grand Opening of State-of-the-Art Healthcare Technology Center", 3D Systems, 2016
- 9 "Company Overview of Aprelia Pharmaceuticals Company", Bloomberg, 2016
- 10 "Czech Tool Manufacturer Relies on Additive Manufacturing for Complex Customer Projects", 2014
- 11 "Tools from 3D Printer Make Car Manufacturing Easier at Opel", Opel, 2014
- 12 IHS Technology, "Asia investing heavily in 3D printing technology", IHS Technology, 2014
- 13 Lockheed Martin, "3-D Printing at Lockheed Martin", Lockheed Martin, 2015
- 14 A. Tilley, "How Carbon3D Plans To Transform The Way We Make Stuff", Forbes, accessed 27 May 2016
- 15 "Ford Is Now Using Carbon3D's CLIP 3D Printers With Astonishing Results While Researching New Materials", 3dprint.com, <https://3dprint.com/75738/ford-is-now-using-carbon3d-clip-3d-printers-with-astonishing-results-while-researching-new-materials/>, accessed 21 June 2016
- 16 "External Collaboration Program Announced to Accelerate Clinical Candidates", Business Wire, www.businesswire.com/news/home/20160107005646/en/Johnson-Johnson-Innovation-Janssen-Pharmaceuticals-Announce-Agreement, accessed 27 May 2016
- 17 E. Krassenstein, "Has This Australian Company Just One-Upped Carbon3D's Super Fast 3D Printer?" 3Dprint.com, <https://3dprint.com/53286/gizmo-3d-printers-fastest/>, accessed 27 May 2016
- 18 "Introducing the HP Jet Fusion 3D printing solution", HP website, <http://h20435.www2.hp.com/t5/The-Shapes-of-Things-To-Come-The-Introducing-the-HP-Jet-Fusion-3D-Printing-Solution/ba-p/296466>, accessed 27 May 2016
- 19 Ben Fox Rubin and Scott Stein, "HP dives into 3D printing with Multi Jet Fusion", CNET, <http://www.cnet.com/news/hp-unveils-multi-jet-fusion-3d-printing/>, accessed 27 May 2016
- 20 Trefis team, "Why Is HP Entering The 3D Printing Industry?" Forbes, www.forbes.com/sites/greatspeculations/2014/03/28/why-is-hp-entering-the-3d-printing-industry/, accessed 27 May 2016
- 21 Doris, "Shapeways stellt ersten HP Multi Jet Fusion 3D-Drucker in Fabrik auf", 3Druck.com, <https://3druck.com/lieferanten-haendler/shapeways-stellt-ersten-hp-multi-jet-fusion-3d-drucker-in-fabrik-auf-2045242/>, accessed 27 May 2016
- 22 Johannes, "Die HP Multi Jet Fusion 3D Drucker sind da!", 3Druck.com, <https://3druck.com/drucker-und-produkte/die-hp-multijet-fusion-3d-drucker-sind-da-3244851/>, accessed 27 May 2016
- 23 T. Wohlers, "History of Additive Manufacturing", Wohlers Report 2016, Wohlers Associates 2016
- 24 "Audi shows the future of toolmaking and additive manufacturing", Metal Additive Manufacturing, Vol. 1 No. 4, 2015
- 25 J. Holl, "The shape of things to come", Forum: All eyes on space, Airbus Group, p.23, Vol. 87, 2016
- 26 Doris, "Autodesk und Airbus stellen bislang grösstes 3D-gedrucktes Flugzeugkabinen-Bauteil her", 3Druck.com, 2016
- 27 "Airbus, John Meyer and 3D Printing, future of Manufacturing", Airbus Website <http://www.airbusgroup.com/int/en/story-overview/Innovators-3D-printing.html>, accessed 20 June 2016
- 28 T. Wohlers, Wohlers Report 2016, Wohlers Associates, 2016
- 29 "X line 2000R", Concept Laser website, www.concept-laser.de/en/industry/automotive/machines.html, accessed 6 June 2016

- 30 "BAAM: Big Area Additive Manufacturing", Cincinnati Incorporated website, www.e-ci.com/baam/, accessed 6 June 2016.
- 31 "Mammoth Stereolithography", Materialise website, <http://manufacturing.materialise.com/mammoth-stereolithography>, accessed 6 June 2016.
- 32 Material data sheet: EOS StainlessSteel 316L, EOS, via www.eos.info/material-m, May 2014.
- 33 "Freeformer system", Arburg website, www.arburg.com/us/us/products-and-services/additive-manufacturing/freeformer-system/, accessed 27 May 2016.
- 34 "Schunk's 3D-Printed grippers grab all attention", <http://software.materialise.com/cases/schunks-3d-printed-grippers-grab-all-attention>, accessed 1 June 2016.
- 35 "These Custom 3D Printed Headphones Could Set You Back \$200 to \$40,000", 3D Printing Industry website, <http://3dprintingindustry.com/news/these-custom-3d-printed-headphones-could-set-you-back-200-to-40000-51371>, accessed 2 June 2016.
- 36 Website Phillips 3D Shaver, www.3Dshaver.com, accessed 1 June 2016.
- 37 Nike Innovation 2016", Nike website, news.nike.com/news/nike-innovation-2016, accessed 1 June 2016.
- 38 "The Future of Running is Here", New Balance website, www.newbalance.com/article?id=4041, accessed 1 June 2016.
- 39 "Base by Wiivv: Custom 3D Printed Insoles to Relieve Fatigue", All3DP, <https://all3dp.com/base-by-wiivv-custom-3d-printed-insoles/>, accessed 1 June 2016.
- 40 "3D-Drucker ermöglichen Titan-Implantate für die Wirbelsäule", Deutsche Gesundheits Nachrichten website, www.deutsche-gesundheits-nachrichten.de/2014/12/16/3d-drucker-ermoeglichen-titan-implantate-fuer-die-wirbelsaeule, accessed 2 June 2016.
- 41 "This is the most successful 3D printed product in the world", Inside3DP website, www.inside3dp.com/successful-3d-printed-product-world, accessed 2 June 2016.
- 42 "EOS - Dental Crowns and Bridges, Dental Models and Removable Partial Dentures (RPD) Alter the Dental Industry" Additive Manufacturing website, <http://additivemanufacturing.com/2013/03/12/eos-laser-sintering-is-replacing-traditional-processes-in-dental-industry>, accessed 2 June 2016.
- 43 "3D Printing for Precision Drug Therapy: An Initial Proof of Concept Study", American Heart Association website, accessed 2 June 2016.
- 44 T. Kellner "Fit to print: New Plant Will Assemble World's First Passenger Jet Engine with 3D printed Fuel Nozzles, Next-Gen Materials", GE Reports website, www.gereports.com/post/80701924024/fit-to-print, accessed 1 June 2016.
- 45 T. Kellner, "World's first plant to print jet engine nozzle in mass production" GE Reports website, <http://www.gereports.com/post/91763815095/worlds-first-plant-to-print-jet-engine-nozzles-in/>, accessed 1 June 2016.
- 46 "Breakthrough for future Airbus A320", Airbus website, www.airbusgroup.com/int/en/story-overview/Pioneering-bionic-3D-printing.html, accessed 1 June 2016.
- 47 "The 3-D Printing Revolution", Harvard Business Review website, <https://hbr.org/2015/05/the-3-d-printing-revolution>, accessed 1 June 2016.
- 48 „Six Myths of Product Development“, Harvard Business Review website, <https://hbr.org/2012/05/six-myths-of-product-development/ar/1>, accessed 20 June 2016
- 49 "Medezin: DePuy Spine - Additive Fertigungstechnologie von EOS beschleunigt Entwicklung medizinischer Instrumente", EOS website, www.eos.info/presse/kundenreferenzen/depuy-spine, accessed 2 June 2016.
- 50 "Volvo Construction Equipment digs up prototype savings of 18 weeks and 92% of costs", Stratasys website, www.stratasys.com/resources/case-studies/automotive/volvo-ce, accessed 30 May 2016.
- 51 "Werkzeugbau: Innomia - Optimierung des Herstellungsprozesses durch Additiv gefertigte Kühlkanäle", EOS website, www.eos.info/press/case_studies/Innomia, accessed 20 June 2016.
- 52 „QTD Insert Drill“, Mapal website, http://www.mapal.com/fileadmin/00_PDF-Dateien/Kataloge/en/Insert_drill_QTD-en.pdf, accessed 21 June 2016
- 53 "BMW Manufacturing Jigs and Fixtures with FDM", Stratasys website, <http://www.stratasys.com/resources/case-studies/automotive/bmw>, accessed 21 June 2016
- 54 "Tools from 3D Printer Make Car Manufacturing Easier at Opel", Opel Website, http://www.opel.com/news/index/2014/08/tools_from_3d_printer_make_car_manufacturing_easier.html, accessed 21 June 2016

- 55 "By the Numbers: 3-D Printing at Lockheed Martin", Lockheed Martin press release, <http://www.lockheedmartin.com/us/news/features/2015/by-the-numbers-3dprintingatlockheedmartin.html>, 2015.
- 56 "Industry: Festo - Additive Manufacturing Enables Automation Specialist to Design its Bionic Assistance System", EOS website, www.eos.info/press/customer_case_studies/festo, accessed 1 June 2016.
- 57 S. Sciortino, "Extrusion blow molding with FDM", www.cimetrixsolutions.com/downloads/AG-ExtrusionBlowMolding.pdf, Stratasys Inc, 2009.
- 58 "Special Machinery", EOS website, www.eos.info/industries_markets/industry/special_machinery, accessed 6 June 2016.
- 59 "Handling & Robotics, Case Studies, Redesigned Handling device", EOS website, http://www.eos.info/industries_markets/industry/handling_robotics, accessed 6 June 2016.
- 60 "Tools Repair", Innomia website, www.innomia.cz/en/services/tools-repair, accessed June 2016.
- 61 "How 3D Printing Is Delivering Airplane Parts On Demand", Forbes website, www.forbes.com/sites/airbus/2014/07/15/how-adding-a-new-dimension-to-airplanes-is-delivering-parts-on-demand/#6316a39c3bc7, accessed 31 May 2016.
- 62 "Material Management for Metal Materials", EOS website, www.eos.info/material-management-metal, accessed 31 May 2016.
- 63 "UPS Tests a 3-D Printing Service", The Wall Street Journal website, www.wsj.com/articles/ups-tests-a-3-d-printing-service-1442618648, accessed 31 May 2016.
- 64 "Angriff auf die Post", Handelsblatt website, www.handelsblatt.com/my/unternehmen/handel-konsumgueter/amazon-angriff-auf-die-post/13071478.html, accessed 31 May 2016.
- 65 "French La Poste to offer 3D printing service, starting with three offices", 3ders.org website www.3ders.org/articles/20131127-french-la-poste-to-offer-3d-printing-service-starting-with-three-offices.html, accessed 31 May 2016.
- 66 "Royal Mail to offer 3D printing", The Telegraph website, www.telegraph.co.uk/finance/newsbysector/supportservices/11278665/Royal-Mail-to-offer-3D-printing.html, accessed 31 May 2016.
- 67 "UPS: 3D Printing Maps Out A New Future", InformationWeek website, www.informationweek.com/iot/ups-3d-printing-maps-out-a-new-future/a/d-id/1323851, accessed 31 May 2016.
- 68 "TNT und trinckle 3D kooperieren bei 3D-Druck", TNT website www.tnt.com/express/de_de/site/home/the-company/press/Archiv_Pressmeldungen/TNT_und_trinckle_3D_kooperieren_bei_3D-Druck.html, accessed 31 May 2016.
- 69 "CloudDDM & UPS: Versand von 3D-gedruckten Teilen am Tag der Bestellung", 3Druck.com website <https://3druck.com/lieferanten-haendler/cloudddm-ups-versand-von-3d-gedruckten-teilen-am-tag-der-bestellung-1435769>, accessed 31 May 2016.
- 70 Doris, "CloudDDM & UPS: Versand von 3D-gedruckten Teilen am Tag der Bestellung", 3Druck, 2015
- 71 UPS, "3D printing", UPS website, visited 05-27-2016
- 72 B. Darrow, "UPS and SAP Push On-Demand 3D Printing", <http://fortune.com/2016/05/18/sap-and-ups-3d-printing/>, accessed 31 May 2016
- 73 UPS, "Materialise - Die Lieferung der Zukunft", UPS Exporttoolkit website, <https://exporttoolkitde.ups.com/artikel-und-erkenntnis/materialise-die-lieferung-der-zukunft/>, visited 27 May 2016
- 74 "Staples look to 3-D printing to remain competitive", Transport Intelligence website, www.ti-insight.com/briefs/15878, accessed 31 May 2016.
- 75 "Amazon's drone delivery: How would it work?", CNN website, <http://edition.cnn.com/2013/12/02/tech/innovation/amazon-drones-questions>, accessed 31 May 2016.
- 76 "Amazon Trucks Would 3D Print Products En Route to Customer", PSFK website, www.psfk.com/2015/03/amazon-trucks-3d-print-products-en-route-patent-retail.html, accessed 31 May 2016.
- 77 U. Dombrowski and S. Schulze, "Lebenszyklusorientiertes Ersatzteilmanagement – Neue Herausforderungen durch innovationsstarke Bauteile in langlebigen Primärprodukten", Beiträge zu einer Theorie der Logistik, p. 439-462, Springer, 2008.
- 78 R. Geissbauer, Serviceinnovation: Potenziale industrieller Dienstleistungen erkennen und erfolgreich implementieren (Springer, 2012).
- 79 "Das Geheimnis der Gewinnspanne beim Autokauf", Die Welt website, www.welt.de/motor/article116695390/Das-Geheimnis-der-Gewinnspanne-beim-Autokauf.html, accessed 2 June 2016.

- 80 "How 3D Printing Is Delivering Airplane Parts On Demand", Forbes website, www.forbes.com/sites/airbus/2014/07/15/how-adding-a-new-dimension-to-airplanes-is-delivering-parts-on-demand/#525f648f3bc7, accessed 2 June 2016.
- 81 "Burner tips for gas turbines", Siemens website <http://www.siemens.com/global/en/home/markets/machinebuilding/additive-manufacturing.html>, accessed 1 June 2016.
- 82 "Additive Manufacturing (3D-printing) of spare parts for industrial gas turbines", Siemens Sustainable Energy website, www.energy.siemens.com/mx/en/services/industrial-applications/additive-manufacturing.htm, accessed 1 June 2016.
- 83 "Automotive: MAN erforscht Ersatzteilproduktion im 3D-Druck", Logistik Heute website, www.logistik-heute.de/Logistik-Magazin-LOGISTIK-HEUTE/Artikel/Magazin-Ausgabe-12-2015/14302/Automotive-MAN-erforscht-Ersatzteilproduktion-im-3D-Druck, accessed 1 June 2016.
- 84 Kazzata website, www.kazzata.com, accessed 1 June 2016.
- 85 "Caterpillar Lays the Groundwork", Additive Manufacturing website, www.additivemanufacturing.media/articles/caterpillar-lays-the-groundwork, accessed 1 June 2016.
- 86 EY Research
- 87 EY Research
- 88 EY Research
- 89 "New Software Combines 3D Printing with Traditional Manufacturing", Siemens website, www.siemens.com/innovation/en/home/pictures-of-the-future/industry-and-automation/additive-manufacturing-3d-printing-and-traditional-manufacturing.html, accessed 2 June 2016.
- 90 "Siemens to Collaborate with HP Inc. to Elevate 3D Printing from Prototyping to Full Production", Siemens PLM Software website, www.plm.automation.siemens.com/se_se/about_us/newsroom/press/press_release.cfm?Component=247628, accessed 2 June 2016.
- 91 "3D Printing", Autodesk website, www.123dapp.com/3D-printing, accessed 2 June 2016.
- 92 "Dassault Systèmes' 3DVIA and Sculpteo Take the '3D Print' Button to New Frontiers", Business Wire website, www.businesswire.com/news/home/20110627006290/en/Dassault-Syst%C3%A8mes%E2%80%99-3DVIA-Sculpteo%E2%80%9C-Print%E2%80%9D-Button, 27 June 2011.
- 93 "Stratasys and Adobe Team Up To Bring Game-Changing Color 3D Printing to Creatives", Stratasys website, <http://blog.stratasys.com/2015/10/06/adobe-max-2015-color-3d-printing/>, accessed 2 June 2016.
- 94 "Materialise Slicing Technology Enables Toyota's Lightweight Car Seat", Materialise website, www.materialise.com/cases/materialise-slicing-technology-enables-toyota-s-lightweight-car-seat, accessed 2 June 2016.
- 95 EY Research
- 96 Other small players may be operating in local restricted areas, but these are not considered in detail in this study.
- 97 "Other" includes family offices and national pension funds.
- 98 "Networking technologies, 3D Printing & Robotics: 4Q15 3D Printing Survey: Q4 system sales poor, but 2016 outlook improves", PiperJaffray industry note, www.i3dmfg.com/wp-content/uploads/2016/02/PiperJaffray-4th-Quarter-3D-Printing.pdf, 18 January 2016.
- 99 "Will Hewlett-Packard buy their way into the 3D printing industry through Stratasys?", 3DPrint.com website, <https://3dprint.com/97608/will-hp-buy-stratasys/>, accessed 2 June 2016.
- 100 EY Research
- 101 Including non-3D printing revenues
- 102 For service providers and 3DP manufacturers, a bottom-up approach was used to estimate future market size (based on current company revenues and AM industry segment individual growth rates). For 3DP materials suppliers and other companies without published financial statements, a top-down approach was used (identical growth rates for the respective groups were applied whereas 3 DP materials suppliers were included with a constant market share of 20% of the total market).

Imprint

Ernst & Young GmbH
Wirtschaftsprüfungsgesellschaft

Images sources

iStockphoto LP. (istockphoto.com)

About the global EY organization

The global EY organization is a leader in assurance, tax, transaction and advisory services. We leverage our experience, knowledge and services to help build trust and confidence in the capital markets and in economies the world over. We are ideally equipped for this task - with well trained employees, strong teams, excellent services and outstanding client relations. Our global purpose is to drive progress and make a difference by building a better working world - for our people, for our clients and for our communities.

The global EY organization refers to all member firms of Ernst & Young Global Limited (EYG). Each EYG member firm is a separate legal entity and has no liability for another such entity's acts or omissions. Ernst & Young Global Limited, a UK company limited by guarantee, does not provide services to clients. For more information, please visit www.ey.com.

In Germany, EY has 21 locations. In this publication, "EY" and "we" refer to all German member firms of Ernst & Young Global Limited.

© 2016 Ernst & Young GmbH
Wirtschaftsprüfungsgesellschaft
All Rights Reserved.

BKR 1607-588
ED None
GSA Agency



In line with EY's commitment to minimize its environmental impact this document has been printed CO₂neutral and on FSC®-certified paper that consists of 60% recycled fibers.

This publication contains information in summary form and is therefore intended for general guidance only. Although prepared with utmost care this publication is not intended to be a substitute for detailed research or the exercise of professional judgment. Therefore no liability for correctness, completeness and/or currentness will be assumed. It is solely the responsibility of the readers to decide whether and in what form the information made available is relevant for their purposes. Neither Ernst & Young GmbH Wirtschaftsprüfungsgesellschaft nor any other member of the global EY organization can accept any responsibility. On any specific matter, reference should be made to the appropriate advisor.

www.de.ey.com