
*The future of
spare parts is 3D*

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A look at the
challenges and
opportunities
of 3D printing

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Executive summary



The business of making, storing, and shipping spare parts has long been a source of time-consuming and costly difficulties for suppliers of spare parts as well as for their customers. Maintaining inventories of infrequently ordered parts is so expensive that suppliers often simply stop offering them. That in turn forces customers to store large inventories of parts or to turn to third-party manufacturers.

The advent of 3D printing, however, is about to change everything. This additive manufacturing technology, long used in the prototyping of new products, will enable suppliers to make and send parts on an on-demand basis — and do so locally, close to where the parts are needed. Alternatively, companies can opt to print their own parts, bypassing the suppliers entirely.

In a survey that Strategy& conducted in late 2015 of 38 German industrial companies, respondents were in agreement that 3D printing will play a major role in the spare parts business. However, not all were aware of the full benefits to be gained from 3D printing. In this report we examine nine key findings from the survey.

Within five years, more than 85 percent of spare parts suppliers will incorporate 3D printing into their business.

Currently, spare parts suppliers are not meeting the needs of their customers; 50 percent of customers have looked into 3D printing their own parts.

In 10 years, German spare parts suppliers will save €3 billion annually by using 3D printing.

Companies still think too traditionally; in the future they will sell copyrights instead of actual parts.

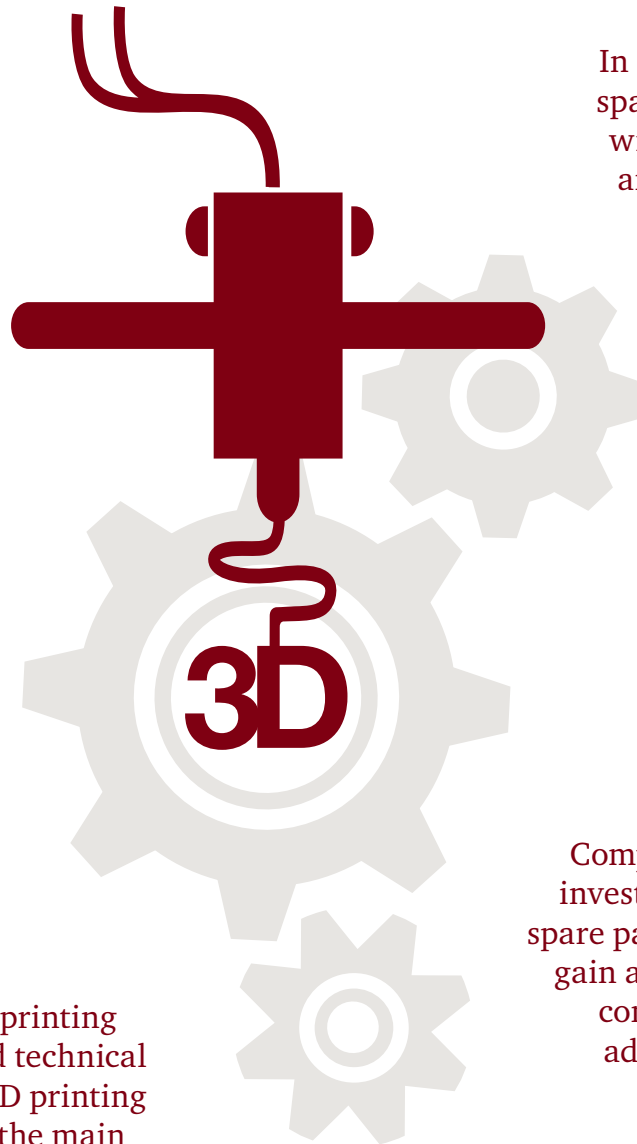
Companies are still not aware of the full potential to be gained from 3D printing spare parts.

Partnering will be key to the successful printing of spare parts.

Companies that invest in printing spare parts today will gain a sustainable competitive advantage.

Lack of 3D printing expertise and technical maturity of 3D printing are seen as the main challenges of 3D printing.

More than half of companies fear to lose market share to third-party spare parts suppliers.



The growth of 3D printing

Since its inception more than 30 years ago, additive manufacturing, better known as 3D printing, has advanced and grown into a technology with a market size that reached US\$5.1 billion in 2015. It has seen an average annual growth rate of 30 percent over the last four years, according to the 2016 [Wohlers Report](#).

[Gartner Research](#) estimates that by 2019, nearly 5.7 million 3D printers will be shipped annually, compared to an estimated 500,000 printers in 2016. One reason for this exponential growth is that 3D printing facilitates complex designs that cannot be produced with conventional manufacturing technologies. While the technology has greatly matured over the past five years and costs have come down significantly, the production of low-volume and complex parts via 3D printing is economically viable only in cases where it reduces supply chain complexity and costs.

Traditional subtractive manufacturing processes are based on the removal of raw materials to create final products. By contrast, 3D printing works by building a product layer by layer — hence the name “additive manufacturing.” Currently there are five 3D printing technologies commercially available (*see Exhibit 1, next page*):

- Selective laser sintering (SLS)
- Fused filament fabrication (FFF)
- Stereolithography (SLA)
- Selective laser melting (SLM)
- Electron beam melting (EBM)

Each of the technologies is designed for specific material types and applications; the most commonly used are SLS, FFF, and SLA.

All major manufacturers of 3D printers are horizontally integrated in that they provide printers, engineering solutions, and raw materials in addition to 3D printing services. By bringing all of these components and services together they are able to reduce their up-front investment costs and offer low entry prices and packages to their customers. In this way, they have created ecosystems around their 3D printing businesses and made it harder for new competitors to find their way into the market.

These integrated services have been an important factor in the rapid rise in demand for 3D printing. However, for many industrial manufacturers and spare parts suppliers, essential questions still remain: Where and how should we start 3D printing? What is the underlying business case?

Exhibit 1
3D printing technologies

	Laser sintering (SLS) and melting (SLM)	Extrusion deposition (FFF)	Stereo lithography (SLA)	Electron beam (EBM)
Principles	Lasers are used to melt or sinter powder material in bulk (like a laser printer)	Molten polymers or ceramics are precisely deposited (ink-jet like)	A UV laser initiates photopolymerization in the liquid phase	Electron beams are used to melt and deposit powder material
Materials	Metal alloys Polymers	Polymers Ceramics	Polymers (resins)	Pure metals and alloys
Resolution	20–50 micrometers			

Source: Strategy& analysis

Impact on the spare parts business

In late 2015, Strategy& conducted an in-depth survey of 38 major suppliers and buyers of spare parts in Germany, including original equipment manufacturers (OEMs) and third-party suppliers. We followed up with executive interviews at many of these companies. Our survey revealed nine key findings about 3D printing in the spare parts industry.

1. Currently, spare parts suppliers are not meeting the needs of their customers; 50 percent of customers have looked into 3D printing their own parts.

The products made by industrial companies are complex and composed of a number of different parts; many of them will have to be replaced over the lifetime of the equipment. In addition, the products may be used at locations around the world. When a customer needs a specific replacement part, it can be a challenge for the supplier to provide a high level of service while also keeping costs down. To meet all of a customer's needs, a spare parts supplier has to manage an elaborate network of suppliers, production, sales, and customers, all of which requires important strategic decisions, including the following:

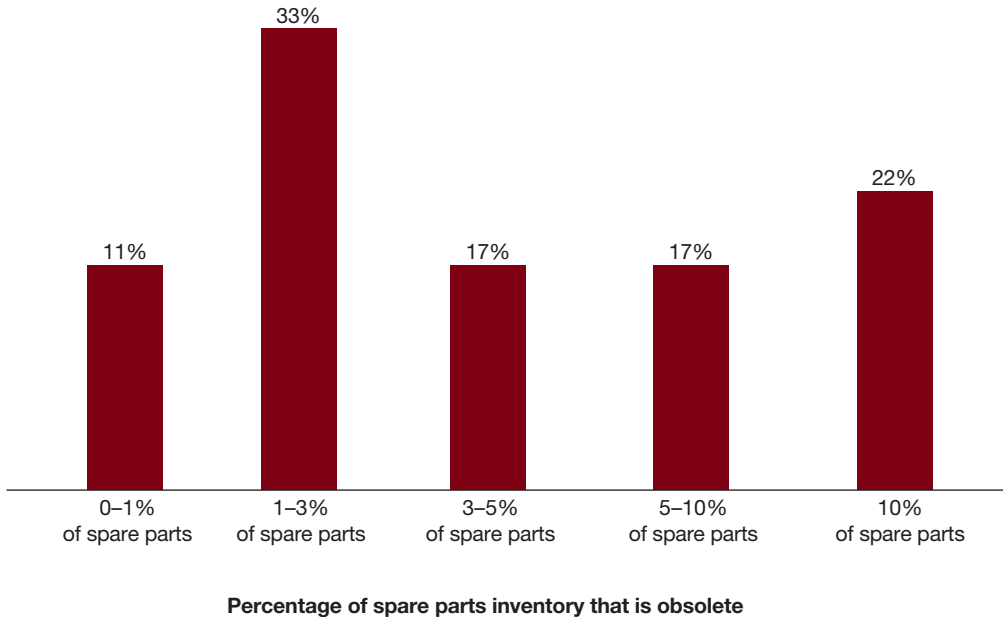
- Whether to make or buy the part
- Whether to make to stock or make to order
- Where to manufacture the part
- What service level to offer
- Whether to continue making the part or discontinue it

When using conventional production methods, spare parts providers have to make trade-offs between their level of service and their costs. In fact, 22 percent of the survey respondents said that more than 10 percent of the spare parts they keep in stock are obsolete or do not contribute positively to margins, and the majority of respondents believe that at least 3 percent of their spare parts stock loses money (*see Exhibit 2, next page*).

Exhibit 2

Does your company keep spare parts in stock that are obsolete or don't contribute to margins?

Percentage of survey participants



Source: Strategy& analysis

As a consequence, companies are discontinuing more of their spare parts every year. Some are moving from a make-to-stock approach to make-to-order, which decreases inventory costs but results in longer lead times and hence a lower level of service. And reducing the level of service, 74 percent of the suppliers in our survey agree, results in real costs as well as opportunity costs (*see Exhibit 3, next page*).

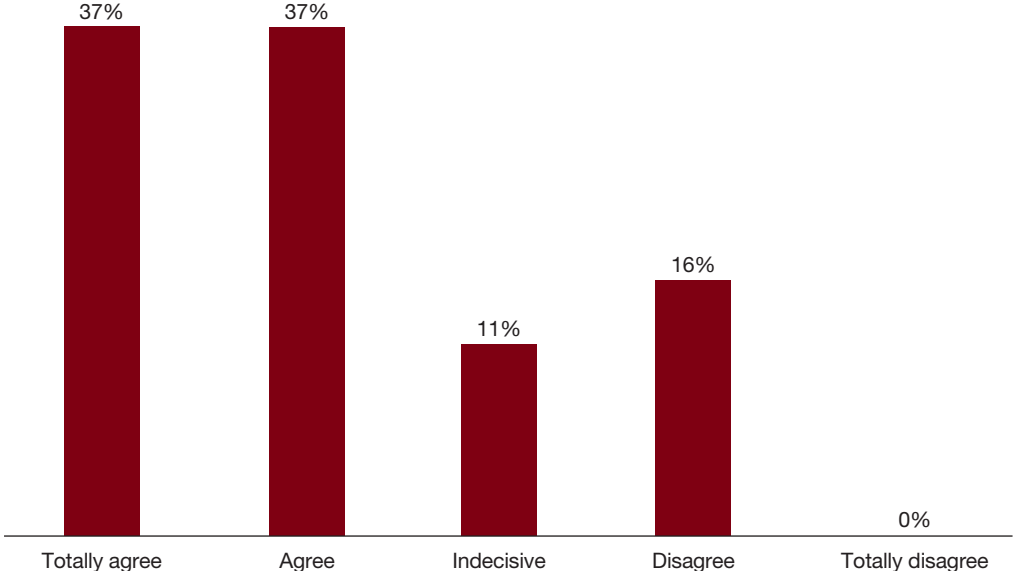
Given the challenges and cost burdens that spare parts customers are facing, it is no surprise that 47 percent of companies that buy spare parts have been looking into using 3D printing to create their own parts (*see Exhibit 4, page 11*). That may be a diversion from their core capabilities; 5 percent of respondents have investigated the viability but decided not to continue. Another 47 percent have not looked into doing their own 3D printing at all. But many feel they have little choice unless suppliers stop discontinuing spare parts and begin to improve their service level.

This is not to say that suppliers are neglecting their customers' needs. Among the suppliers we surveyed, 45 percent have begun a prototyping phase for 3D printing (*see Exhibit 5, page 12*). Yet many suppliers

Exhibit 3

Long lead times lead to significant real and opportunity costs. Do you agree or disagree?

Percentage of survey participants



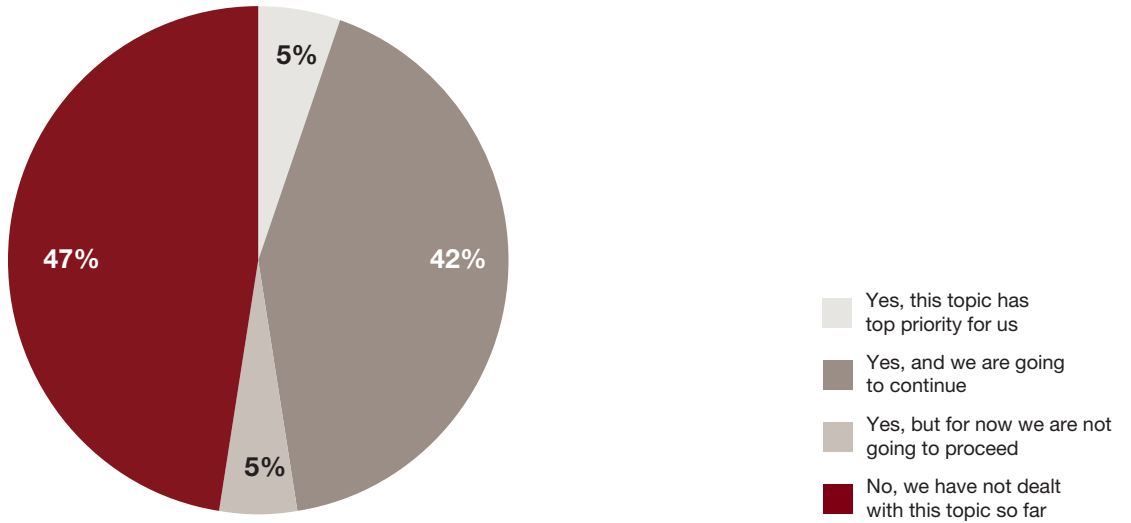
Note: Due to rounding, percentages may not total 100.

Source: Strategy& analysis

Exhibit 4

For customers: Are you investigating the viability of printing your own spare parts?

Percentage of survey participants



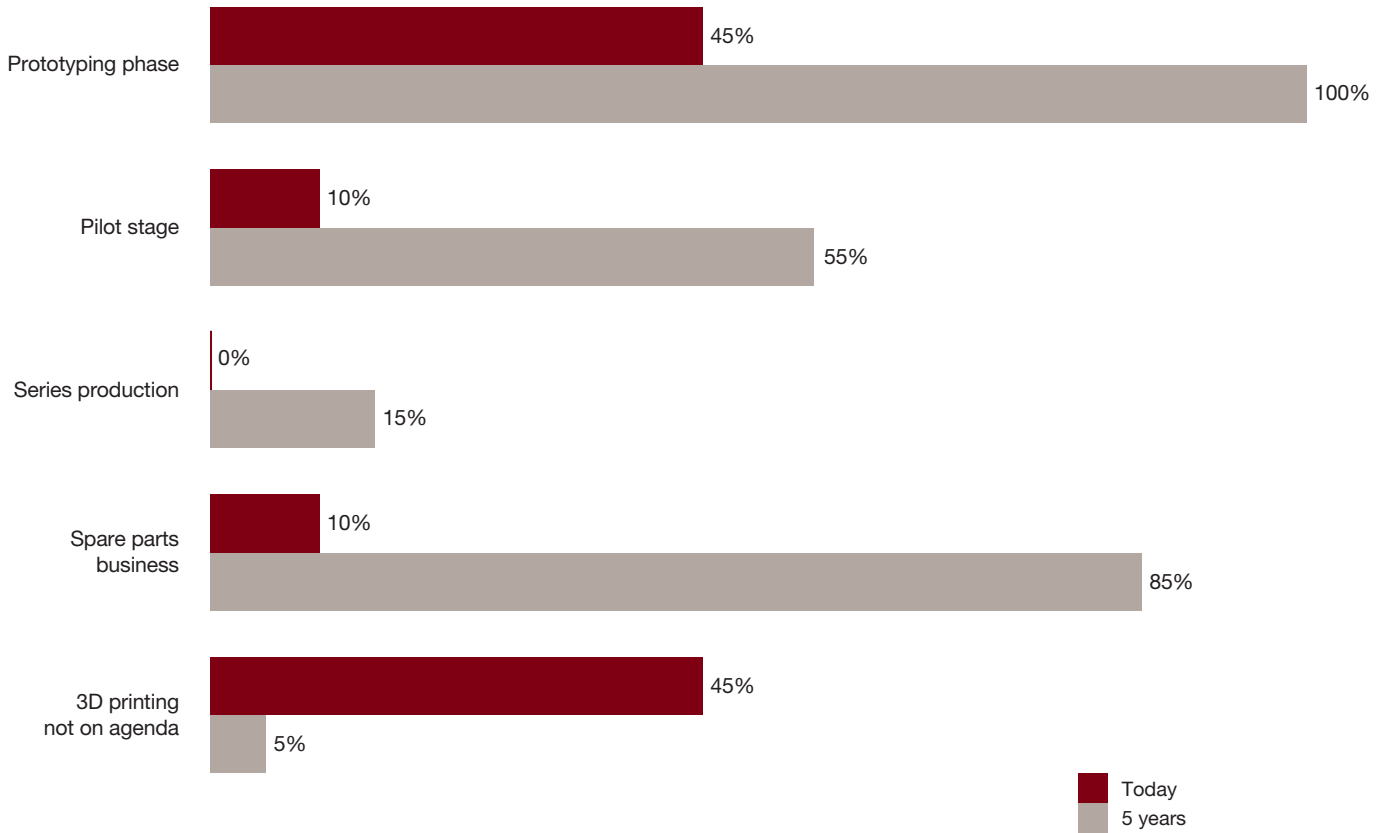
Note: Due to rounding, percentages may not total 100.

Source: Strategy& analysis

Exhibit 5

**Where does 3D printing fit into your product life cycle today?
Where do you expect it to fit in five years?**

Percentage of survey participants



Source: Strategy& analysis

continue to underestimate the technology's business value. Almost half of those responding to our survey characterize the potential for 3D printing to lower the total cost of ownership of their spare parts as low, and about the same proportion say it is not even on their agendas yet. But it should be.

2. Within five years, 85 percent of spare parts suppliers will incorporate 3D printing into their business.

“3D printing will transform the spare parts market fundamentally. It will become feasible to produce complex parts in ways that we can't imagine today.”—Constantin Jauck, Merck KGaA, Strategy& survey

Within five years, 3D printing will be fully established as an important complementary manufacturing method, widely used in dedicated areas. All of the companies we surveyed believe that 3D printing will become the standard method for producing prototypes. And 85 percent of the spare parts providers assert that 3D printing will also play a dominant role in the spare parts business.

Exhibit 6 (*next page*) is a heat map that indicates where we see 3D printing becoming a leading manufacturing technology. The data shows a clear trend: 3D printing will become a game-changer for low-volume parts, complex high-volume parts, and high-performance parts (those that improve efficiency and effectiveness during operation). Moreover, since 3D printing requires no tooling, companies can start printing parts during any phase of their products' life cycle.

Design changes can move a part from one category to another. So development engineers need to change their traditional way of designing parts to fully realize the potential of 3D printing (*see Case study: World's first 3D-printed injection nozzles for production jet engines at GE, page 18*).

Spare parts suppliers participating in our survey said that today, no more than 1 percent of their spare parts are manufactured through 3D printing. Only a few front-runners have successfully implemented 3D printing in their spare parts businesses. Most companies are still in the testing phase.

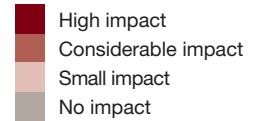
However, both spare parts suppliers and customers expect that the number of parts produced through 3D printing will increase dramatically; according to our survey, respondents expect that in five years, 85 percent of all spare parts suppliers will have incorporated 3D printing in their business. Some companies even anticipate that 10 to 25 percent of their spare parts will be produced through 3D printing in that time frame (*see Exhibit 7, page 15*).

Exhibit 6
Future 3D printing applications

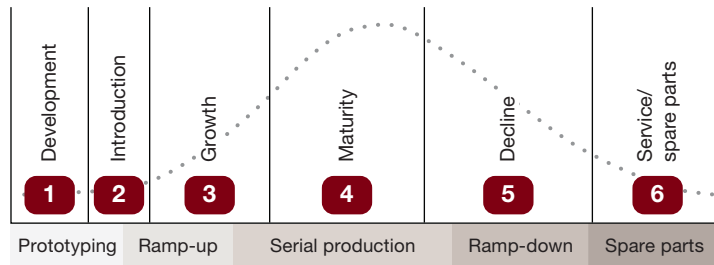
Product life-cycle phase	Segments							
	High volume				Low volume			
	Simple parts	Assemblies	Precision parts	Performance parts	Simple	Complex	Performance (precision)	Performance (weight/strength)
Prototyping and tooling	High impact	High impact	Small impact	High impact	High impact	High impact	Small impact	High impact
Production ramp-up	No impact	Considerable impact	No impact	High impact	Considerable impact	High impact	No impact	High impact
Serial production	No impact	Considerable impact	No impact	Considerable impact	Considerable impact	High impact	No impact	High impact
Production ramp-down	No impact	Considerable impact	No impact	High impact	Considerable impact	High impact	No impact	High impact
Spare parts	Considerable impact	High impact	No impact	High impact	High impact	High impact	No impact	High impact

Precision parts: Demand for tight tolerances and tight fit to ensure precision operation

Performance parts: Demand for high strength and low weight to reduce cost during operations and to increase lifetime



Product life cycle

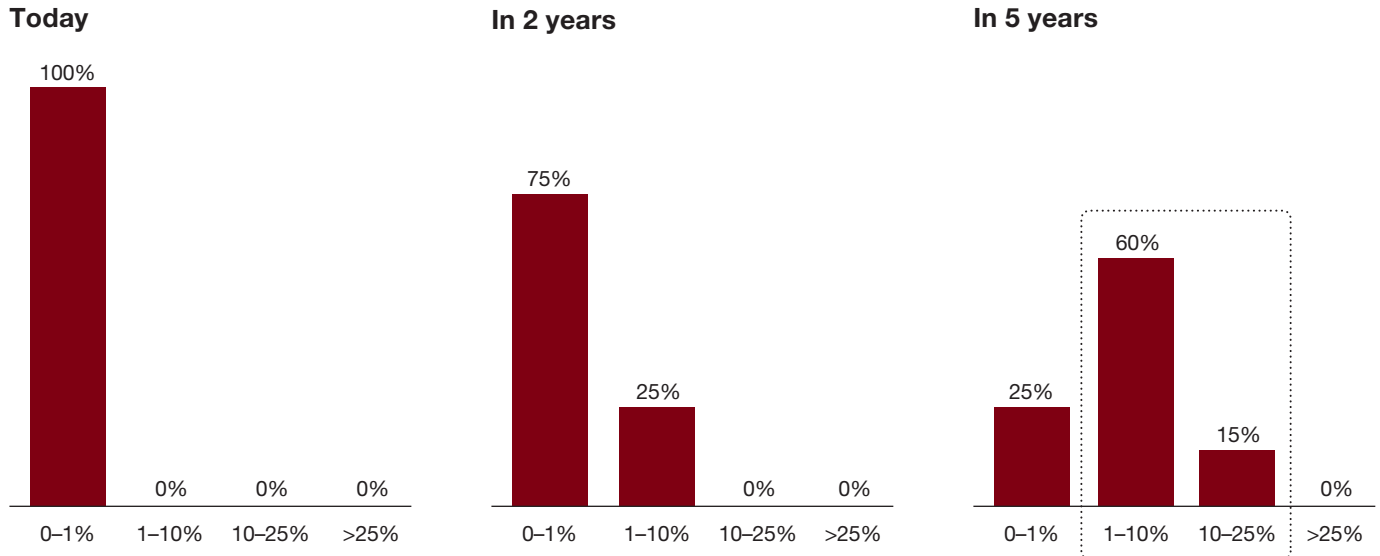


Source: Strategy& analysis

Exhibit 7

What percentage of your spare parts are produced by 3D printing today?
What percentage do you expect to see in two years? In five years?

Percentage of survey participants



Source: Strategy& analysis

The desire on the part of executives in a variety of industries to incorporate 3D printing into their product development and spare parts operations is strong. But the technology's impact will vary considerably depending on the stage in the product life cycle where it is used, as well as on the nature of the part to be made.

3. In 10 years, German spare parts suppliers will save €3 billion annually by using 3D printing.

“3D printing of spare parts will revolutionize the spare parts business. On the one hand, it will change the use of materials and reduce waste in logistics. On the other, it will increase speed and flexibility.” —Michael Caspar, Caspar GmbH, Strategy& survey

The operational benefits of printing spare parts are clear. First of all, there will be a significant decrease in the number of spare parts that companies need to hold in inventory, since 3D printing allows companies

to shift from make-to-stock to make-to-order while maintaining, or even improving, lead times. Production interruptions due to tooling changes can be reduced to near zero. And even if additional machining is needed, the overall setup time is greatly reduced.

Second, parts can be manufactured near where they are needed. This will ensure that parts are available when customers need them, with shorter lead times and less logistics planning.

Manufacturing concerns such as feasibility and production costs are not the whole story, however. The full potential of 3D printing does not become evident until companies factor in its effects on the entire supply chain, and ultimately the total cost of ownership (TCO) as well as the potential benefits of radical changes in product design (*see Case study: European railway operator: Reducing spare parts inventories with 3D printing, page 26*).

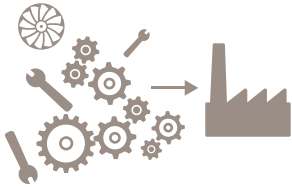
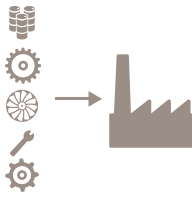




Consider a supplier that needs a certain spare part and is able to order it from the manufacturer's Web page. Within hours, a 3D printing service in the customer's vicinity receives the order, prints out the spare part, and delivers it to the customer. Or the manufacturer might send a downloadable 3D file to the customer, which can print out the spare part on its own equipment, thus avoiding any shipping costs or delays.

With these scenarios, no one needs to keep an inventory of spare parts. There is little or no interruption of production for changes in machine tooling, because the manufacturer is not actually selling parts, but rather is providing customers with the 3D file for creating the part (*see Exhibit 8, next page*).

3D printing will not have the same impact on all industries, however. The lifetime of the equipment for which spare parts are needed, the volume of spare parts to be printed, and the level of customization of the spare parts play a decisive factor in how rapidly and far 3D printing will penetrate any industry. Those likely to see the highest impact include the machine tool, rolling stock, medical equipment, and aerospace and defense industries.

Based on our research and experience, we estimate that 3D printing will ultimately make it feasible for suppliers to realize an average saving of 20 percent in total cost of ownership. The increase we project in the number of spare parts made by 3D printing would allow German spare parts suppliers to save €3 billion (US\$3.2 billion) annually over the next 10 years. There will also be additional revenue from the sale and servicing of spare parts that would have otherwise been discontinued.

Exhibit 8
How 3D printing will shrink the supply chain

	Current state	vs.	3D printing	Benefits of 3D printing
Source	 <p>~50 parts shipped in from different places</p>	vs.	 <p>5 components/ materials shipped in</p>	<p><i>(not exhaustive)</i></p> <p>Simplified supply chain, fewer suppliers</p> <p>Make to order</p>
Make	 <p>Production offshore in low-cost location</p>	vs.	 <p>Production in proximity of customer</p>	<p>Lower labor units</p> <p>No need to follow cheap labor rates</p> <p>No tooling costs</p> <p>Faster reaction</p>
Deliver	 <p>Multistage delivery</p> <p>Spare shipped in from large inventory</p>	vs.	 <p>Local van delivery</p> <p>Spare printed on demand and delivered same day</p>	<p>Local production</p> <p>Fast response time</p> <p>No warehousing costs</p> <p>Reduced inventory cost</p> <p>Low-cost delivery</p> <p>Fast delivery</p>

Source: Strategy& analysis

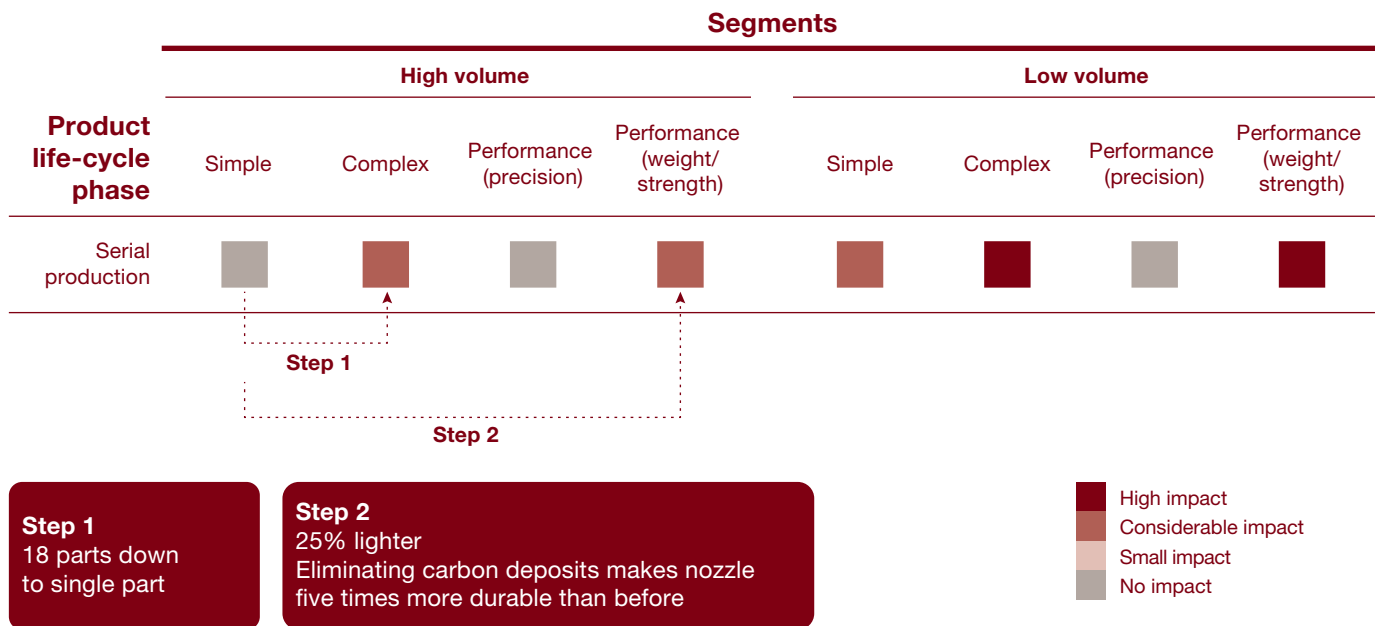
Case study: World's first 3D-printed injection nozzles for production jet engines at GE

GE Aviation, the world's largest jet engine manufacturer, used to make its fuel injection nozzle from 18 different parts that had to be sourced from a number of different vendors, then assembled. In 2015, GE began using 3D printing to produce the same nozzle. The company was able to reduce the 18 parts to just one.

Not only did 3D printing dramatically simplify the supply chain; the new

design also reduced the weight of the part by 25 percent and eliminated carbon deposits that would build up in the old design's internal support structure and advanced cooling pathways. As a result, the durability of the nozzle increased by a factor of five, leading to reduced costs. The technology made it possible for the nozzle to become a segment of the aircraft that fits into the category of "considerable impact" (see Exhibit A).

Exhibit A GE Aviation case



In 2015 GE Aviation began using a 3D printing process called powder bed fusion to produce fuel nozzles for jet engines.

Source: Strategy& analysis

4. Companies are still not aware of the full potential to be gained from 3D printing of spare parts.

Almost half of the spare parts producers we surveyed believe that the potential of 3D printing to reduce their production costs is low. Overall, 49 percent of the companies surveyed do not see the potential to reduce costs through 3D printing within their spare parts business. It is true that, currently, 3D-printed spare parts are often more expensive than conventional parts; this has led to a perception that total costs will remain high. We believe that this does not factor in the impact 3D printing will have up and down the entire supply chain.

We strongly support the conclusion of the 16 percent of our respondents that see high or very high cost-saving potential in 3D printing. Those costs are highly dependent on the parts themselves as well as the costs of raw materials. We find that the projections among companies are not nearly optimistic enough. While 84 percent of respondents agree that the cost to warehouse their spare parts will decrease, and none expect an increase, just 53 percent believe in 3D printing's potential to decrease logistics costs. The majority of companies, however, do believe that the costs involved in manufacturing individual parts will be reduced (*see Exhibit 9, next page*).

New design options will contribute to lower TCO in various ways; for example, 3D-printed parts can be lighter, leading to energy and fuel savings when equipment has to be moved. Logistics costs will go down, too, because 3D printing will reduce supply chain complexity and costs.

Only 59 percent of the companies agreed that 3D printing will reduce machine setup times. Since no tooling, such as the preparation of a casting mold, is needed, we would have expected a much higher percentage here.

In addition, more than 60 percent believe that planning costs will stay the same or increase. This also contradicts our experience; we have observed that a less complex supply chain and a reduction in the number of parts to be handled will reduce the planning effort significantly.

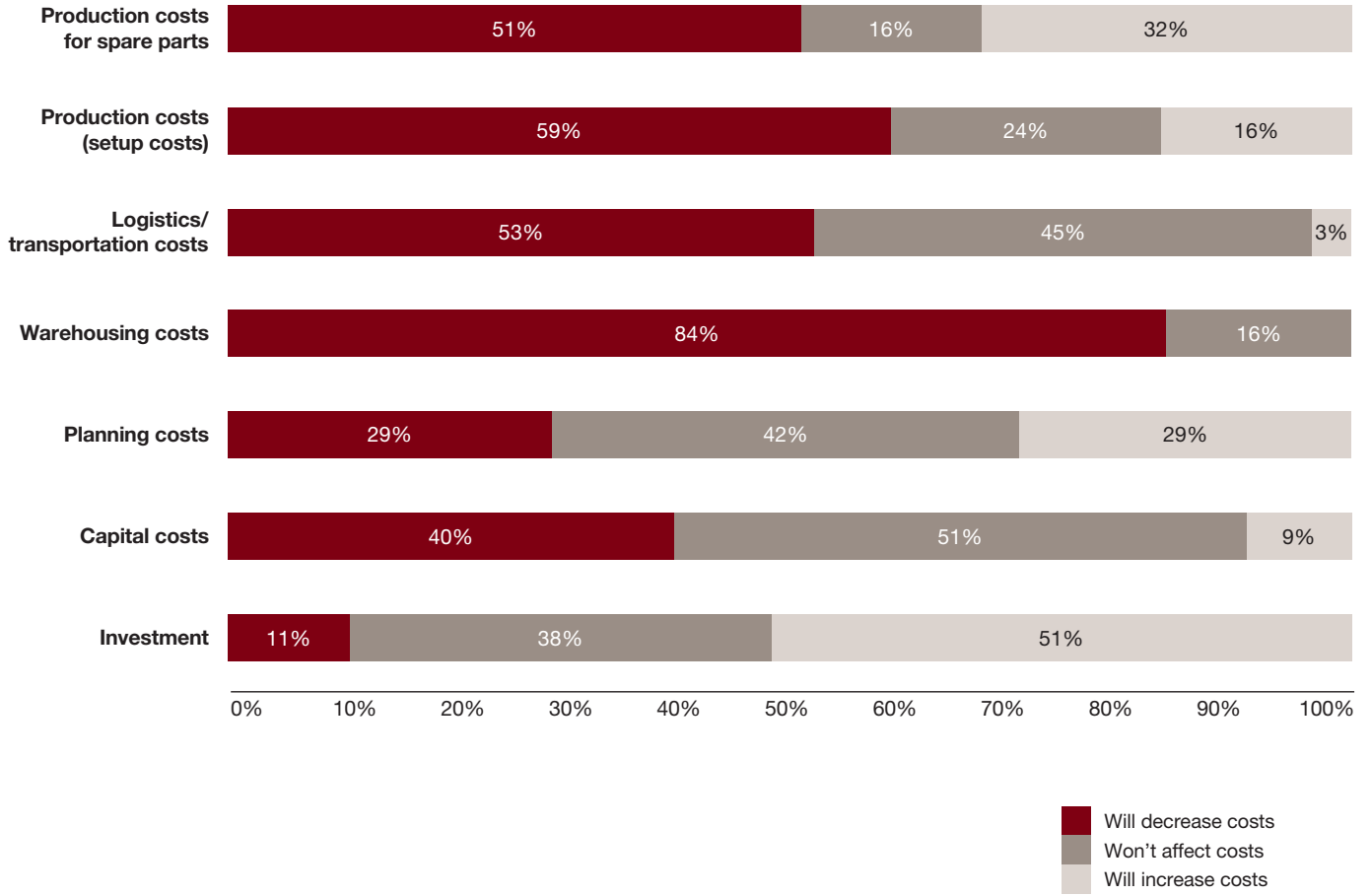
5. Companies that invest in 3D printing of spare parts today will gain a sustainable competitive advantage.

“Only those who recognize the additional value of 3D printing and invest into it will be successful in the future.” —Reinhard Ortner, Krones AG, Strategy& survey

None of our respondents disagreed with the statement that companies that invest in 3D printing of spare parts today will have a competitive

Exhibit 9
How will 3D printing of spare parts affect your costs?

Percentage of survey participants



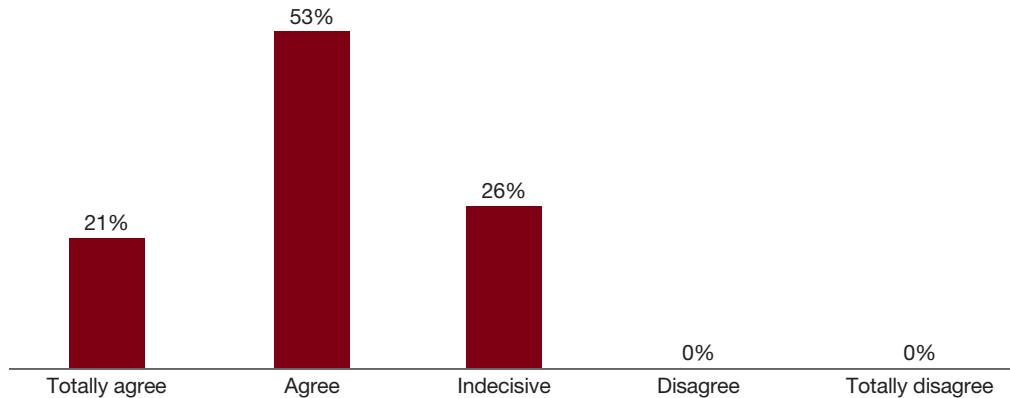
Note: Due to rounding, percentages may not total 100.

Source: Strategy& analysis

Exhibit 10

Companies investing in 3D printing today will have a significant competitive advantage and thereby will gain market share. Do you agree or disagree?

Percentage of survey participants



Source: Strategy& analysis

advantage; 74 percent agreed, although that was split between those who “totally agree” and those who “agree” (see *Exhibit 10*).

3D printing will not transform the spare parts business immediately. But companies that don’t begin investing in the capabilities and technologies needed, including in the supply chain, will find it difficult to catch up with first-moving competitors in the future (see “*The case for printing spare parts,*” page 29).

6. More than half of the suppliers surveyed are worried about losing market share to third-party suppliers.

Spare parts customers are less concerned about the cost of parts than they are about availability and the time it takes to get them; what’s important to them is avoiding opportunity costs and the additional planning effort required when spare parts are late or unavailable. Spare parts providers are very much aware of this. In our survey, half of the suppliers agreed that they were at risk of losing market share to third-party suppliers. Those that disagreed were, in many cases, suppliers of spare parts that are more difficult to make by 3D technology or were providing unique value-added services with their spare parts.

7. Lack of 3D printing expertise and lack of mature 3D printing technology are perceived as the main challenges.

Suppliers and customers alike continue to express a variety of concerns about 3D printing. Suppliers in particular remain doubtful about the maturity and technical feasibility of 3D printing, their own level of technical expertise, and the availability of the right materials. They do see a need to improve 3D manufacturing costs, materials, and quality. Surprisingly, of less concern are the issues of customer acceptance and copyrights (see Exhibit 11, next page).

Customers also worry about the availability of materials and the quality of the final parts, but do not see manufacturing costs and TCO as major hurdles.

It has been shown that the quality of 3D-printed parts can be just as high as parts produced through conventional methods, and in some cases the quality is actually higher. The availability of materials used in 3D printing is increasing rapidly; most of the commonly used materials are widely available today. Prices will drop further.

However, we see three main areas where additive manufacturing needs to improve from a technology point of view in order to increase its field of application.

- The spatial resolution of 3D printers needs to improve. Many 3D-printed parts have to undergo an additional treatment step such as machining or drilling before being used.
- The speed of 3D printers and their related software needs to increase.
- 3D printing materials must be standardized and uniform. Since general material norms do not exist yet, companies need to set — and meet — quality standards for their spare parts and, even more important, for the materials and printing processes. Suppliers are focusing on partnering with technology partners and manufacturing companies to achieve this goal.

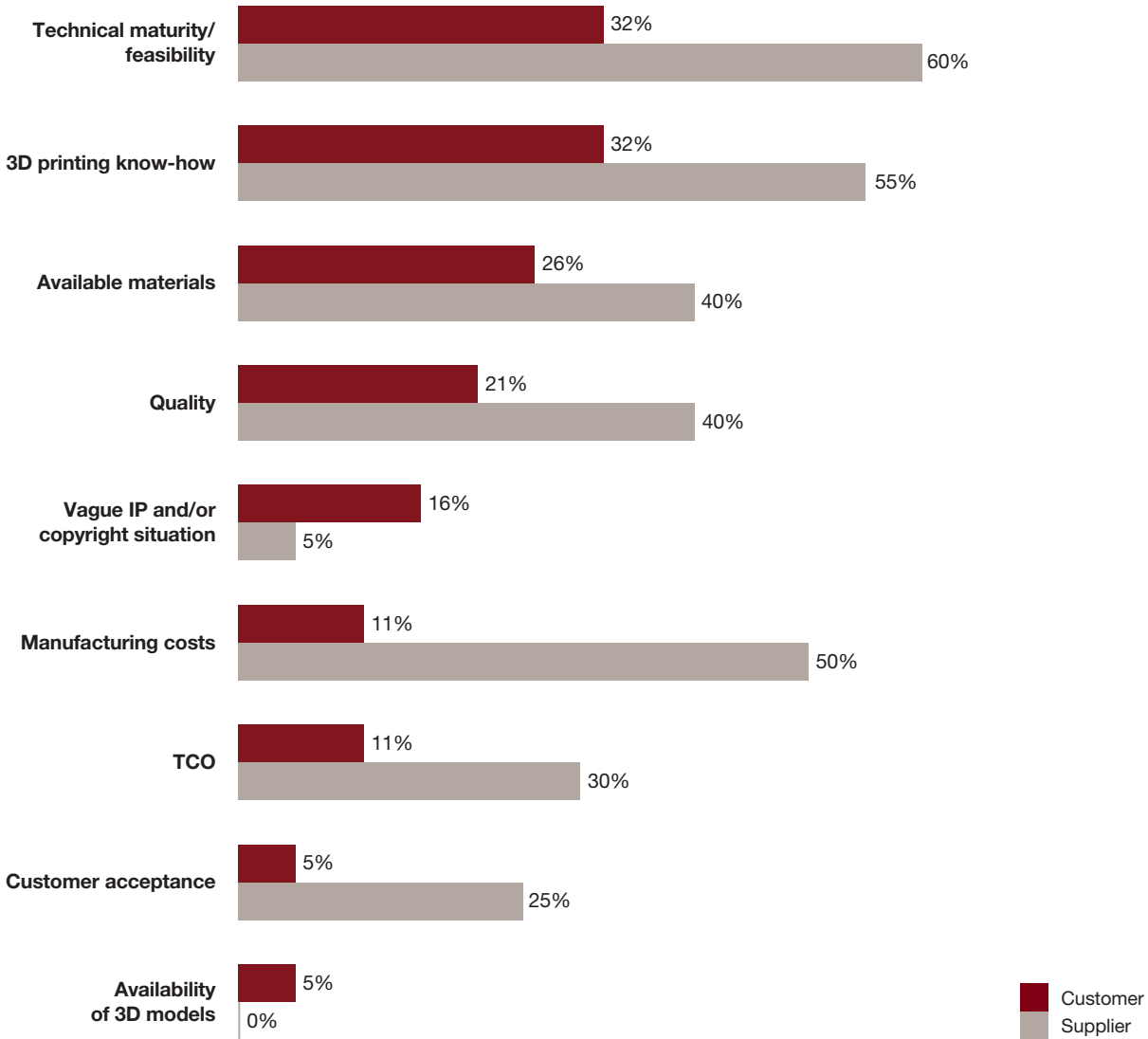
8. Partnering will be key to the successful printing of spare parts.

When customers and providers of spare parts were asked about their views on the most likely partnerships, both pointed to technology partners — printer and material producers. Providers also expressed their need to work with product development partners that can design the parts to be 3D-printed. Customers, for the most part, said they expected to seek less external support. Our findings indicate that many

Exhibit 11

What are the biggest challenges to the adoption of 3D printing for spare parts?

Percentage of survey participants



Source: Strategy& analysis

customers would prefer to outsource the printing of spare parts than incorporate it into their own production activities (see Exhibit 12).

9. Companies still think too traditionally; in the future they will sell intellectual property rather than actual parts.

“In the future we will not buy spare parts anymore, but data.”

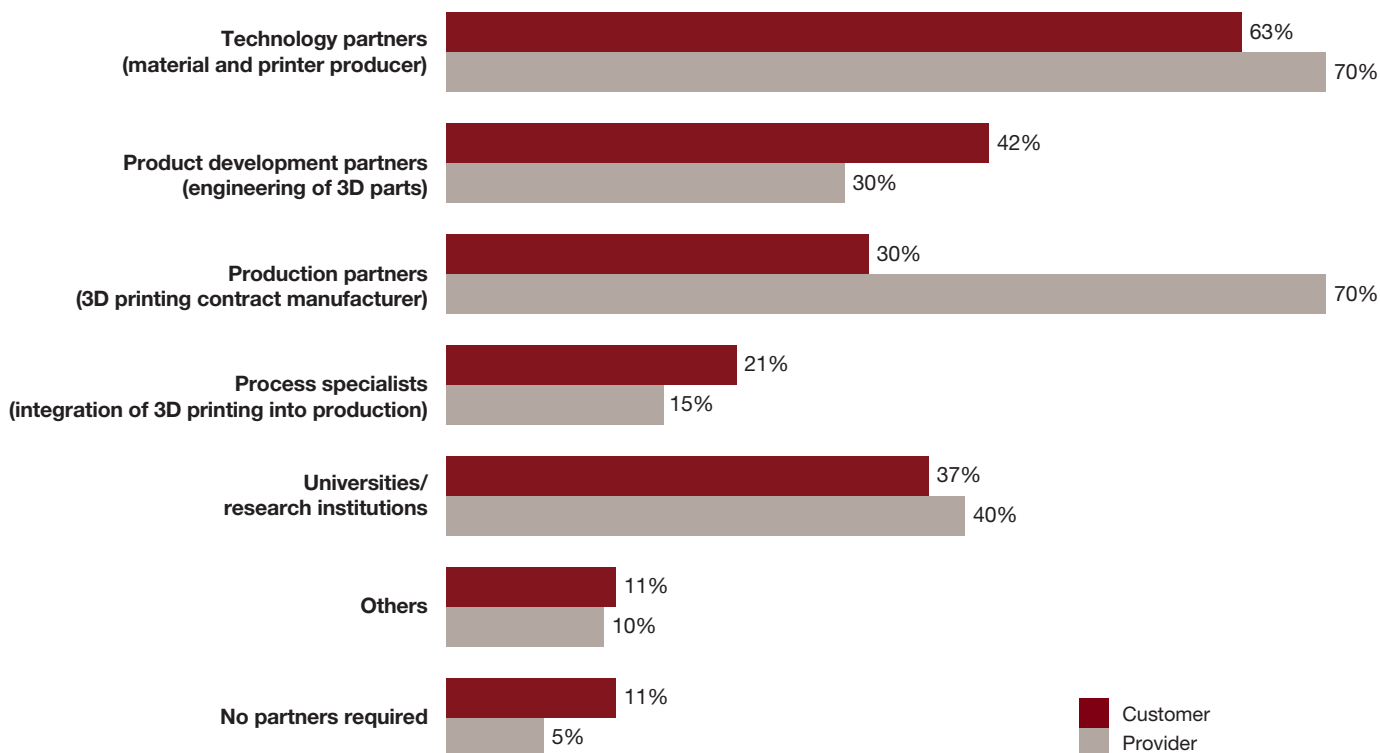
—Reiner Rohr, BASF SE, Strategy& survey

The full potential of 3D printing will be evident only when companies can download a 3D file that contains all of the data required to create a spare

Exhibit 12

What kinds of partners will you require to meet the challenges of 3D printing?

Percentage of survey participants



Source: Strategy& analysis

part, including the CAD file, process parameters, and material composition.

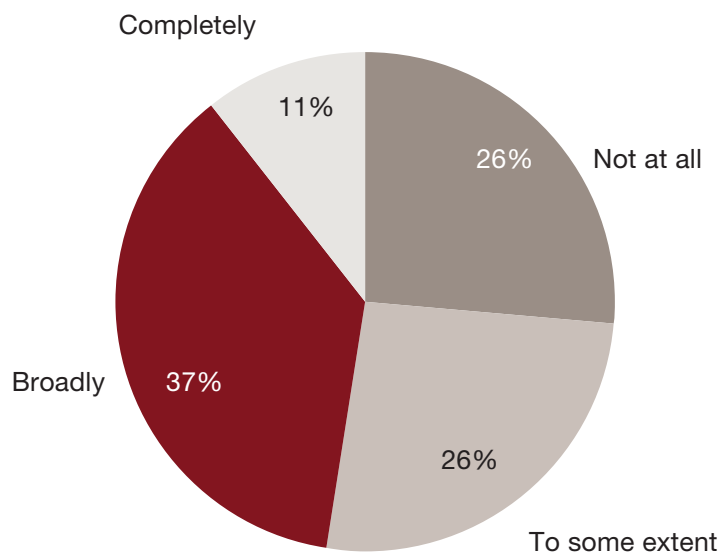
How to manage the intellectual property (IP) that is bound up in these components is not yet a major concern among either suppliers or customers — but it should be.

Only 25 percent of the spare parts suppliers that responded to our survey say that they have decided whether to sell the data files for their spare parts independently of the physical part. On the other hand, just 11 percent of the companies that purchase spare parts say they fully understand whether or not the designs of the parts they buy are protected by copyright; 37 percent say they broadly understand it, 26 percent understand it to some extent, and another 26 percent say they don't understand it at all (*see Exhibit 13*). This uncertainty regarding IP among both suppliers and customers needs to be addressed before companies are willing to sell spare parts design data as well as the physical part. To move to this next stage of manufacturing they need to know that their IP is safe. One likely outcome will be the rise of “platforms” for the sale of 3D printing files, similar to music streaming platforms — a shift that could totally transform the spare parts business, just as it has the music industry.

Exhibit 13

For customers: Do you know the details of the copyright laws related to spare parts?

Percentage of survey participants



Source: Strategy& analysis

Case study: European railway operator: Reducing spare parts inventories with 3D printing

A large German railway company was faced with the challenge of having to stockpile an ever-increasing amount of spare parts in multiple warehouses, for long periods of time, to keep its aging train fleet operational. Once depleted, the stock of parts would have to be replenished with exact matching parts as soon as possible. Considering the negative impact on the total cost of ownership (TCO) from warehousing and replacement costs, the railway was determined to find a way to reduce the size of its inventory and avoid the risk of unexpected costs incurred in having to custom-fabricate replacement parts in small lots.

The company looked into several manufacturing technologies that would allow for the production of spare parts in small batches at reasonable cost. It identified 3D printing as the most promising option. Then it partnered with industry experts specializing in the 3D printing of custom parts to further evaluate the technological and economic feasibility of integrating 3D printing into the company's established spare parts replacement program. The exercise showed that spare parts that satisfied all of the railway's tests could be successfully printed at a reduced TCO — and that the technology will soon become a highly attractive option in prolonging the lifetime of this company's rolling stock.

A plan for successfully implementing 3D printing

Most companies will need time and more confidence in the maturity and cost-saving potential of 3D printing technology before embarking on it at a large scale. But companies that move ahead with it now will have an advantage.

The process of becoming a supplier of 3D-printed spare parts requires taking six key steps (*see Exhibit 14, next page*).

- **Analyze your spare parts portfolio.** The analysis should cover key performance indicators that represent the challenge of supplying your current portfolio, including such indicators as days of inventory, minimum order quantity, lead times, and total cost. This is the foundation for building the business case. It also allows you to clearly identify the parts where 3D printing will deliver the biggest benefit.
- **Perform a 3D printing feasibility study.** Begin with a technical analysis to determine which parts within your spare parts portfolio are “printable,” then group the portfolio based on the 3D printing technology needed for each.
- **Challenge existing designs.** If applicable, redesign your parts to unveil the full potential of 3D printing. For example, produce a set of individual parts for assembly as a single 3D-printed part.
- **Develop the business case.** Determine the savings potential of the spare parts portfolio as well as the savings potential of the individual parts as factors in the TCO.
- **Define your 3D printing strategy.** Your strategy should cover the entire supply chain as well as the potential for selling data instead of actual parts.
- **Pilot and roll out your 3D printing strategy.** Pilot projects are essential for testing, improving, and adapting the capabilities and strategy needed to succeed at 3D printing. The selection of the right

pilot programs is important for future funding and management support, and for a company's capability development. Pilot projects will also lay the foundation for the new spare parts supply chain. Rolling out a complete spare parts printing program will transform the manufacturing and distribution of spare parts. As such, it will require a detailed road map and a dedicated execution team.

Exhibit 14
A plan for successfully implementing 3D printing



Source: Strategy& analysis

The case for printing spare parts

An acknowledged expert in the field of 3D printing, Claus Emmelmann has more than 25 years of experience in laser material processing. He is currently the director of the Institute for Laser and Plant Systems (iLAS) at Technische Universität Hamburg-Harburg and CEO of LZN Laser Zentrum Nord GmbH. In 2015, he was nominated for the German Future Award for his joint work with Airbus on 3D printing in the civilian aircraft industry.

In November 2015, PwC Strategy& Germany interviewed Professor Emmelmann about his high hopes for how 3D printing will transform the spare parts business, and the challenges that remain.

PwC Strategy& Germany: Do you believe that 3D printing will become a game-changer in the spare parts business? If so, why?

Prof. Emmelmann: Yes, indeed. I believe that 3D printing will become a common way of producing spare parts. Firstly, because 3D printing improves the short-term availability of spare parts. At the same time, small-lot sizes of spare parts can be produced economically with 3D printing, resulting in new approaches to the pricing of spare parts. Finally, it facilitates the overall logistics of the spare parts business. The business case will be especially strong for geometrically complex parts.

PwC Strategy& Germany: What is your estimate for the percentage of spare parts that will be 3D-printed in five years?

Prof. Emmelmann: For 2015, the estimate for the metal printing market is about €1 billion, but the current

estimates go up to €100 billion in total for the 3D printing market within 10 years. In the near future, I see this market as mostly driven by the printing of spare parts. Hence, within five years we should see 3D printing gaining 10 percent of the market for spare parts.

PwC Strategy& Germany: Why should companies start looking into 3D printing in the context of spare parts now?

Prof. Emmelmann: Besides the reasons I mentioned above, it's obvious that companies can earn money with spare parts when they offer new services based on 3D printing. The possibility of maintaining high availability — as much as 99.5 percent — of machines and equipment in industries such as railways by providing spare parts with a short lead time makes a strong business case for 3D printing. This is why it isn't just the OEMs looking into 3D printing, but their customers too.

PwC Strategy& Germany: Do you see a scenario in which third-party suppliers offer 3D-printed spare parts with short lead times to customers? Are there already examples you can name?

Prof. Emmelmann: Yes, I think it likely that third-party suppliers of spare parts will enter the market using 3D printing. We have clients that are working on such a business model now. The driving forces behind these activities are the rising prices of spare parts and their availability. Even though legal barriers have to be overcome and issues of warranties and the like have to be resolved, in some markets, like China, companies are already getting used to purchasing spare parts from non-OEM suppliers.

(Continues)

PwC Strategy& Germany: What are the top three challenges for 3D-printed spare parts?

Prof. Emmelmann: Quality management, machining productivity, and the business case itself. Since standards still haven't been established, companies have to show that each individual part, and the printing process itself, is able to provide the required physical properties. And the printing process has to become faster, which would make the business case for many parts.

PwC Strategy& Germany: Intellectual property (IP) and copyright issues also have to be addressed. How do you see this issue affecting the rise of platforms on which companies offer printable blueprints, as well as how third-party manufacturers operate?

Prof. Emmelmann: Companies like Amazon and Google are looking into business models based on platforms for

3D printing design files and blueprints. With respect to copyright and IP, it depends on the age of the part. In many cases, IP rights have already expired. In the case of new parts, we see models where IP is shared between suppliers and OEMs, and within these models, the sharing of blueprints is encouraged. IP is certainly an important topic; however, we will see changes in the market in the context of 3D printing as well.

PwC Strategy& Germany: What are your expectations regarding how 3D printing material costs will develop? Is there a trend to a more open, less OEM-dominated market?

Prof Emmelmann: Yes, indeed. The market for 3D printing materials is already changing. Large players like Alcoa are investing in large-scale plants to produce metal powder for selective laser sintering. There will be an OEM-independent market for 3D printing materials in the near future, with the result that materials prices will decrease.

Conclusion

The results of our study of 3D printing indicate that the technology will have a significant impact on the spare parts business. 3D printing will enable suppliers to increase the availability of spare parts, reduce lead time, and decrease costs. And customers see 3D printing as an opportunity to reduce their own costs and increase the efficiency of their operations. Companies that invest in 3D printing today will gain a considerable competitive advantage over those that don't. The key is to start now.

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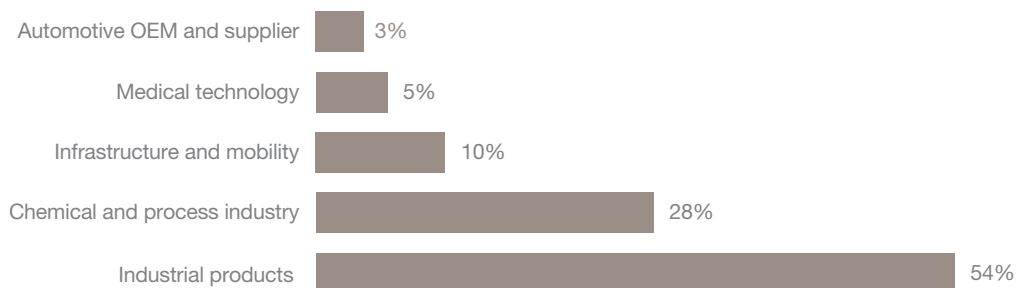
Morten Grunwald, associate, PwC Strategy& Germany, Munich
Melanie Schröpfer, associate, PwC Strategy& Germany, Munich
Karsten Spiekermann, associate, PwC Strategy& Germany, Frankfurt
Laura Gebhardt, senior associate, PwC Strategy& Germany, Frankfurt
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Methodology

In 2015, Strategy& conducted a study called “How and why 3D printing will capture the spare parts business,” in which we surveyed 38 German companies and conducted 39 interviews with their executives. For a better understanding of the market, we surveyed and conducted interviews with both spare parts suppliers and customers.

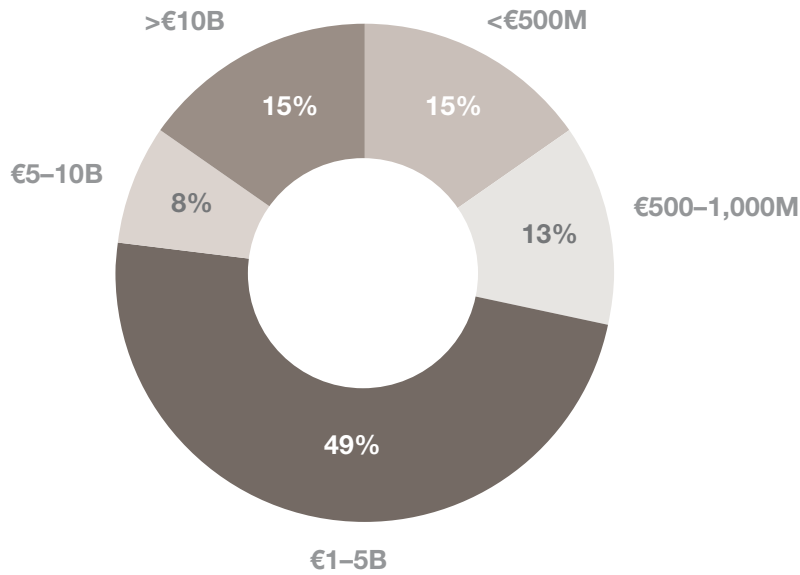
The study focused for the most part on both large and small companies in the industrial products, chemical/process, and infrastructure/mobility industries. Most of the participants from spare parts customer companies came from the procurement and supply chain management functions, while on the spare parts supplier side, participants came primarily from customer service and R&D.

Breakdown of the companies surveyed by industry sector



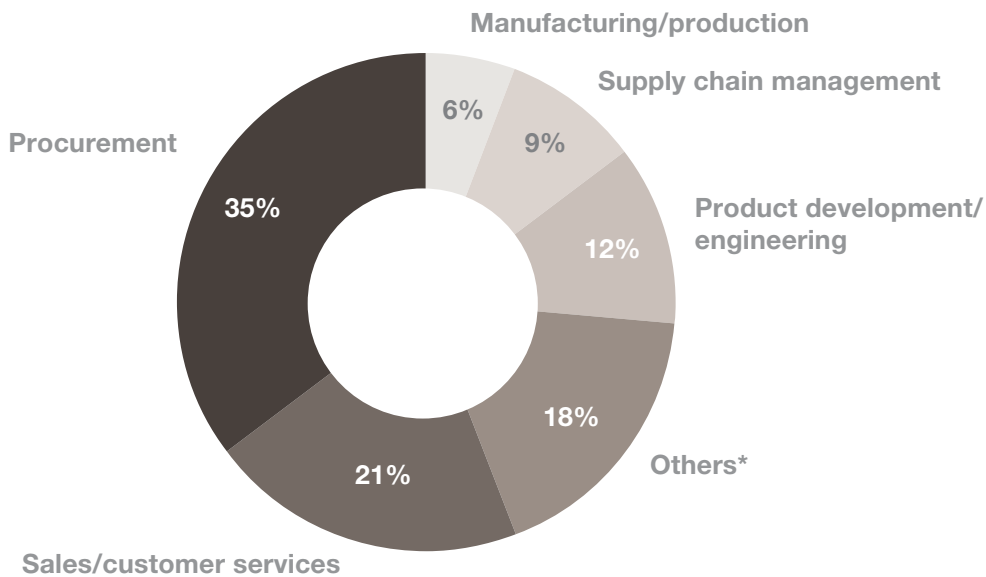
Source: Strategy& analysis

Size of the companies surveyed



Source: Strategy& analysis

Functions of participants



* CEOs, project management, innovation management

Source: Strategy& analysis

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