Technology deep dive: 3-D or 4-D printing

Main opportunities

Description of technology

Additive manufacturing (AM), also known as 3-D or 4-D printing, is the process of joining materials to make objects from 3-D model data, usually layer upon layer.

AM is the opposite of traditional (subtractive) manufacturing, which cuts or hollows out material.

AM can be applied across a range of materials (often including plastics, steel, and ceramics) and industries (often including industrial parts, architectural-scale models, and consumer and medical products).

Technology maturity

Technical maturity — Fundamental research — Mass adoption

Manufacturers expect **6.7 million** 3-D printers to get shipped over the duration of 2020

~10% of current manufacturing processes across industries are expected to be replaced by AM by 2030

Industry applicability

Industry applicability — Niche — Industry cross-cutting

What it enables companies to do

Broader design possibilities

Freedom of design enables products with higher performance, new features, or weight reductions

More customizable products

Customization of products possible at virtually no extra cost while it increases customer value

Production at point of sale or use

Remote manufacturing at location of sale or use increases availability and accessibility of parts, leading to lower working-capital requirements

Reduced OEM dependence

Ability to adjust or remanufacture parts in locations where no suppliers exist or cases in which OEMs have stopped supply (eg, for older machinery)

Higher levels of material and energy efficiency

3-D printing minimizes waste of material or energy, as printed products do not rely on removal process as much as products from subtractive manufacturing

Example use cases

I ***Higher customer value through customizations***
As products become better and more customizable to specific use cases, customer value increases accordingly

II ***Fewer costs due to higher-performing designs***
As product performance increases through new, innovative designs, companies spend less on upgrading and replacing parts

III ***Reduced time to market***
With AM, companies are able to reduce turnaround times and react quicker to market demands, designing and producing a fitting product within a short time frame

Enable new business models
Existing AM-enabled companies can offer printing-as-a-service capabilities; 3-D-design companies can shift toward only supplying 3-D models and let customers print themselves

Source: Expert interviews; *Globalization in transition: The future of trade and value chains,* McKinsey Global Institute, January 2019; McKinsey analysis

Use case deep dive: 3-D or 4-D printing

Proof points

Use case	Situation and approach	Impact
I/II **Better-performing and customizable parts lead to fewer costs and higher customer value**	Global aerospace supplier wanted to improve production of off-the-shelf (OTS) fuel nozzles to meet need for customizable products in large quantities Deployed additive-manufacturing (AM) solution to enable quicker prototyping and more efficient production at scale	Company was able to quickly prototype 3-D-printed fuel nozzle and advance into production at scale AM-produced fuel nozzles are 25% lighter and thus cost less to produce and offer higher customer value through reduced complexity (1 customized part instead of 18 OTS parts) and increased durability (5×)
III **Reduced time to market**	Automotive-part supplier relied on existing OTS assembly tools (eg, clamps, jigs, and supports springs) in its repair work Company wanted to cut down reliance on external tools by 3-D printing them in-house	Supplier ended up producing >30 tools in-house, reducing turnaround time from 30+ days to <5 days Increased tool-production costs on average ~10%,[1] varying by tool complexity, were compensated by faster time to market

1. Costs depends heavily on complexity of tools; simpler tools only added around 3% in costs, while more complex tools added more than 70% in costs.

Source: Expert interviews; McKinsey analysis

Expected technology-development horizons: 3-D or 4-D printing

Expected technology-development horizons in next 5 years

AM for prototyping & niche applications

Companies will mainly use additive manufacturing (AM) for prototyping, toolmaking, and initial stages of direct manufacturing (only on very special products, brackets in aerospace, jet engine parts, and medical devices)

Moreover, application is centered on low-volume, high-price items due to high costs

AM is considered standard manufacturing process in few industries, including hearing aids

Efficient, at-scale AM production

Technology platform will be significantly enhanced to enable an end-to-end technology platform including full software suites—that will allow companies to create critical mass in their parts pipeline leading to business-case development

We will start seeing printer farms emerging and OEMs building own in-house production

There will be a larger breadth of industries using AM and the application space will enlarge to include high-volume, low-price products as well

AM becomes mainstream tech

Operating models defined by industry needs, and tradeoff between speed and costs of AM (eg, highly customized products and services with owned 3-D-printing capabilities, such as new tooth crowns designed, produced, and implemented at a dentist's office)

Various deployment models of AM, including in-house, third-party microplants or using "print as a service"

Expansion of range of materials and qualities from AM, including human tissue, high-performance polymers

Companies embrace co-design/creation for consumer-driven customization

1. LBM (laser-beam melting): high precision, good for components with complex geometry and demanding requirements; EBM (electron-beam melting): similar to laser-beam melting, but additional specific use cases (eg, processing titanium); LMD (laser metal deposition): larger dimensions and higher volumes/speed—useful for repair/cladding as material can be added to existing structure and ability to mix different materials.

Source: Expert interviews; US International Trade Commission (USITC); McKinsey analysis

Enablers

End consumers are demanding more customizable products, which forces manufacturers across industries to both mass produce and individually customize products, which is achievable via AM's flexibility

New product designs emerge with distinct advantages over traditionally manufactured ones (eg, more-complex and greater geometric freedom); AM allows for new complex designs with little extra cost

Innovation in printing technologies (eg, metal tech LBM, EBM, LMD[1]) enables more efficient production at scale with wider range of materials

Emergence of monetization models (eg, pay per part, print as a service) reduces operational and capital costs

Barriers

Currently, limited number of efficiently scalable applications due to high up-front investment in design and prototyping infrastructure

High material costs to achieve quality of traditional manufacturing processes (eg, plastic polymers and sheet-metal materials for AM range between 10× and 200× that of traditional inputs)

Reduced compatibility with conventional manufacturing materials given narrow selection and uncertain properties of inputs required for AM

AM still demands trade-offs between product size, accuracy, and fabrication pace compared with traditional mass-production processes