



3D printing and additive manufacturing (AM)

Dr Robert Martens offers an insight into the disruptive technology that impacts procurement and supply chains.



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Additive Manufacturing

The evolution of 3D printing

Three-dimensional printing, 3D printing, or even 3DP, are layman's terms for the technology officially called Additive Manufacturing (AM), a manufacturing process invented back in 1983 by engineer Charles (Chuck) Hull. Outside business hours, Chuck was searching for a solution that could help him to produce plastic prototypes, faster. Based on the technology of an inkjet printer, Hull invented the machine that created products layer-by-layer. For many years this technology, then often called Rapid Prototyping (RP), was indeed mainly used for that: making prototypes. First users came from automotive and aviation, followed by the implants, hearing aids, healthcare, and defence industries.

Upon the expiration of some essential patents in the 2000s, more competitors entered the supply market resulting in substantial growth of AM equipment availability. Although the primary application of AM was with the do-it-yourself and maker movement platforms, AM has undergone a dramatic transformation, which is still ongoing. Some researchers expect the scale and quality of the AM technology will soon improve sufficiently to enter mainstream markets. For example, General Electric is already investing substantially in AM factories to reduce their dependency on suppliers, extend the lifetime of their aircraft engines, and produce fuel nozzles for their LEAP aircraft engines. These examples show that additive manufacturing has now reached a stage of maturity, enabling the production of industrially made products.

AM technology builds items layer by layer, enabling design freedom and supporting the production of customised products in small series, so uncoupling design and manufacturing, enabling local production that may enable advanced business models and simplified supply chains. Products made using AM are often lighter and or stronger than products created traditionally. Moreover, items produced with AM enhance sustainability as they can be designed lighter, produced locally, produce less by product during the production process and require fewer natural resources. These phenomena have the characteristics of disruptive innovation.

Problem statement

The general business problem is that managers often fail to adapt to disruptive innovations, such as AM, which may result in threats to the existence of their organisations. AM has emerged as a disruptive technology affecting multiple organisations' business models and supply chains, threatening incumbent businesses' health and increasing their risk of obsolescence. This threat is increasing significantly because the world market for products created by AM has grown more than 25% each year over the last 25 years.

The biggest question organisations need to ask of themselves is where can AM add value to our organisation? And when is the best time to invest?

The challenges companies face

In 1997, Harvard Professor Clayton Christensen introduced the *disruptive technology* theory, which he later relabelled into the *disruptive innovation* theory. This concept describes a process where at first people use innovative products or services in uncomplicated situations outside the mainstream application. Next, the disruptive innovators take over the existing market and, in the end, force incumbent companies out.

Often, disruptive technologies initially perform less well than the current ones. Slowly, the novel technology improves, in performance or price, until the demands of the mainstream marketplace are met; this is the

moment the disruptive technology supplants the most prevalent one, and new firms replace nonadapting companies.

Some companies use new technologies strategically to turn them into a disruptive technology. Rather than centring their attention on their products, disruptors put their efforts into establishing a disruptive business model. A typical example of a disruptive innovation is the business model Netflix which was introduced into a market dominated by Blockbuster who were renting out videotapes and DVDs from shops. Contrary to Blockbuster, Netflix offered an online library and delivered movies by mail to customers who did not care to wait. When the Internet enabled Netflix to stream movies instantly, their service also became attractive to Blockbuster's primary customers. Blockbuster's leaders had ignored the disruptive threat Netflix was posing to them and their company subsequently failed.

The emergence of AM technology shows a similar pattern to events covered in the theory of disruptive innovation. Already in the 2013 state of the union address, President Obama stated that 3DP has the "potential to change the way we make almost anything". AM has not yet reached the same level of adoption as traditional production methods, but early indications highlight that AM has ignited the fourth industrial revolution.

AM will make conventional business models and supply chains antique because of its disruptive aspects: no more economies of scale, less capital investment will be required to start producing a broad range of different goods, or the maker movement where consumers become product designers and producers (*prosumers*). Peer-to-peer technology disrupted the music industry. AM's disruptive characteristics could arise from consumers violating IP, like P2P.

To answer the question why "AM", despite the higher cost, it is considered by many to be the next manufacturing revolution, a look at its history is useful: AM originated from the need to create prototypes faster, a requirement not focused on cost but speed. From there, AM has the potential to be utilised for making serial products. Furthermore, when using AM beyond prototyping, users discovered the possibility to create products of unique and complex design.

Benefits of additive manufacturing

AM technology builds items layer by layer, thereby enabling design freedom and supporting the production of customised products in small series. Whereas traditional manufacturing requires careful studying of an article's geometry to understand how to manufacture and assemble it, AM users only need to know how to operate the equipment and what materials to use. Because of local production possibilities, AM enables in-situ maintenance or emergency relief response in difficult to reach places, such areas struck by natural disasters, ships, remote plants, or even space stations. Among the most prominent advantages of AM are advanced product designs, weight reduction, additional complexity, design freedom, and reduction of the bill of materials.

Products made using AM may be lighter or even stronger than products created with traditional manufacturing processes. In combination with the possibility to optimise product design, some companies have achieved remarkable results in improving some of the parts used in their products. Engineers at Airbus used AM to create parts that were 67% lighter, and General Electric redesigned fuel nozzles as one unit, originally consisting of 18 parts, which reduced their weight 84%. Lockheed Martin's joint strike fighter brackets and Airbus' aircraft components are using 90% less energy and weigh 30-55% less.

The impact of additive manufacturing on supply chains

The most prominent benefits for supply chains are new business models such as selling the design instead of the product, customisation or personalisation, fewer suppliers, shorter delivery times, reduction of inventory, and transportation. Resulting from the possibility to combine design with production, AM supports the concept of servitisation of manufacturing and incumbents need to start to develop innovative business models.

AM technology minimises the number of nodes in a supply network and enables localised production of highly customised products in small factories. This reduced complexity decreases the risk of supply chain disruption. Because AM impacts existing supply chains, manufacturing locations will move, consumers will become producers, production activities will be reshored, different workforce competencies will be required, and traditional designs will change.

Assertive customers are demanding faster delivery and more personalised items. The modern manufacturing industry is a highly competitive, global sourcing environment that is encountering increased customer demands for innovative, customised or individualised products. Due to the lifetime of goods reducing, a faster time-to-market is required, and AM can support these needs.

Sustainability

AM enables sustainable manufacturing. Compared to traditionally manufactured goods, AM technology requires less energy when used for producing a small series of items. As AM products need less long-haul transportation, CO₂ emissions are expected to decline. Both aspects could reduce pollution, thereby improving people's quality of life. Furthermore, utilising AM production may shift employment back from developing to developed countries, which could attenuate unemployment rates in deprived areas.

Using AM will help to solve ecological challenges such as scarcity of resources and pollution, as the AM process does not generate waste or scrap. With the sustainability and environmental impact of manufacturing processes becoming increasingly meaningful for business leaders, AM could offer a plausible solution to support waste reduction. However, the net overall effect on the environment of producing highly customised items is not yet clear.

Is your market ready for Innovation?

Novel technologies attract first users because of their different features, such as more natural use or being more convenient, cheaper, smaller, or more flexible than existing technologies. Usually, incumbent firms' most profitable clients are initially not interested in these innovations; so, as a result, disrupters can test their innovative technologies in smaller markets that existing companies tend to ignore.

Christensen discovered that start-up companies introducing disruptive innovations often have leaner organisations resulting in a substantially lower cost structure than incumbents, which even enhances the attractiveness of these newcomers to the market. By the time existing firms realise the threats posed by the disruptive technology, they typically also decide to adopt this technology. Because these established companies are often too late or unable to offer comparable price levels, they quickly lose market share. Through continuous technological enhancements, these disruptive innovations swiftly become attractive to the higher-value marketplaces.

The term disruption has an alarming connotation among business leaders, but managers can test if the theory is useful for their situation. To determine an innovation's disruptive potential, business leaders need to identify three areas:

- (1) does a large group of potential consumers exist who currently are constrained to buy this product or service,
- (2) is there a population interested in buying this product or service at a lower price and accepting a lesser performance, and from this, is our firm able to create a profitable business model,
- (3) is this innovation disruptive to all incumbents?

Conclusion

When faced with an industry disruptor, managers need to know how to respond. Three possible reactions to a disruptive innovation threat exist: beat, join, or outwait the disruptors. Managers are warned of the danger of not recognising and adequately responding to new technology. Just think of now-obsolete technologies: typewriters, tape recorders, VCRs, or floppy disks. The impact of AMs technology should not be underestimated. Therefore, managers and policymakers need to start considering the disruptive effects of 3DP to their business and to society.

Further reading



Dr Martens' doctoral study, *strategies for adopting additive manufacturing technologies into business models* is available in book print or PDF from the author at: info@3dstrategies.nl



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