Abstract

In recent years 3D printing technology is developing rapidly. In the near future, when 3D printing will be widely used, the world’s industrial structure will be greatly changed. As 3D printing becomes more integrated in manufacturing, it is easy to conclude that logistics should be influenced as well. 3D printing could bring massive changes to manufacturing processes and logistics functions, such as: global logistics, inventory levels, fulfilment process, stock location, transportation routes or consumer relationships. This article will briefly describe the technology of 3D printing, application possibilities in logistics and its impact on the Supply Chain.

Key words

3D printing, additive manufacturing, supply chain

INTRODUCTION

From engineering to automotive to healthcare, companies are recognizing that 3D printing presents an opportunity to “do things differently”. It allows us to profoundly rethink the way we create and manufacture products, as well as fundamentally reassess the design of supply chains.

3D printing have potential for revolutionize manufacturing, enabling companies to produce almost anything, layer by layer within the boundaries of a single 3D printer. 3D print technology makes it possible to create nearly any geometric form with the help of design software – incorporating hollow spaces and filigree honeycomb structures, for example, that are much lighter than traditionally manufactured components, but offer the same stability.

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Manufacturers from all industry sectors are exploring which items they may be able to produce using 3D print technology, and logistics service providers are launching pilot projects to identify the need, potential and options for adjusting their business models to include 3D print services. Increasing number of companies beginning to realize, on the one hand, the possibility for new 3D printing business models and services and, on the other hand, the major economic advantages of 3D printing compared to conventional manufacturing techniques.

1 WHAT IS 3D PRINTING

3D printing, technically known as additive manufacturing (AM). 3D printing is an additive technology used for making three dimensional solid objects up in layers from a digital file without the need for a mould or cutting tool. 3D objects are created by a highly specialized printer, which prints successive layers of a material from the bottom upward in a continuous fashion. In essence, each layer is a cross section of the finished product.

Three basic ingredients are essential for creation of an 3D object [1]:

1. **A digital model** – this is the digital design information needed to print an object. Digital models can be created from scratch using design programs such as CAD (Computer Aided Design) or by using a scanner to capture a 3D virtual image of an existing object. Slicing software automatically transforms virtual model into hundreds or thousands of horizontal layers, depending on the size and structure of the object (fig. 1).

2. **Feed material** – this is the material that is used to ultimately manufacture the final object. Materials are joined in successive layers one on top of the other through additive processes under automated computer control.

3. **A 3D printer** – this is the hardware used to create the solid object out of the digital model and feed material. 3D printers come in various forms utilizing different additive techniques to produce the object. Selection depends on whether the application is for consumer or enterprise purposes.

![Fig. 1 Generalized additive manufacturing process](image_url)

Source: Campbell T, Williams C [2]
The 3D object is printed, not with ink, but with a wide variety of materials. Material is added layer by layer instead of molding or cutting or bending materials. In recent years 3D printing technology continued developing, especially the breakthroughs in the material application. More than one hundred of raw materials can be used for 3D printing. Some of the most common materials used include plastics, glass, metal, polymers, wax, sand and glue mixes, nylon, ceramic, edible material, and even human tissue. The expansion of the material type will promote the application of this technology in more productive areas. Nowadays this technology could be used to produce spare parts, singular parts, bioconstructs, micromachines, electronics, and even jewelry. [3, 4]

### Additive technologies

The term “3D printing” covers a range of additive technologies that apply different approaches. Today there are to choose over ten different 3D printing technologies. But mainly three technologies are used. These are selective laser sintering, fused deposition modeling, and stereolithography (fig. 2).

- **Stereolithography (SLA)** uses a moving laser beam to build up the object, layer by layer, from a liquid polymer that hardens on contact with the laser’s light. SLA is well established for rapid prototyping applications.

- **Selective laser sintering (SLS)** uses lasers to melt powdered feed material into the desired object. It is most established in professional and industrial contexts as it also allows the printing of metal-based materials.

- **Fused deposition modeling (FDM)** is the most widely adopted and user-friendly 3D printing technology and the one that’s most familiar to consumers. FDM printers use hardened feed material (usually plastic on a coil) which is then fed into the printer and melted layer by layer to produce the final object.

![Additive technologies SLA, SLS, FDM](source)

**Fig. 2 Additive technologies SLA, SLS, FDM**

2 IMPLICATIONS FOR SUPPLY CHAINS

With traditional manufacturing, materials are usually sourced and shipped from several locations to centralized factories that develop and assemble the final product. The finished goods then pass through several steps in the supply chain, usually being stored in warehouses before delivery to stores or directly to the end-customer once an order has been placed.

3D printing, in contrast, can greatly reduce complexity in manufacturing and holds a number of additional advantages over conventional production techniques.

Key advantages of 3D printing:

- Lower number of production steps to design, prototype and manufacture highly complex and/or customized products
- Faster delivery time through on-demand and decentralized production strategies
- Lower logistics and production costs (e.g., reduced shipping and storage costs, potential elimination of import/export costs through localized production, elimination of new production tools and molds and costly modifications to factories)
- Higher sustainability and efficiency in production through using the least amount of material and energy in production

A major benefit of 3D printing is the ability to produce a variety of products from a single 3D printer. This reduces the number of steps in the production chain, essentially enabling companies to leverage on-demand and decentralized production concepts. As a result, potentially significant economic savings can be made on logistics and production costs. It is relatively clear that 3D printing will not be used to mass produce anything and everything. The greatest potential of 3D printing technology’s lies in its capability to simplify the production of highly complex and customizable products and parts.

Spare parts on demand

At present, hundreds of millions of spare parts are kept in storage all across the world to service products. Although most spare parts warehouses have a high proportion of fast-moving items, many items will rarely be used and some may never actually be needed. Not only is it costly for companies to store this unused stock but it also builds inefficiency into the supply chain, as excess inventory is being produced with no guarantee that all parts will ever come into use.

Thanks to 3D printing, companies may no longer need to store spare parts physically in a warehouse. Instead, they can print these parts on demand, where required, and rapidly deliver these items to the customer. In order to achieve coverage and efficiency in lead-time reduction, logistics providers could support companies in creating a dense network of 3D printers to instantly print and deliver spare parts on demand.

The virtual print files of spare parts would be securely stored in software databases that essentially act as a “virtual warehouse”. One organization that has already developed and implemented this type of virtual warehouse concept is Kazzata. The company aims to provide an online marketplace for spare parts, effectively establishing a CAD repository for obsolete and rare parts. [6] When a part is required, users can simply search for the right part and send the file to the nearest 3D printer.
Each logistics provider can achieve economies of scale by building up an owned network of shared 3D printers located in warehouses and distribution centres around the world. In the same way as many companies today provision spare parts to a third-party logistics provider, in future companies will be able to entrust their logistics provider to efficiently process, print, and deliver spare parts orders in a fast, low-cost manner.

3D print shops for businesses and consumers

Businesses and consumers can also use future networks of 3D print shops for a variety of applications. In the consumer context, one application could be for companies to retrofit their many service points or retail points with a 3D printing infrastructure. In essence, this would allow them to offer local communities access to state-of-the-art 3D printing services. The root of this concept is not new; it would work in a similar way to how consumers currently print paper documents by taking a file on a USB drive to their local copy shop or print photos at a photo kiosk in stores. Looking into the future, these 3D print shops could eventually integrate not just 3D printers but also design tools and scanners, as well as a wide selection of materials.

3D print shops like this could also be used by companies to rapidly prototype new products without having to invest in and maintain the latest 3D-printing infrastructure. These facilities could also serve local businesses such as architects and small design studios that need to produce 3D models, as well as craftspeople creating tailor-made items for their customers. Personnel working inside 3D print shops will be trained to offer varying levels of support to match each customer’s 3D printing skillset. And because the printing process itself can take some time, the 3D print shop could also offer a delivery service to its customers. To enable a 3D print shop, key success factors will be the ability to provide a range of printing materials and low operating costs. Generalized processes in traditional and 3D printing supply chain see Fig. 3.

![Fig. 3 Supply chain with 3D print shop](image)

Source: A. Wieland, [7]
Individualized direct parts manufacturing

There are many exciting examples of companies in aviation, automotive, healthcare, and other industries using 3D printing to produce individualized parts.

When customers require high levels of customization, 3D printing can represent a source of competitive advantage for the organization; companies are incentivized to create tailored parts that can be delivered quickly to the point of use.

One of the future vision is the idea of manufacturing individualized parts not in a stationary location such as a warehouse but in a moving vehicle. This can additionally reduce delivery lead times. Amazon, for example, has filed a patent for a truck fitted with 3D printers, with the intention of manufacturing products on the way to a customer destination. At scale, this could enable companies to produce parts very close to demand and thereby drastically reduce the lead time of individualized parts delivery to customers. [8]

3 POTENCIAL IMPLICATIONS AND CHALLENGES

The following summary highlights some of the key potential implications of 3D printing for logistics and transportation (in no particular order of priority or significance). [9]

- A shift to more localized production, resulting in more on-demand manufacturing and smaller inventories.
- Supply chains and distribution networks for certain types of goods will disrupt both national and international trade.
- Transportation providers will need to become more flexible and agile to adapt to changes in logistics and the supply chain.
- Capital projects and investments in transportation facilities may need to be re-prioritized to reflect shifting changes in logistics and the supply chain (i.e. less emphasis on ports).
- Centralized manufacturing in Asia and Latin America will shift toward smaller hubs near end users.
- More products will be manufactured in customers country, reducing long-distance distribution and a likely decline in the cargo industry.
- Truck traffic patterns may shift toward smaller vehicles, with an emphasis on regional or local deliveries, and lesser long-hauls.
- Lower costs and less difficulty of procuring hard-to-find parts and supplies for transportation providers and fleets.
- Deliveries of finished goods may decline, while shipments of raw materials might rise. This could mean reduced infrastructure requirements, as some products currently manufactured overseas shift to domestic production.
- Wear and tear impacts on transportation infrastructure could be reduced, but may be partially offset by more local deliveries with smaller vehicles.
- The service part industry will be replaced in part by portable 3D machines and operators.
- Third party logistics providers will be impacted by growing numbers of businesses printing on demand.
- Portions of the retail sector will become only store fronts with no inventory, or will cease to operate.
- Continued growth in companies specializing in 3D printing service providers.
- New safety standards and industry regulation likely to be instituted.
Following are the key areas in supply chain and logistics likely to be impacted by 3D printing technology:

- **Rationalization of inventory and logistics:** Logistics will adjust to print on demand, eliminating the need to carry inventory
- **Resource efficiency:** Material saving during production and ability to utilize recycled materials
- **Customer demand will be met more quickly:** Reduction in manufacturing lead time and strategic near-shore manufacturing facility
- **Customization:** Tailoring individualized offers to each customer, involvement of client in design, and providing ability to test prototypes
- **Global Logistics:** Reduction in cost of international logistics by reducing overseas manufacturing thus decreasing quantity of air and ocean freight and brokerage cost

The supply chain traditional model is founded on traditional constraints of the industry, efficiencies of mass production, the need for low cost, high-volume assembly workers, and so on. But 3D printing bypasses those constraints. From that point of view, the traditional model stops making sense. It is no longer financially efficient to send products zipping across the globe when manufacturing can be done almost anywhere at the same cost or lower.

However, disruptive technologies come with challenges. Following are challenges for 3D printing:

- **IP Issues** – Authors of digital design templates could be targeted by hackers and incur copyright infringement.
- **Security Concerns** – For example, when printing harmful objects such as a knife, gun etc., which party would be held responsible?
- **Liability** – For example, who is to blame if a 3D product fails: the company printing and selling it, the material supplier, the printing machine manufacturer, or the designer?
- **Mass Production** – It cannot compete with the speed of traditional manufacturing process.

**CONCLUSION**

Of course, not all products and parts can and will be 3D printed. Therefore it will be essential to understand early on where 3D printing will be advantageous to manufacturing and supply chain strategies.

3D printing is likely to complement rather than entirely substitute traditional manufacturing techniques. Simply put, not all products can and should be 3D printed. However, 3D printing is likely to substitute traditional manufacturing in industry segments that produce highly complex and customized goods. This is, in fact, already happening in aviation, automotive, and medical and healthcare applications. To achieve wider application and adoption, companies must collaborate and innovate in order to overcome 3D printing’s remaining challenges – such as speed of production, cost, and limited material inputs.

In logistics, 3D printing will play a much more prominent role in the areas of spare parts logistics and individualized parts manufacturing. As manufacturers adapt their production
processes and supply chains, this will open new opportunities and will also challenge logistics providers to find new customer solutions.

To understand the full implications of 3D printing in a company’s supply chain, it is necessary to consider each company’s operating environment, manufacturing capability, customer needs, and product portfolio.

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