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3D Printing effects on supply chains: lead-time, inventory and transportation
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In *The Printed World,* the Economist describes how additive manufacturing (AM or 3D printing) begins with a digital 3D image. A 3D printing program slices the digital image into thin layers. This allows the 3D printer to begin making a replica as it prints layer-by-layer until the final product if realized. The additive process is unlike the subtractive process of cutting and drilling because the printed object is ready-made and requires no further assembly. Advances in 3D printing technology have expanded the materials 3D printers can use—plastics, metals, ceramics, nickel chromium, cobalt chromium, stainless steel, titanium and polymers (Mavri). Software programs allow designers to instantly change designs and send them to 3D printers anywhere in the world. Products that face the greatest threat from 3D printers have high shipping costs, are sold in low volumes or require a high degree of customization—footwear, toys, electronics, auto parts, ceramic parts, plastics, glass, aircraft parts and guns (Schmahl). 3D printing has the potential to disrupt supply chains by reducing lead-time, inventory and transportation costs.

In "Redesigning a Production Chain Based on 3D Printing Technology", Marvi describes how 3D printing will reduce lead-times through simplification of the production process. 3D printed objects are either final goods or components for a final good—they are ready for use. According to Marvi, "work centers and parallel work flows will be eliminated because manufactures will be able to print finished goods that do not require sub-procedures". In *Additive Manufacturing: Making Imagination the Major Limitation,* Zhai explains how lead times attributed to retooling and casting are eliminated. Since a 3D printer's head does not need an adjustment to print different objects, manufacturing plants can immediately change the object being produced by uploading new design and clicking "print". Lead-time currently required creating molds and re-tooling is eliminated.

According to Petrick, since finished products can be produced locally on demand, warehousing inventory will decrease or be eliminated. In "Redesigning a Production Chain Based on 3D Printing Technology", Mavri argues that companies will shift from a push to pull strategy—printing finished goods only after receiving the customer order. The recent UPS and Stratasys (3D printing company) partnership is evidence of further disruption to the traditional inventory-warehousing model. This partnership allows customers to send designs of an object to a UPS location that will then use a Stratasys 3D printer to print the object. The customer can pick up the 3D printed object once it is printed or have it shipped—eliminating inventory and safety stock entirely (Petrick).

Historically, supply chains have relied on the transportation industry to facilitate the

movement of intermediate components around the globe. (Bresinger). 3D printed products can be designed to reduce the number of components required in the assembly of the finished product. For example, Local Motors is experimenting with a 3D printed car body, the Strati. A traditional car requires thousands of assembles parts, whereas the Strati requires only 50. In another example, GE redesigned its Airbus A32 LEAP jet engine fuel nozzle from a 20-piece traditionally manufactured unit to a one-piece 3D printed unit. Since GE plans to produce 25,000 fuel nozzles for Airbus, the streamlining of the components represents a decrease of 475,000 component parts (19 x 25,000) (Wray, pg. 20). According to Schmahl, "41% of air cargo and 37% of ocean container shipments and 25% of trucking freight business are threatened by 3D printing". The loss for the transportation industry will be a gain for supply chain managers and consumers capable of printing goods on commercial and home 3D printers.

Shipping costs for replacement parts will also decrease. In the "Out of the Box", the Economist describes how businesses that owns a 3D printer, can download a digital design and print any object on site—eliminating the ordering and shipment of replacement parts. The Economist envisions a domestic appliance repairman downloading and printing a replacement part in his/her van while on a house call. Even when there is no original design file for a replacement part, clever software allows for reverse engineering. According to Mavri, a broken part can put through a 3D scanner to create a 3D image. That image is used by a 3D printer create a duplicate without the defect. Reengineering in this way has already given classic-car restorers the ability to print replacement parts that manufacturers no longer sell.

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