IBM Institute for Business Value

Shifting transport paradigms

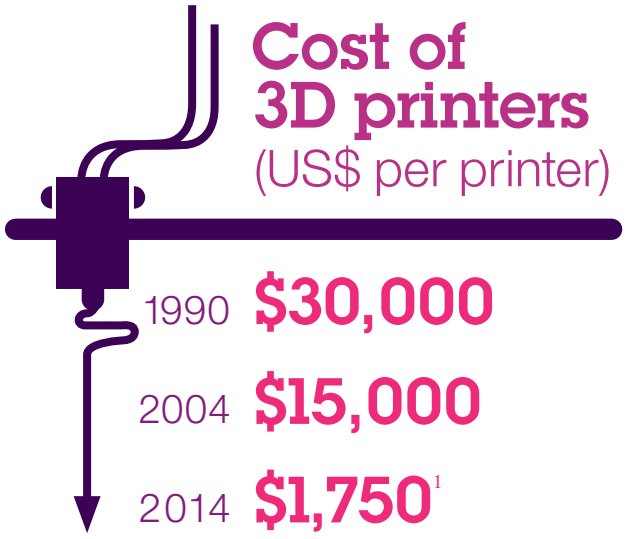
Understanding the implications of 3D printing on the global transportation industry

Turning travel and transportation challenges into opportunities for excellence

To succeed in today's hyper-competitive world, travel and transportation companies need to solve increasing complex problems and seize new and exciting opportunities faster than their competitors. They must continue to drive operational excellence and enable collaboration across enterprise functions and between members of emerging ecosystems. Above all, industry leaders must run the business well amidst constant change. The IBM Travel & Transportation practice understands these challenges and brings its extensive industry experience, business insight and technical prowess to bear on these challenges everyday.

By Steve Peterson, Mark Bedeman and Daria Godunova

3D printing is a hot topic in many industries and a source of uncertainty. From the perspective of transportation providers, however, if just one industry—or even a small portion of many industries—embrace 3D printing, it could have profound impacts on size and shape of demand for transportation services. This report uses scenario envisioning to examine the potential impacts of 3D printing and provides insight into how transportation providers from all geographies and sub-segments can capitalize on this rapidly emerging technology.



The pillars of modern consumption, design, production, transport, selection and final delivery, are inexorably linked. The practical constraints inherent in each step in this chain of activities are inherited by the entire process. For this reason, beautifully designed plans that cannot be built are about as commercially useful as masterfully crafted products that cannot be not delivered. This fact gives rise to the demand for transportation services of all sorts—for moving raw materials, transporting intermediate goods and parts, and, of course, for delivering finished goods to wholesales, retailers and consumers who buy them.

Another more subtle consequence of this deep interdependence is that radical leaps forward in any one of these pillars have the potential to dramatically impact the others and change the way the whole system of consumption works. On its face, 3D printing could change the fundamentals of modern consumption and alter the role transportation companies play within it.

The printing press and assembly line production had step-change impacts on production, and both of these developments eventually resulted in radical changes to the way products were designed, selected and delivered to consumers. 3D printing, which translates digital designs into physical objects, is an intriguing development because it is one of the few categories of technological development with the potential to change several of the pillars of consumption. As depicted in Figure 1, the shift in customer control over each aspect of the consumption process changes significantly if 3D printing becomes more prevalent.

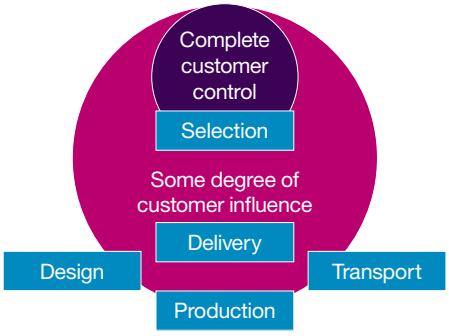
It is, of course, impossible to know precisely how 3D printing may evolve in the next several years, but considering the potential impacts of this technology to consumption and to global supply chains, it seems prudent to explore the possibilities. This report employs scenario-envisioning methodology to examine the theoretical and practical possibilities of this disruptive development, so that transportation providers can capitalize on the opportunities 3D printing may bring to the industry.

New methods of production reveal new possibilities and trade-offs

A 3D printing-based production process circumvents many of the challenges and limitations of traditional manufacturing, especially those that lead to trade-offs between production and design and between production and transport. While 3D printers cannot make every imaginable product, the inventory of what can be produced is astonishing. 3D-printed products include those made from materials as diverse as plastic, metal and human tissue, and as complex as replacement joints, consumer clothing and engine parts. The number and complexity of products continues to grow rapidly.

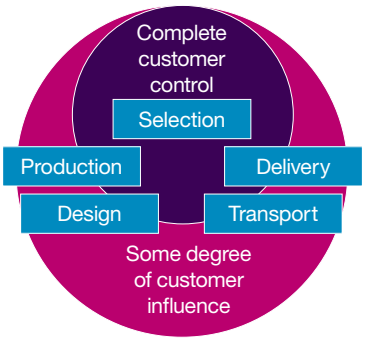
3D printing provides opportunities to improve upon the limitations imposed on the normal product cycle by traditional production processes. Even after centuries of refinement, traditional manufacturing is defined, in part, by trade-offs. While the products we see in the world today offer a dizzying array of selection and complexity, their designs are, in part,

Current manufacturing paradigm



- Consumers have limited influence over design
- Production and transport decisions are made by companies, not consumers
- Customers select available products and specify delivery preferences, but companies control most of the supply chain

3D printing-enabled production



- Consumers become much more deeply involved in design and production
- Transport and delivery of 3D printing cartridges are influenced by customer decisions
- Customers enjoy complete control over selection

Figure 1: 3D printing has the potential to change the manufacturing paradigm by giving customers more influence over design, production and distribution.

Source: IBM Institute for Business Value.

limited by the constraints of both transportation and production. For example, cost and complexity often doom promising products before they leave the design stage; product features that are too costly or difficult are left "on the design room floor." Similarly, weight, repair and packaging decisions in traditional manufacturing are all influenced by transport considerations.

Specific to transportation providers, what are some of the potential long-term ramifications of 3D printing? How will it impact customer interactions, business models and supply chains? We understand that, with such a revolutionary technology that has, as yet, much untapped potential, a specific future cannot be predicted. However, we are able to predict possible future developments in this new and rapidly developing landscape by using scenario envisioning.

3D printing benefits are worth pursuing…

Most analysts and market participants are unified in their optimism about the potential of the 3D printing market. In 2012, the market for 3D printers and services was estimated to be worth US$2.2 billion, but is expected to reach $6 billion by 2017 and $8.4 billion by 2025. Whatever form 3D printing takes, it is clear that it is, and will continue to be, big business.[2]

But some of the most transformational changes that 3D printing promises to bring to modern production relate not just to the production process improvements, but also to their outcomes. 3D printing opens up new possibilities in product design, quality control and labor investments (see Figure 2).

Design innovation is possible because 3D printing is a new way of producing goods. Not only are new single-piece goods and components easy to produce, specific materials, colors and other customizations are enabled through 3D printing, which make it relatively easy to alter outcomes by adjusting inputs.

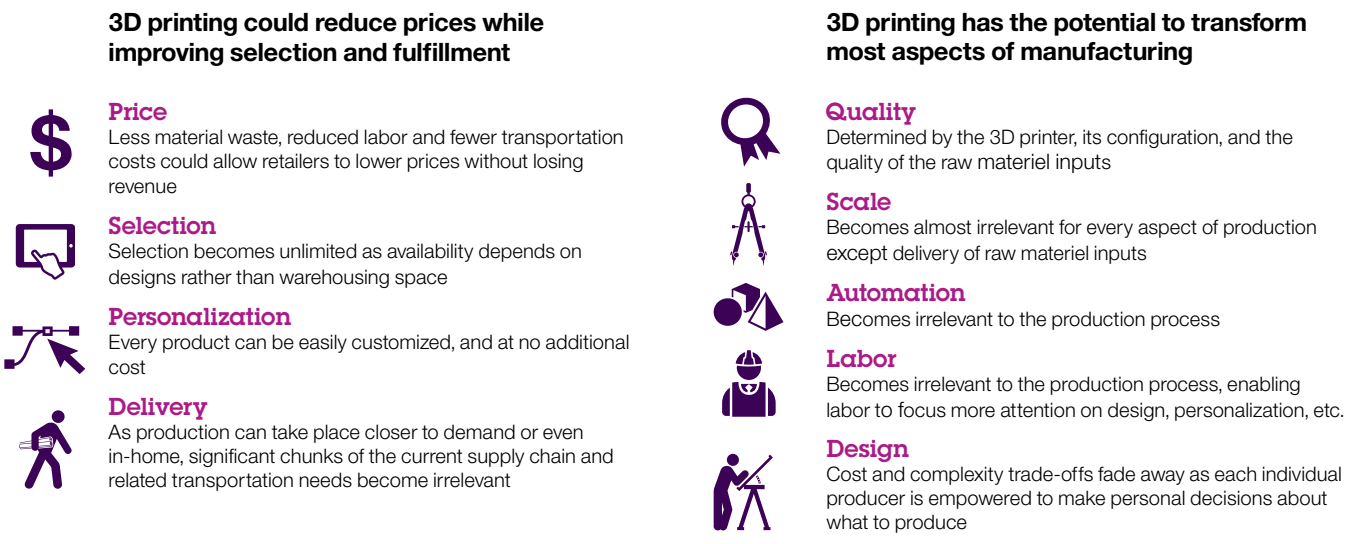


Figure 2: 3D printing could diminish the importance of manufacturing location, which would have profound impacts on transportation.

Source: IBM Institute for Business Value.

Quality enhancement is enabled through 3D printing in two ways. First, whereas traditional manufacturing requires significant testing, adjustment and process control to bring about high quality, 3D printing quality is a result of the equipment and materials used and the quality inherent in the product's design. In other words, with 3D printing, quality control teams could become optional.

The prices of 3D printing are significantly higher than traditional manufacturing today, but that, too, may change. 3D printing reduces, and often eliminates, waste. It also reduces transportation costs. Once the necessary 3D printing cartridges and printers are in place, production can begin and end at or very near the final point of use or purchase. Ultimately, 3D printing has the potential to reduce the costs of many products.

Because 3D printing can occur on such a small scale, there can be a far greater degree of customer-driven personalization. Despite the dizzying array of products available today through traditional manufacturing methods, 3D printing promises to significantly increase the level of personalization and selection by letting each customer imprint products with not just their own color schemes, monograms and messages (all of which are available today), but also with their own custom-designed features, enhancements and variations. In these ways, 3D printing might soon enable mass personalization, a concept that has been bandied about for decades, but has remained more of a theory than a real-world transformation.

…but many persistent challenges remain

Of course, 3D printing it not on a clear trajectory to overturn the decades of development and investment in traditional manufacturing and the robust supply chains that support it; there are significant impediments that must be overcome before its future will be secured. One such impediment is the potential of governments to impose a sea of regulations and provisions that raise costs or tighten controls. Such efforts seem unlikely, given the wide-ranging governmental support for 3D printing, including non-trivial investments and incentives in place in many countries today.

3D printing was initially limited to only a few printable materials with relatively low levels of complexity. Today, however, technological developments are quickly removing these barriers. Modern 3D printing technology can now print materials as diverse a plastic, tissue and gold in complexity that might soon rival that of large-scale manufacturing environments. This is because 3D printers can print very small and intricate pieces as one unified whole, which reduces the number of small parts that must then be assembled to produce finished goods.

One obvious factor that will influence the extent to which 3D printing remains a niche solution for a relatively small number of companies and customers, or a revolutionary one that disrupts the status quo for the masses, is the cost of the technology. In 1990, when 3D printing was in its infancy, Polylactic Acid printers, which used biodegradable plastics, and Acrylonitrile Butadiene Styrene, which used mostly oil-based plastics for printing, cost upward of US$30,000 per printer. By 2004 those costs had fallen to $15,000, and today the equivalent technology can be obtained for $1,750.[3] Cost must continue to fall if 3D printing is to continue to have significant and widespread impact.

In traditional manufacturing, once materials are extracted and refined, they are shipped elsewhere for intermediate processing, which involves the development of sub-assemblies and other parts. All parts must then be shipped to one location for final assembly, so finished goods are often assembled far away from their final destination. Similarly, warehousing, packaging and final retail sale all add to the price of final goods in the traditional manufacturing chain. Finally, consumers often buy the goods from a store (or online storefront) and then transport the product to their homes or other final-use locations. In simple terms, 3D printing cuts out at least three transportation events and up to two steps in the production process.

The existing supply chain, with all its inefficiencies, is deeply entrenched. More important, 3D printing production, while more efficient and straightforward in theory, is not yet supported by its own supply chain. This gap may actually be an opportunity for transport providers, which can play a vital role in positioning inputs and products where they are needed in a 3D printing-centric supply chain.

Four distinctly different futures for 3D printing

The first and most important step in effective scenario envisioning is defining the right axis of change. These axes define the range of futures that may develop over time and are typically among the most important areas of uncertainty for the chosen subject (see Figure 3). In this case, the impacts of 3D printing to commerce in general, and to transportation companies in particular, will be influenced by: 1) the speed at which the underlying 3D printing technologies develop and; 2) the reaction consumer markets have to 3D printed products. Using these simple axes as our baseline, we envision four distinct future scenarios for 3D printing (see Figure 4).

Two organizing assumptions we made at the outset are that technological innovation in 3D printing will not slow, and that consumers will not recoil against 3D printed products. For this reason, our most moderate scenario is an extension of the status quo, called the "quiet evolution," with the general 3D printing developments maintaining their current course and speed.

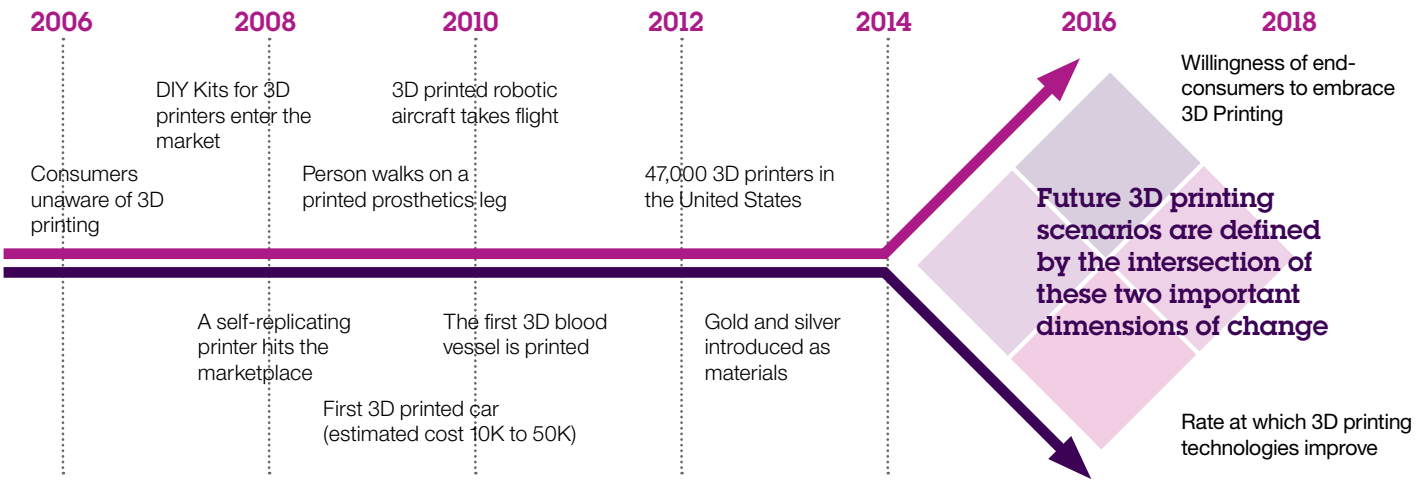


Figure 3: Scenario envisioning methodology predicts the implications of 3D printing for the global transportation services sector.

Source: IBM Institute for Business Value.

At the other extreme is the scenario defined by extremely rapid technology developments and consumers eager for 3D printed products. We dubbed this scenario the "reinvention of consumption" because big changes made to any of the pillars of consumption almost always change the entire system in significant, if unpredictable, ways.

Less extreme scenarios are defined by moderate and rapid technology innovations and swift and moderate changes in consumer acceptance of 3D printed products. In one of these scenarios, the main impacts of 3D printing are likely to manifest in a "manufacturing revolution" where companies recognize the power of 3D printing to alter product design and production, but choose to shield reluctant consumers from these innovative development methodologies. Alternately, if consumer acceptance moves forward more quickly than the underlying technologies that make 3D printing work, consumers will lead the way into this new future. In this scenario, 3D print shops will emerge to slake consumer appetite for this new technology, but many manufacturers may continue to pursue 3D printing innovations somewhat reluctantly. For this reason, we call this the "print shop revolution" scenario.

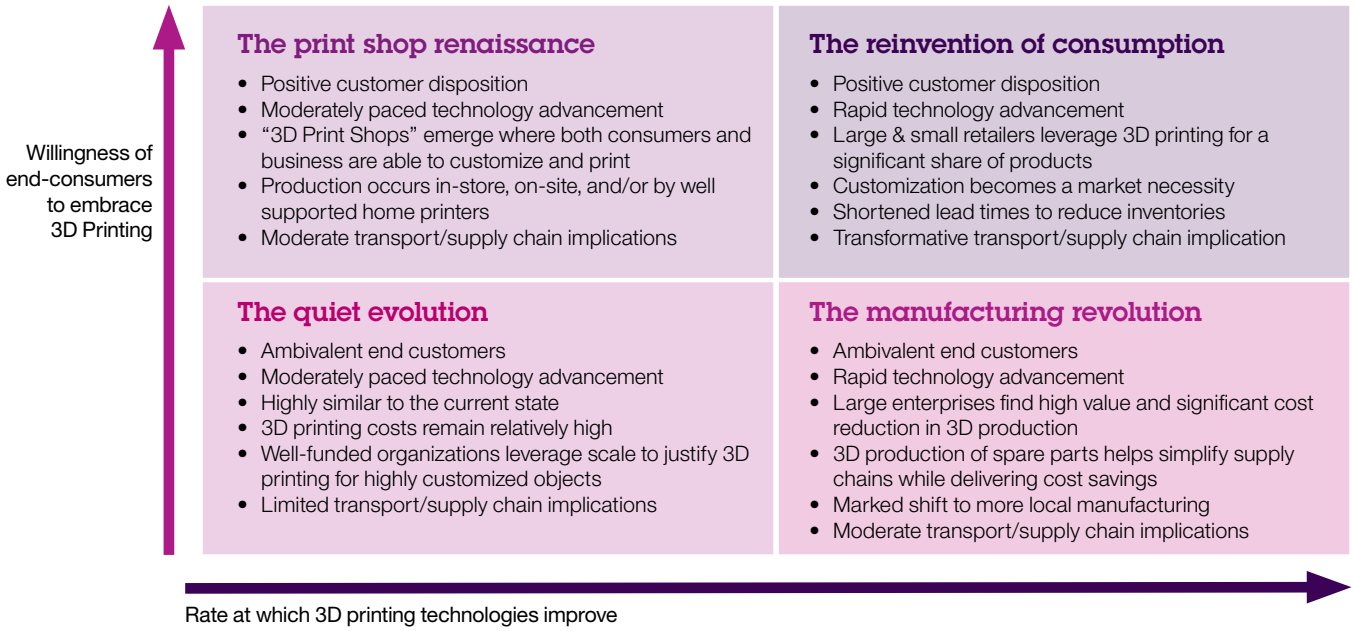


Figure 4: Four possible scenarios occur, according to varying rates of technical improvement and levels of customer acceptance of printed goods.

Source: IBM Institute for Business Value.

The quiet evolution

In our most mild 3D printing scenarios, we expect 3D printing technologies to develop at about the same speed, and in the same direction, that they have in the past several years. Similarly, consumers are expected to embrace 3D printed products with a similar level of interest as they do today. For this reason, this scenario results in an evolution toward a future with more 3D printed products, but traditional manufacturing continues to dominate consumption, as 3D printing maintains niche status (see Figure 5).

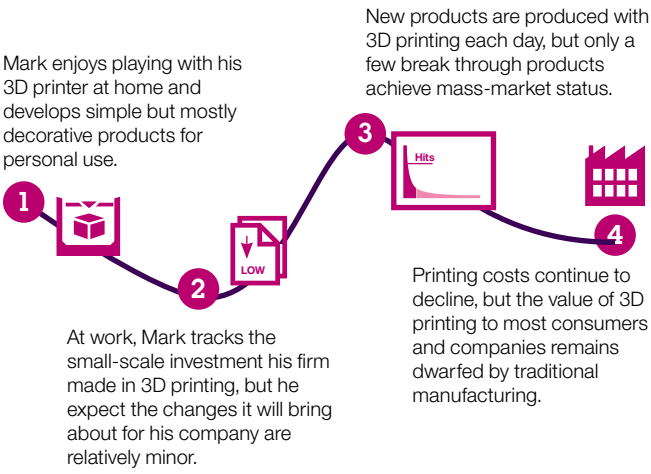


Figure 5: This scenario most moderate of future states will come about if the current speed and direction of change in 3D printing remain constant.

Source: IBM Institute for Business Value.

But the future looks very different if we change just one of our two variables. In a future in which consumers develop a hunger or preference for 3D printed products, even if the technology only continues to evolve as it has in the past, it is easy to imagine the market organizing to satisfy these needs.

In this scenario, one we call the "print shop renaissance" the future is a more significant departure from the current state. Under these conditions, specialist 3D print shops emerge that enable consumers to leverage the presence of large and still somewhat expensive 3D printers in the local communities to custom produce products on their behalf. 3D print shops become the hub of production for a large number of consumer goods. As a result, the transport networks around these centers of activity would adjust accordingly.

The print shop renaissance

In one of the four scenarios we forecast for the 3D printing market, consumers primarily experience 3D printing through their local print shops. These hubs of production house 3D printers of all sorts and are staffed with people who can help consumers adapt their designs, select materials and print their products. Pick up and delivery of final products, as well as the delivery of raw materials and 3D printer cartridges, is a clear opportunity this scenario creates for transportation companies (see Figure 6).

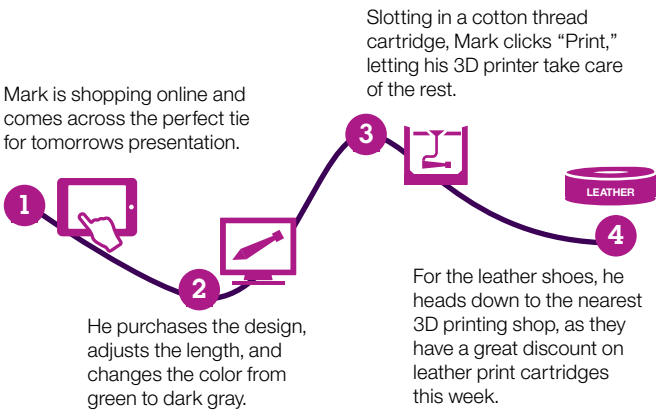


Figure 6: A dominant player in the 3D print shop market could arise from a wide range of industries by enabling customers to direct their own 3D printing.

Source: IBM Institute for Business Value.

The third scenario is all about 3D printing technology and what large companies can do with it. In this scenario, consumers are not much more willing to buy 3D printed products than they are today, but the technology itself has advanced to the point that it can revolutionize manufacturing, which is why we call this scenario the "manufacturing revolution."

The 3D printing-enabled manufacturing revolution is made possible by quick and significant advances in 3D printing technology such that large companies enjoy substantial value in the incorporation of 3D printing into their traditional manufacturing processes. For some companies, this could take the form of spare parts printing on demand, in the locations in which the parts are needed. And for other companies, 3D printing might allow them to rethink their entire development process, as well as the supply chain they have developed to support it. Final assembly gets closer to the point of use of distribution in this scenario, so transportation companies become less critical to the movement of finished goods.

Predictably, the most significant impacts on the consumer markets, and on transportation companies that serve them, come in the fourth and final scenario—the one in which both 3D printing technologies and consumer preferences shift significantly. In a world in which consumers prefer 3D printed products and in which the underlying technologies enable the most complex conceivable product printing at low costs, a substantial portion of what we consume would be made with 3D printers.

In this radical, if less predictable, scenario, retailers and their suppliers turn to 3D printing as a matter of course. Local production of finished goods becomes more common than goods produced elsewhere and shipped to final consumers by transportation companies and their intermediaries. Customization becomes the norm in this development path. The time lag between specific and unique consumer preferences and the delivery of goods that satisfy those preferences shortens. Clearly, this is a radically different version of consumption than the one that dominates our current experiences.

The manufacturing revolution

In this scenario technologies that underlie 3D printing evolve rapidly, but consumers remain reluctant to embrace the byproducts of these advances. For this reason, 3D printing is exploited by manufactures, which use this new technology to reinvent their manufacturing processes by printing spare parts on demand, designing products for more 3D printed inputs and sharing product and component designs across partner value chains (see Figure 7).

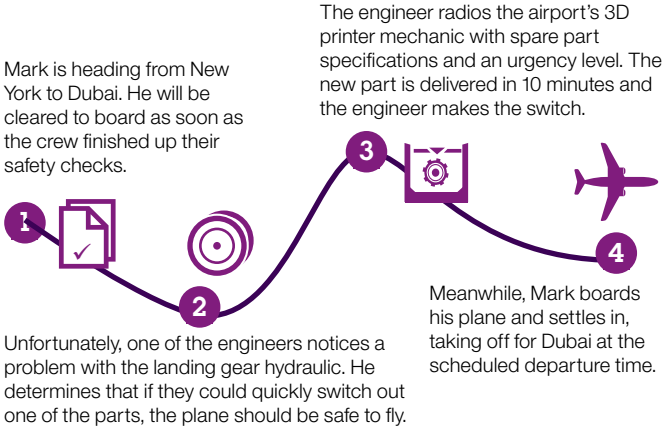


Figure 7: Currently, major manufacturers have had the most success in leveraging 3D printing as a value add and have invested billions as a result.

Source: IBM Institute for Business Value.

The reinvention of consumption

This is our most radical scenario, in which consumers are hungry for 3D printed products and the technology has developed by leaps in bounds. As a result, 3D printing has displaced traditional manufacturing in many industries and consumers have become deeply involved in product design, production and transport (see Figure 8).

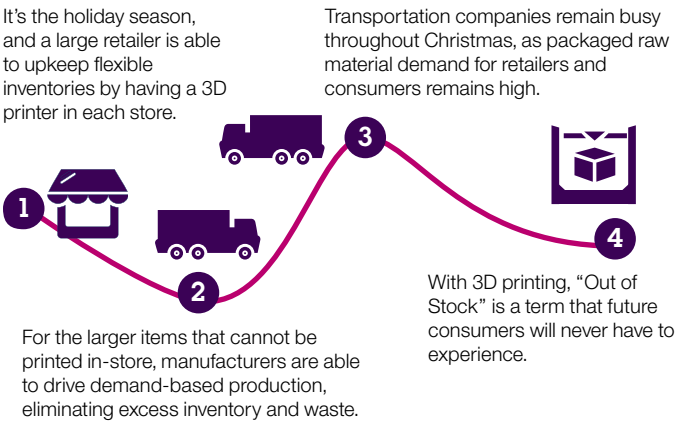


Figure 8: Retailers could recognize the sales and customer experience opportunities 3D printing offers and begin installing them as the new "Photo Centers."

Source: IBM Institute for Business Value.

The idea behind creating these scenarios was not to predict a specific outcome or development path, but to help transportation companies position themselves to succeed in a number of different futures, particularly as they apply to the current state of global transportation networks and supply chains.

Recommendations for transport providers

No matter which of these scenarios plays out, the disruptions to global transport could be significant and warrant deep thinking on the part of transportation providers about how to adjust. Specific ideas are suggested for each major sector of the transport industry, but in aggregate, regardless which scenario plays out, we believe there are four key imperatives all transportation companies should consider, which are summarized in Figure 9. These imperatives, if implemented, should help position transportation companies to establish a more strategic position in the emerging 3D printing value chain.

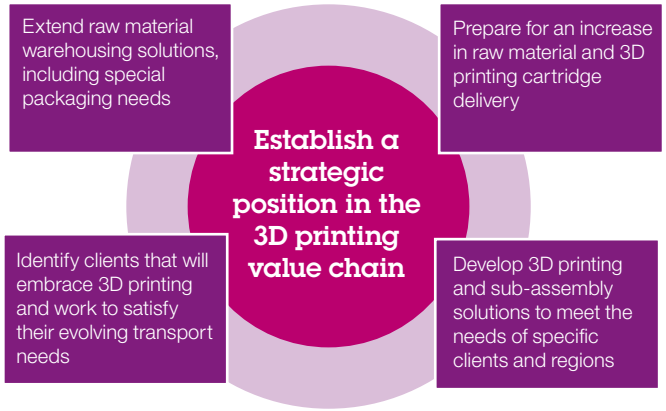


Figure 9: To respond to the possible developments in the 3D printing domain, transport services companies should consider four specific responses.

Source: IBM Institute for Business Value.

The most important recommendation for transportation companies is to identify the subset of current clients most likely to embrace 3D printing. Understanding what aspects of 3D printing they hope to embrace and how they plan to position their 3D printed products in the market will reveal insights about their future transportation needs. Initiating a dialogue with these clients will not only help your transport company satisfy its evolving needs, but might also reveal changing needs in the broader supply chain. Given the relative newness of 3D printing, this is likely to be a learning process for all involved, so starting that process now will pay dividends in the long term.

Regardless of how 3D printing plays out with specific customers, it is clear that many of the changes it will bring to global supply chains will require specialized packaging and warehousing solutions. Raw materials may need to be stored before or after they are processed into printing cartridges, so transportation companies that can service this need globally might be well positioned to succeed with 3D printing customers. Similarly, processed raw materials and cartridges may require special packaging that 3D printing customers may be willing to pay transportation companies to provide.

Even for transportation companies that decide not to get involved with raw materials or packaging, growing demand for 3D printed products will result in increased movement of 3D printing cartridges. Because these key inputs will be needed at a large number of relatively small production facilities (like print shops, businesses and homes), transportation companies may need to adjust their delivery networks and partnership agreements to satisfy these emerging needs.

Finally, for transportation companies that wish to become a more central cog in the production lifecycle, opportunities may emerge to develop final assembly or sub-assembly capabilities in local markets. While this opportunity may be attractive to a wide array of companies not involved with transportation, the insights transportation companies have on the inflow and outflow of goods to these sorts of production centers should position them well to add value to a company hoping to streamline production and delivery.

Of course, the direction transportation companies choose to take in the 3D printing space will be defined by not just the scenario they expect to unfold, but also by the specific position they hold in the global transportation value chain and the extent to which the companies they serve embrace 3D printing.

Under all of the future scenarios, there will be a shift in the importance of raw materials transport for all provider segments. Freight logistics companies and rail freight operators that rely on the transport of both intermediate and finished goods today will need to adjust to the needs of clients that choose to employ 3D printers close to the final distribution or consumption points and, therefore, require the delivery of more 3D printing cartridges.

Container shipping companies would likely benefit from 3D printing-driven supply chain changes that make it more economical to position raw materials closer to the points of final consumption. Even for raw materials that require processing before transport, container shipping lines might be called upon to move great quantities of semi-processed raw materials, or even 3D print-ready cartridges, in bulk between continents. Of course, these gains may be offset, in part or in full, by decreased demand for companies to ship intermediate goods between locations before final assembly.

For the most part, air freight operators would experience only minor changes in demand as a result of the growth of 3D printing. Many of the shipments they deliver are time sensitive and are less directly influenced by the current production processes that define traditional manufacturing. To the extent air freight operators notice an impact at all, it will be as a result of the increase in spare parts that are produced by 3D printers, which would obviate the need to urgently ship them on an air freight carrier.

3D printing brings both opportunity and uncertainty to many industries, including the transportation sector. But where other industries enjoy control over their own actions in the 3D printing space, transportation service providers must be ready to respond to the 3D printing decisions of their customers. Because most transport companies serve such a diverse array of customers and industries, they would be well served to think through the potential impacts of 3D printing and prepare themselves for the uncertainties that are surely coming their way.

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