What Should Commercial Manufacturers and Product Developers Consider when Investing in 3D Printing?

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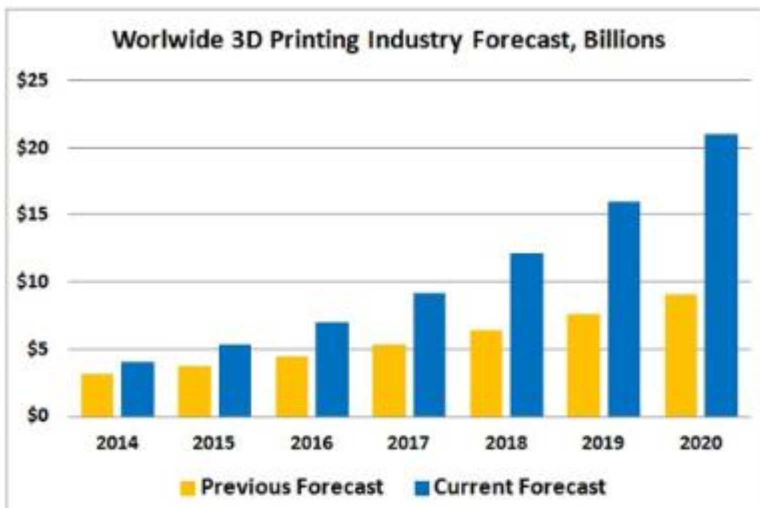
Investment in 3D printing technology can provide significant business advantages. Product development, customer value, manufacturing costs and product life cycle management can all be positively impacted by this technology. Determining where to make the investment requires careful consideration of the expected outcomes and thorough analysis of business, process or product that will be impacted by the investment.

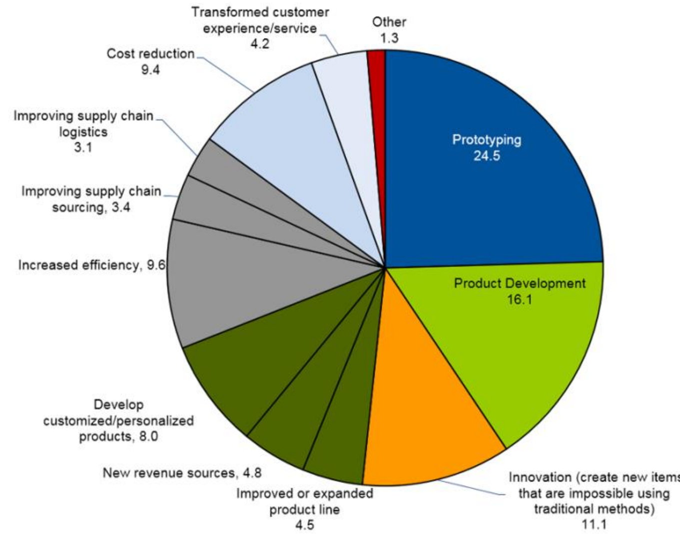
For companies considering investing in 3D printing, outsourcing to a reputable service bureau is a viable, cost-effective alternative that is less susceptible to changes in technology and materials than in-house ownership. The benefits derive from eliminating the initial capital cost of the equipment and the infrastructure set-up cost to avoiding the operating costs of ownership and obsolescence issues relating to the rapid development of 3D technology.

History of 3D Printing Market: The technology for 3D printing, also known as additive manufacturing, has existed since the 1980s. Although the additive manufacturing market took approximately 20 years to reach $1Bn, five years later in 2012, it had reached $2Bn, and by 2013, consensus estimates (Gartner, Wohlers) indicate it had reached $2.5Bn. A significant portion of this revenue was derived from 3D printer sales, but estimates (PwC and ZPryme) indicate that by February 2014, 67% of manufacturers who responded were already testing or using 3D Printing.



Despite advances in speed, reliability and material availability, 3D printing has to this point still been largely used for prototyping, testing and tooling. Although rapid prototyping remains important, the pivot to printing more fully functional finished products and components is the direction that analysts see the sector heading. For example, GE plans to mass produce 25,000 LEAP engine nozzles using additive manufacturing and already has $22Bn in commitments (Dr. Mark Cotteleer, Deloitte Services – Oct. 2014). Medical, dental and automotive are other sectors that report increasing use of 3D printing to create fully functional parts.

Yet, in a recent December 2014 Gartner worldwide study, 60% of respondents cited the high acquisition and start-costs as delaying their investment in 3D printers. Of those surveyed, 37 percent had just one 3D printer within their organizations, with 18 percent owning 10 or more. The average number of printers per organization was 5.4. One interesting finding was that respondents felt overwhelmingly that using a 3D printer as part of their supply chain generally reduces the cost of existing processes, especially research and product development costs. The study concluded that those companies who were using the technology for product development were seeing a 4% improvement in costs.



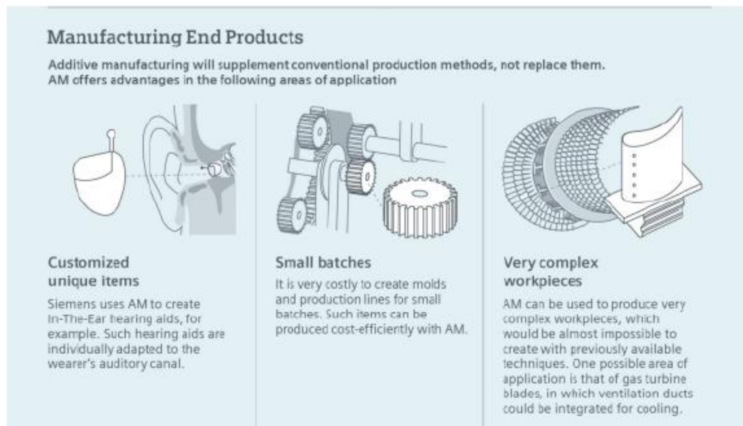
Types of Technology and Materials: Despite the widely held misbelief that 3D printers can "print anything", commercial manufacturers and product developers are still faced with the reality that there are many types of 3D printing processes. Each process has speed, part tolerance and quality-related factors to consider. Similarly each 3D printer is designed to work with a select set of materials. Most commercially available 3D printers (often called Professional or Production printers) are designed to work with either plastic or metal. However in the case of plastic, the material or polymer will vary depending on the 3D printing process as will the mechanical, aesthetic and functional properties of the finished part. UV-cured polymers behave differently to laser-sintered nylons. Similarly in the case of metals, parts printed on a laser-sintered machine will have different properties to those produced on an electron-beam or laser-melt style printer. Complexity further increases when the user has to consider ceramic, biomaterials, and materials needing regulatory approval which may require not only specialized materials but also printers with unique attributes.

3-D printing technologies

- **Stereolithography (SLA):** This 3-D printing technology uses an ultraviolet beam to harden liquid resin, bonding each successive layer.
- **Fused filament fabrication (FFF):** A stream of melted thermoplastic material is extruded from a nozzle to create layers, with each layer bonding to the previous layer. Common inks include ABS (acrylonitrile butadiene styrene) and polyactic acid polymers.
- **Selective laser sintering (SLS):** SLS uses powdered materials (such as nylon, titanium, aluminum, polystyrene, and glass) instead of the liquid polymers used in FFF. Powder is jetted from many nozzles onto the print surface, much like an inkjet printer. Laser is used to sinter or fuse the powder, layer by layer.
- **Selective laser melting (SLM):** SLM is similar to SLS, but rather than fusing the powdered material, the powder is melted at very high temperatures.
- **Electron beam melting (EBM):** EBM is similar to SLS, but EBM employs an electron beam as its power source.
- **Laminated object manufacturing (LOM):** In this additive process, laminates of materials (such as metals, plastics, or paper) are bonded in successive layers and then cut into shapes. In some cases, the shapes are worked on further (for example, through machining or drilling) to finalize the product.

Most materials, often termed feedstock, are pre-processed to create the liquid or powder that is ultimately reformed as a printed part. The cost of materials is a significant factor in the adoption of 3D printing. Depending on the material type, prices can range from $35/kg to $600/kg; speciality materials that have unique applications can be much higher. In many cases, companies that supply 3D printers try to control the material supply using, for example, prefilled cartridges or other means. Of late, this practice is beginging to change as new 3D printer manufacturers enter the market, alternate material suppliers emerge and machine owners determine how to override printer settings. In fact, the study conducted by Roland Berger Strategy Consultants showed that experienced 3D printer owners had effectively created their own supply chain, and this was driving down material costs.

<u>Traditional Manufacturing Comparisons:</u> 3D printing is still in the early adoption phase when it comes to the production of finished components and products. Speed of printing has yet to match the rates of typical mass production techniques. Companies such as GE, Siemmens and Autodesk envisage 3D printing being used in conjunction with or alongside traditional manufacturing techniques. The rate at which 3D printing will supplant traditional manufacturing techniques such as CNC machining, injection molding or casting is openly debated and will largely depend on advances in technology, materials and software.

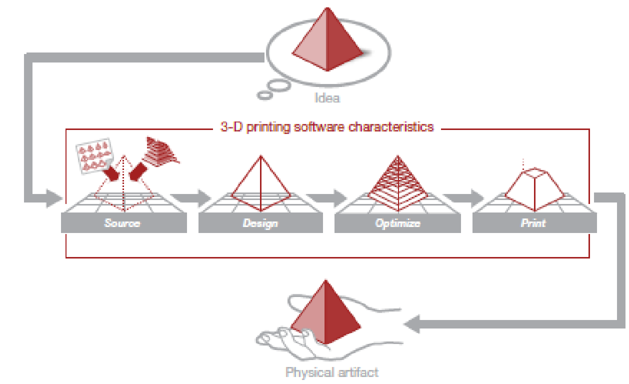


But according to a recent Siemmens report by Sandra Zistl, "Even though analysts at Wohlers Associates expect the rapid prototyping market to grow to more than $5 billion by 2020, 'Money will be made with manufacturing, not with prototypes,' forecasts Tim Caffrey, a consultant at Wohlers. This assessment is shared by Bernhard Langefeld, a machine construction expert at Roland Berger Strategy Consultants and one of the authors of the study titled *Additive Manufacturing – A Game Changer for the Industry?"*

What is also often a source of debate is the degree to which commercial manufacturers and product developers should own or outsource 3D printing technology. Here we have to turn to traditional methods for evaluating capital investment and make-buy decisions. At the same time, we have to consider the risks of obsolescene, premature adoption of new technology, and the true cost of ownership. In order to asses the capital investment or make-buy decision, we first must understand the expected financial and commercial returns from the decision, and to do that, we have to carefully consider the benefits of 3D printing technology and where to apply it.

The capital cost of acquiring a professional or production 3D printer varies tremendously. UV polymer printers vary from the mid $30,000 range to $200,000 for the more complex machines. Metal-laser sintering machines will cost anywhere from $500,000 to $1MM plus. It is also important to realize that just like traditional manufacturing, there will be additional costs for cleaning systems, dust collection, chamber gas-delivery and recovery systems, and for more sophisticated printers, complex material handling systems will be needed. Similarly space and building requirements also have to be considered as do machine layout, material flow and cell design.

3D printing is able to create a part directly from a digital file. Howeve this creates additional considerations because the ability to create an effective part is a function of the quality of the file; for example, is it an accurate representation of the desired finished part? Software that can manipulate the file to change the structure of the part or can adapt the file to more effectively print the product is also available. For each printer type, there is often a need for different types of software. The costs of this software must also be conisdered as part of the capital investment. Workflow software is also required when managing multiple files and parts if the production of these parts is to be efficient.



1 "The road ahead for 3-D printers," PwC *Technology Forecast* 2014, Issue 2.

3D Printing Applications: As this white paper indicates, there are many potential applications and markets for 3D printing technology. In general, these can be characterised into four primary categories; marketing and promotion, product development and design, production elements such as tooling, fixtures, products and components, and business services. When considering an investment in 3D printing, determining the application or intended purpose requires the investors to make a careful asssessment of their existing business, process or product. Secondly, it requires a clear understanding of the expected outcomes from the investment; reduction in product development time, increased customization, lower supply chain costs, improved quality, new commercial opportunities and added customer value are some of the examples often cited for investment. For example, the USPS (United States Postal Service) estimates turning postal processing centers into 3D printing hubs could generate $646MM in commercial packaging revenue. However reaching such a conclusion requires analysis and investigation of multiple factors as well as a thorough understanding of available technology, materials and software. In these cases, businesses are often turning to existing 3D printing companies such as Stratasys, RapidMade and Baker 3D Solutions to help them navigate the decision process.

3D Printing Total Cost of Ownership: Having identified the need for investment in 3D printing, the business leader is most often faced with the make-buy decision (or in-house versus outsource). A number of factors must be considered. Traditional factors such as the protection of intellectual property and the criticalness of the product or component remain important. Of additional importance is the degree to which the 3D printing technology itself is evolving. In 2009, the FDM patents expired, which led to the launch of many low-cost desktop copies. Similarly, in 2014, the SLS sintering patents expired, and this is expected to impact the cost of these printer types. 3D printer speeds are expected to increase 4X over the next five years with companies such as Siemmens stating that material feed rates will improve from 10cm^3/hr to 80cm^3/hr.

While many 3D printer manufacturers market and advertise the simplicity of these machines, the reality is that print builds fail and need to be reprinted. Similar to traditional manufacturing processes, there are usually post processes required to finish the product. There are waste streams that have to be managed; support material often has to be removed, and production has to be planned to ensure the printers run efficiently. Labor operating costs are similar to modern CNC machines, although these can be automated if volumes dictate.

For a typical commercial manufacturer or product developer who is producing products constructed of multiple materials and components, multiple 3D printer types will be required. It is not uncommon to require multiples of the same machine because print rates sometimes result in day-long builds. The Gartner survey from December 2014 found that, for those owning 3D printers, the average number of machines owned was 5.4. For a simple product development, for example, it is not uncommon to need three different types of 3D printers.

This total cost of ownership analysis and the recommendation to buy versus make is very similar to the analysis that would been done for a traditional machine tool. What is the labor cost to operate; what are the waste factors; what are the utilization rates; what are the utility and space considerations; what are the maintenance costs, etc. Factors that will also need to be considered are the material limitations of each 3D printer type, the software and pre-processing that is required along with the associated costs.

In most cases, there will be fixed engineering and operating support costs that will have to be applied over the planned usage hours. Consumable costs will include materials as well as print heads, UV lamps, lasers, build plates, support material, part-cleaning solutions, chamber gas, etc.

For many situations, the option to buy from a “Service Bureau” will be more cost effective than owning the technology. As with traditional manufacturing, a service bureau can specialize by using one type of 3D printer or by better leveraging costs over aggregated production volumes. As a cautionary note, it is important to select a reputable service bureau. Not all 3D printers are built to the same quality and their ability to maintain build tolerance or part strength will vary. So it is important to understand how the part will be printed. As with traditional manufacturing, service bureaus can be differentiated by those that have engineering expertise, a quality management system, a maintenance program and certified technicians compared to those that do not. Just like traditional manufacturing, there are print tolerance limitations that have to be considered in the design, and a service bureau with embedded engineering capabilites will be able to address these issues.

Consider also the importance of ensuring that the material supply chain is robust. Whether the decision is made to print In-house or through a service bureau, control of the material supply chain, both from a traceability and a material compliance viewpoint, is a consideration. For mission critical or complex materials, organizations such as Lawrence Livermore National Laboratory can provide independent certification of the material. In general, because these are essentially created materials, their properties will approximate but not always replicate traditional materials. Having access to knowledgeable resources will help avoid common pittfalls.

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