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3D opportunity in the automotive industry

Additive manufacturing hits the road

A Deloitte series on additive manufacturing

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Introduction

SIGNIFICANT advances in additive manufacturing (AM) technologies, commonly known as 3D printing, over the past decade have transformed the potential ways in which products are designed, developed, manufactured, and distributed.[1] For the automotive industry, these advances have opened doors for newer designs; cleaner, lighter, and safer products; shorter lead times; and lower costs. While automotive original equipment manufacturers (OEMs) and suppliers primarily use AM for rapid prototyping, the technical trajectory of AM makes a strong case for its use in product innovation and high-volume direct manufacturing in the future. New developments in AM processes, along with related innovations in fields such as advanced materials, will benefit production within the automotive industry as well as alter traditional manufacturing and supply chain pathways.

In this report, we not only look at how AM can improve the competitive position of automakers but also explore the four paths OEMs and suppliers can take to more broadly apply AM. We also explore the drivers supporting the use of AM and the potential challenges impeding its large-scale adoption in the automotive industry. For a detailed view on the different groups of technologies under the AM umbrella, refer to *The 3D opportunity primer: The basics of additive manufacturing*.[2]

For the automotive industry, these advances have opened doors for newer designs; cleaner, lighter, and safer products; shorter lead times; and lower costs.

The role of AM in driving competitiveness

GLOBAL automotive manufacturing has high barriers to entry, especially at the top where the four largest OEMs accounted for a third of the global industry revenue of over $2 trillion in 2013.[3] On the other hand, the $1.5 trillion parts and accessories manufacturing sector is characterized by high competition among a large number of smaller players.[4] To survive and succeed in such an environment, companies should focus on specific capabilities that can lead to greater competitiveness.[5] As authors, we believe there are two areas where AM will have the greatest influence on competition between automakers and potentially be a game changer:

1. **As a source of product innovation:** AM can produce components with fewer design restrictions that often constrain more traditional manufacturing processes. This flexibility is extremely useful while manufacturing products with custom features, making it possible to add improved functionalities such as integrated electrical wiring (through hollow structures), lower weight (through lattice structures), and complex geometries that are not possible through traditional processes.[6] Furthermore, new AM technologies are increasingly able to produce multimaterial printed parts with individual properties such as variable strength and electrical conductivity. These AM processes play an important role in creating faster, safer, lighter, and more efficient vehicles of the future.

2. **As a driver of supply chain transformation**: By eliminating the need for new tooling and directly producing final parts, AM cuts down on overall lead time, thus improving market responsiveness. In addition, since AM generally uses only the material that is necessary to produce a component, using it can drastically reduce scrap and drive down material usage. Furthermore, AM-manufactured lightweight components can lower handling costs, while on-demand and on-location production can lower inventory costs. Finally, AM can support decentralized production at low to medium volumes. All these AM capabilities combined allow companies to drive significant change within the supply chain—including cost reductions and the improved ability to manufacture products closer to customers, reduce supply chain complexity, and better serve consumer segments and markets without the need for extensive capital deployment.

Together, product innovation and supply chain transformation have the potential to alter the business models of automotive companies. The extent to which the potential offered by AM is harnessed depends on the path chosen by individual companies. Four possible paths and their impact are described in the following framework (figure 1).

Understanding the four AM adoption paths and value drivers

THE value from AM is in its ability to break two fundamental performance trade-offs: **Capital versus scale** and **capital versus scope.**[7] On one hand, by reducing the capital required to achieve manufacturing economies of scale, AM lowers the minimum efficient scale required for production. On the other hand, AM facilitates an increase in flexibility and increases the scope, or variety of products that a given capital can produce.

Achieving scale with less capital has the potential to impact how supply chains are configured, while achieving greater product scope with less capital has the potential to impact product designs.

Our view of the strategic impact of AM relies on understanding the ways in which the technology breaks trade-offs between capital and economies of scale and scope. Based on this understanding, we have developed an AM framework that identifies the tactical paths companies can follow as they seek business value using AM. This framework is summarized in figure 1.

AM is an important technology innovation whose roots go back nearly three decades. Its importance is derived from its ability to break existing performance trade-offs in two fundamental ways. First, AM reduces the capital required to achieve economies of scale. Second, it increases flexibility and reduces the capital required to achieve scope.

Capital versus scale: Considerations of minimum efficient scale shape the supply chain. AM has the potential to reduce the capital required to reach minimum efficient scale for production, thus lowering the barriers to entry to manufacturing for a given location.

Capital versus scope: Economies of scope influence how and what products can be made. The flexibility of AM facilitates an increase in the variety of products a unit of capital can produce, reducing the costs associated with production changeovers and customization and/or the overall amount of capital required.

Changing the capital versus scale relationship has the potential to impact how supply chains are configured, while changing the capital versus scope relationship has the potential to impact product designs. These impacts present companies with choices on how to deploy AM across their businesses.

The four tactical paths that companies can take are outlined in the framework below:

Path I: Companies do not seek radical alterations in either supply chains or products, but may explore AM technologies to improve value delivery for current products within existing supply chains.

Path II: Companies take advantage of scale economics offered by AM as a potential enabler of supply chain transformation for the products they offer.

Path III: Companies take advantage of the scope economics offered by AM technologies to achieve new levels of performance or innovation in the products they offer.

Path IV: Companies alter both supply chains and products in the pursuit of new business models.

Figure 1. Framework for understanding AM paths and value

Source: Mark Cotteleer and Jim Joyce, "3D opportunity: Additive manufacturing paths to performance, innovation, and growth," *Deloitte Review* 14, January 2014.

Graphic: Deloitte University Press | DUPress.com

Path I: Current AM path in the automotive industry

WITHIN the automotive industry, AM has largely been utilized to break the capital versus scope trade-off to enhance performance. High-volume automotive OEMs and suppliers have long applied AM to enhance overall manufacturing capabilities and reduce costs—which categorizes them as following path I of our framework.

Most OEMs and suppliers are currently on path I (stasis)

AM has the ability to produce prototypes without creating tools, thus accelerating design cycles and lowering costs. Today both OEMs and suppliers use AM to enhance existing operations: to support decision-making at the product design stage, to establish quality at the preproduction stage, to develop custom tools, and to reduce the overall time to market.

ON PATH I, COMPANIES DO NOT SEEK RADICAL ALTERATIONS IN EITHER SUPPLY CHAINS OR PRODUCTS, BUT THEY MAY EXPLORE AM TECHNOLOGIES TO IMPROVE VALUE DELIVERY FOR CURRENT PRODUCTS WITHIN EXISTING SUPPLY CHAINS.

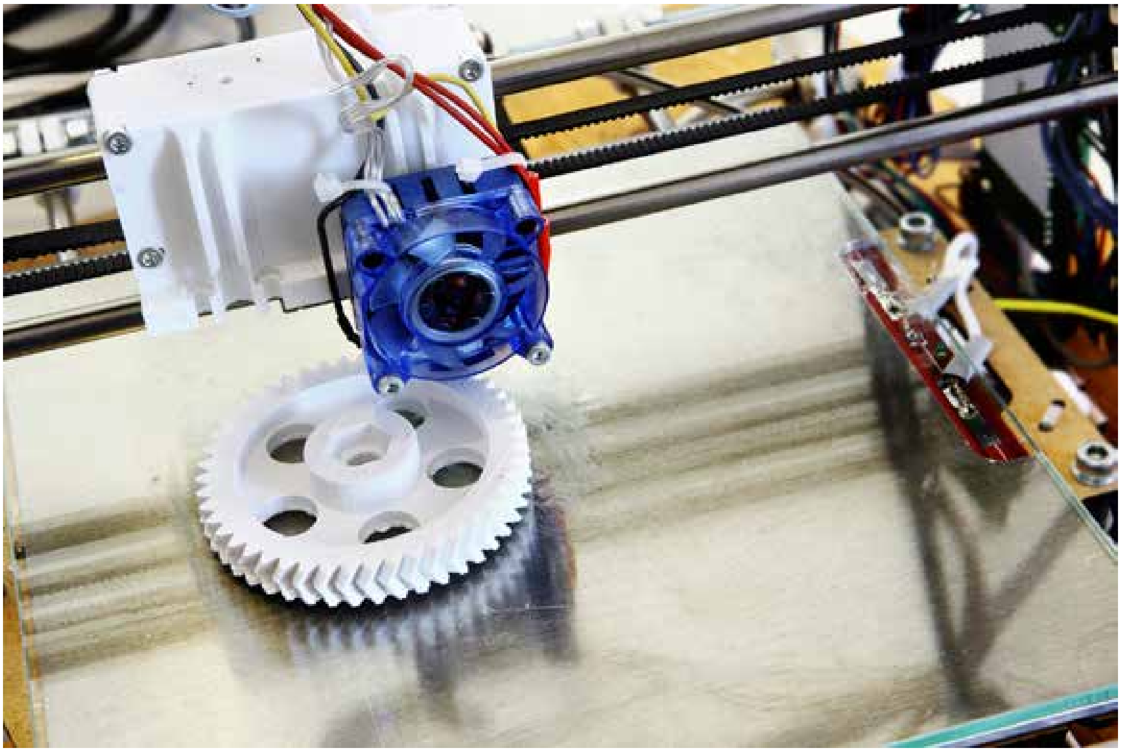
Accelerating the product design phase of new product development: In the product design stage, companies go through several iterations before deciding on the final design. One of AM's greatest advantages is that it can produce multiple variations of a product with little additional cost, helping auto companies improve their product designs with the support of physical models. For example, a well-known tire company uses AM to rapidly create prototypes during the design process and chooses the best design after checking the touch and feel of various alternatives. Interestingly, the prototypes benefit the company by not only customizing options based on OEM needs but also enabling brand differentiation: The physical models give the company an advantage over competitors who may be limited to design specifications and plans alone when sharing new products with their OEM customers.[7]

Enhancing quality via rapid prototyping: By using AM to create prototypes well before the final production, automakers are able to test for quality ahead of actual production schedules. Given the design flexibility of AM, companies can build and test a large variety of prototypes. GM, for example, uses the AM technologies of selective laser sintering (SLS) and stereolithography (SLA) extensively in its preproduction and design processes across its functional areas—design, engineering, and manufacturing—with its rapid prototyping department producing test models of more than 20,000 components.[8]

Another example is Dana, a supplier of driveline, sealing, and thermal management technologies for OEMs. It uses a combination of rapid prototyping and simulation to create prototypes that can be tested for form and fit.[9]

Customized fabrication of tooling:[10] For automakers, tooling plays a prominent role on the assembly line by producing consistent, high-quality products. AM allows for the fabrication of customized tools to enhance productivity on the shop floor. BMW, for example, has used AM in direct manufacturing to make the hand tools used in testing and assembly.[11] These custom-designed hand tools have better ergonomic design and are 72 percent lighter than traditional hand tools.[12] According to BMW, the customized tools helped save 58 percent in overall costs and reduce project time by 92 percent.[13]

Reducing tooling costs in product design: For some automotive components, tooling and investment castings are prepared for specific designs prior to production runs. This means that with every design change, tooling has to be appropriately adjusted or remade—a time-consuming and expensive process. OEMs have reduced their dependence on tooling and casting in the design phase by using AM.[14] According to Ford, the company saved millions of dollars in product development costs by choosing to create prototypes using AM and skipping the need for tooling. By additively manufacturing prototypes of components such as cylinder heads, intake manifolds, and air vents, the company also cut down drastically on the time that would usually be required to create investment castings. For a single component such as an engine manifold, developing and creating the prototype usually costs about $500,000 and takes about four months. Using AM, Ford developed multiple iterations of the component in just four days at a cost of $3,000.[15]



Paths III and IV: Future paths of AM in driving performance and growth

MOST automakers today operate on path I—which offers them ample scope to improve their AM strategies. The analysis presented here suggests AM's major role in the auto industry over the long term is along path IV—business model evolution. However, this route also includes product innovation typically associated with path III. The automotive business model of the future will likely be characterized by OEMs working closely with a smaller, more tightly knit supplier base and supporting faster refresh rates for automobiles with innovative characteristics. OEMs can achieve this business model by continuing to rationalize their supplier base and enhancing their partnerships with what are called "tier 0.5" suppliers.[16] Currently it takes years from initial design to final production before a vehicle hits the market. With AM, automakers can significantly shorten the development phase of the product life cycle and expand the growth and maturity phases.

Path III: OEMs' intermediate-term advantage will emerge from product innovation

Our framework characterizes the use of AM for product innovation and enhancement as path III. AM capabilities along this path break the traditional capital versus scope trade-off, driving down the capital intensity required for innovation. A critical advantage in the near term of using AM is the potential production of components with lower weight, leading to vehicles with improved fuel efficiency. Over the longer term, AM-enabled part simplification and associated reductions in the complexity of assembly could fundamentally change design-development-assembly processes.

ON PATH III, COMPANIES TAKE ADVANTAGE OF THE SCOPE ECONOMICS OFFERED BY AM TECHNOLOGIES TO ACHIEVE NEW LEVELS OF PERFORMANCE OR INNOVATION IN THE PRODUCTS THEY OFFER.

More complex designs that drive weight reduction: Automakers are constantly seeking ways to improve the fuel efficiency of vehicles—not only because of increasing demand for compliance with fuel standards such as Corporate Average Fuel Economy but also as a way to grow revenue by delivering greater value to consumers. One of the routes that automakers are taking to improve mileage is through weight reduction in automobiles. Over the years, OEMs have sought to incorporate lighter materials such as carbon fiber and aluminum into the vehicle body. The 2015 Ford F-150 is a good example. Unveiled in January 2014, the F-150's body is made almost entirely of aluminum—cutting vehicle weight by as much as 700 pounds (around 317 kg).[17] Another way to reduce weight is through alterations at a structural level. The ability of

AM to create complicated configurations plays an important role in reducing the weight of parts using lattice structures without compromising structural strength.[18] In this regard, the automotive industry can take cues from the aerospace and defense (A&D) industry, where a third of the revenues are spent on fuel, and reducing component and overall weight is critical. Driven by this need, major A&D companies such as Airbus and GE have incorporated AM in production to produce lightweight versions of components such as nacelle hinge brackets and complex parts used in unmanned aerial vehicles.[19]

Reducing assembly and production cost through part simplification: Conventional manufacturing techniques impose design limitations that can proliferate the number of parts required to produce a component. As the number of parts increases, the length and complexity of the assembly process also increase.[20] AM can produce parts with complex designs that can overcome the need for multiple parts. Fewer parts translate into a shorter assembly process, and consequently there is less chance that a quality problem will arise. Some auto companies are already making use of these attributes of AM, albeit in a limited fashion.

Delphi, a tier 1 automotive supplier, currently uses selective laser melting (SLM) instead of traditional machining of aluminum die castings to make aluminum diesel pumps.[21] Through the use of SLM, Delphi not only was able to make the pump as a single piece—drastically reducing the part count and simplifying the assembly processes—it also reduced overall production costs. Producing pumps as a single piece also helped Delphi avoid several postprocessing steps, resulting in a final product that is less prone to leakage.[22]

Greater application of AM freeform capability in the future can simultaneously reduce assembly time and cut down on assembly costs, with the integration of individual parts such as flow control valves, mounts, and pumps into a single-part design. This way, even complicated systems such as complete engine blocks can be built as a single part, with integrated electrical and cooling channels. The optimized engine design can improve fuel efficiency and lower weight.[23] AM makes it possible to produce designs that have "conformal cooling," which directly integrate fluid-handling channels into the component, avoiding the need for separate cooling channels.[24] In the future, automakers can benefit from the potential integration of mechanical and electrical functions through multimaterial printing.[25]

Path IV: OEMs' long-term advantage will emerge through business model innovation

The eventual path for automotive OEMs is business model evolution through a combination of product innovation, rapid turnaround, and market responsiveness, leading to AM-supported supply chain disintermediation. Business model innovation will incorporate the current-use (path I) advantages of AM—improved design and reduced time to market—along with the intermediate product innovation (path III) advantages—part simplification, reduced need for assembly, and weight reduction of components—that we have previously discussed; it can then combine these with a more geographically distributed supply chain to alter business models in important ways related to market responsiveness and supply chain disintermediation.

ON PATH IV, COMPANIES ALTER BOTH SUPPLY CHAINS AND PRODUCTS IN PURSUIT OF NEW BUSINESS MODELS.

Customization and improved market responsiveness: Advances in AM technology and adoption are leading to product innovations that will transition AM from a product-design support tool to a conduit for the direct production of high-performance parts with fast turnaround. While automotive companies have conventionally used modularity and postponement to support customization, AM provides greater flexibility. An interesting segment of the auto industry that has already adopted AM is the ultraluxury segment. In this segment, where production runs are small, AM is being used to customize and manufacture parts for use in final assembly. Some ultra-luxury car makers already use AM to deliver designs specialized to customer requirements. Bentley, for example, used its in-house AM capabilities to customize the dashboard in a case where manual modification would have been time consuming.[26]

Using AM for the rapid turnaround of application-specific parts is presently prominent in the proving ground of new auto technologies—motor sports. With lead time becoming a precious commodity, lessons learned in motor sports can be applied to mass production to reduce turnaround times—a competitive capability that will likely become increasingly critical for all automakers. One of the best motor sports examples comes from Joe Gibbs Racing, which used AM to produce a duct outlet and reduced the design and machining time from 33 to just 3 days.[27]

The question is how to transfer the advantages of AM from the small scale of motor sports and ultraluxury segments to mass-market vehicles. In this regard, the experience of the medical technology (medtech) industry offers important lessons. Products in this industry, such as custom insoles and dental crowns, are built for unique settings and customized to each individual's requirements. Yet they can be produced on a large scale using AM.[28] The challenge of scale can be addressed, if not immediately then in the not-too-distant future, by combining strategies from the medtech industry with scalable AM technologies that are currently under development.

Smaller supply chains and greater value contribution from OEMs: As OEMs adopt the product evolution route, the eventual outcome will be twofold: smaller supply chains and OEMs' greater value contribution. An important effect of AM may be shortening and simplifying the enormous automotive supply chains that currently operate. OEMs work with thousands of suppliers to source the different components in cars. Owing to the fact that supply chain management is a massive planning and logistics exercise, consuming time, effort, and cost, OEMs are constantly seeking ways to trim their supply chains. Ford, for example, was working with over 1,250 suppliers in 2012. In October 2013 it announced intentions to cut this number by as much as 40 percent.[29] As OEMs build their innovative parts rapidly with less supplier involvement, the time and money they spend on part sourcing can be brought down.

Conventionally, OEMs outsource the manufacturing for most components. OEMs accounted for about 35 percent of total value created, while suppliers accounted for the rest in 2002. Without an external impetus, OEMs' share is expected to fall to around 23 percent by 2015.[30] With AM, OEMs may be able to buck this trend by relying on internal capabilities and stronger partnerships with system integrators (tier 0.5 suppliers) to retain, or even increase, their value creation share in R&D and production without needing to manage a bulky supply chain. A greater role for OEMs could represent a major shift in the industry, causing a ripple effect on lower-tier suppliers, who might see a smaller role and greater consolidation in the future.

An important but highly fragmented part of the automotive supply chain is the aftermarket parts and accessories industry, which is likely to follow a different path from the OEMs (see sidebar).

Aftermarket parts sales to compete by following path II (supply chain evolution)

ON PATH II, COMPANIES TAKE ADVANTAGE OF SCALE ECONOMICS OFFERED BY AM AS A POTENTIAL ENABLER OF SUPPLY CHAIN TRANSFORMATION FOR THE PRODUCTS THEY OFFER.

While OEMs will seek to drive product innovation, aftermarket parts suppliers, who deal with standardized product designs, are expected to be impacted more by AM's altered economies of scale. Using AM, automotive suppliers can produce components on demand and at locations closer to the point of use. This affords them the added benefit of balancing demand and supply and drastically lowers the cost of inventory. In addition, maintenance and repairs of automobile parts can be done in entirely new ways using newer AM technologies, which can potentially reduce long lead times to get cars back on the road.

Reducing service, spare, and aftermarket part inventory: Delivery time and parts availability is an important basis of competition in the aftermarket segment of the automotive industry. Owing to high costs of carrying inventory, most automotive part distributors and retailers hold only commonly sold parts, maintaining stockpiles of low-demand or expensive components only at more remote, consolidated locations. AM can help match supply with this demand for "long-tail" components—parts that are in demand but only in small volumes—through on-demand production.

Closely related is the performance parts segment of the market. This segment, accounting for approximately 20 percent retail auto part sales, is considered a discretionary expense by most consumers, and therefore its demand pattern is not uniform.[31] We imagine a day when (as AM system and material costs fall) auto part providers can maintain performance parts availability while holding less inventory. Distributors may also be able to reduce costs and turnaround times by using AM, thus reducing operational expenditure.

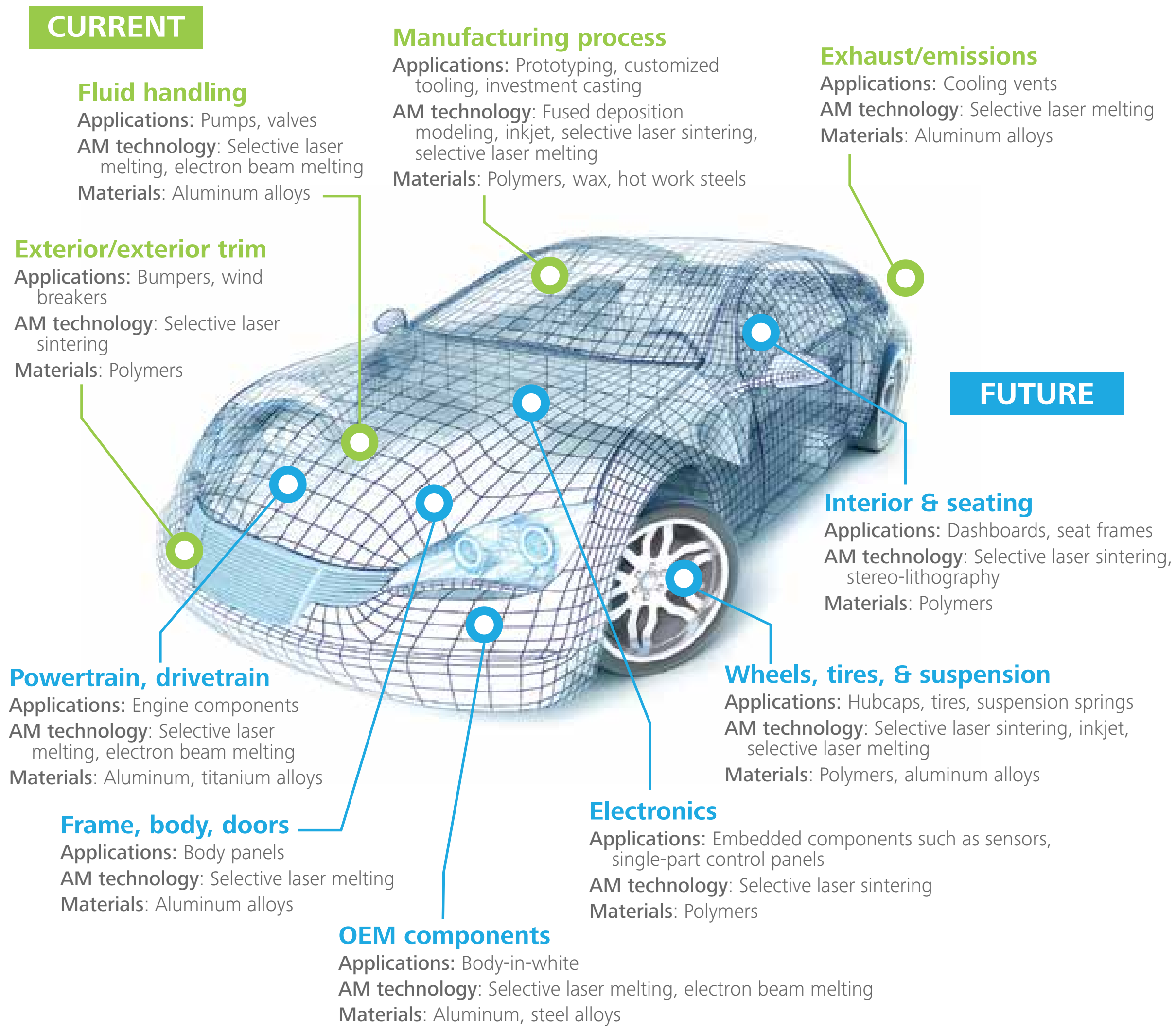
Finally, when combined with 3D scanners, AM might also prove ideal for producing components for out-of-production models where the computer-aided designs (CAD) of the parts may not be available.[32] 3D scanners can create the CAD file for the base design of the component, and AM can then produce the component from the CAD file. One of the most well-known examples is the use of Rapidform to reproduce parts of vintage cars from the garage of popular talk show host, Jay Leno.[33] Eventually, we might see the creation and growth of a market for CAD files, which act as a central repository, for all parts. Consumers could then purchase the digital design for a part and print it on their personal AM device or make use of a local AM device or a service bureau.

On-site fabrication to accelerate maintenance and repair: Certain automotive parts, such as drivetrain or engine components, may be expensive to replace when they wear out. In such cases, they could be repaired using AM at service locations. Laser metal deposition (LMD) is a technology that has high net-shape accuracy and can be used to repair small- to medium-complexity parts on site. Developed for aerospace applications, LMD is known to extend the overall life of products, avoiding the expense of replacement. The technique is beneficial in cases where costlier, high-performance alloys are used. Although the technology is already substantially advanced in A&D, cost remains a prohibitive factor for the automotive industry.[34] As the volume of applications rises, we expect the overall costs to decrease and the technology to become commercially viable in the long term.

Now and beyond: Where is AM headed?

TODAY production dashboards and cooling vents in some vehicles are already made using AM. With new improvements in process and materials technology and a wider adoption of AM, it is possible that we could see AM-based production of a greater number of components in the future. A nonexhaustive summary of which components are presently manufactured using AM and which parts will be potentially manufactured in the future is shown in figure 2.

Figure 2. Illustrative applications of AM in an automobile[35]

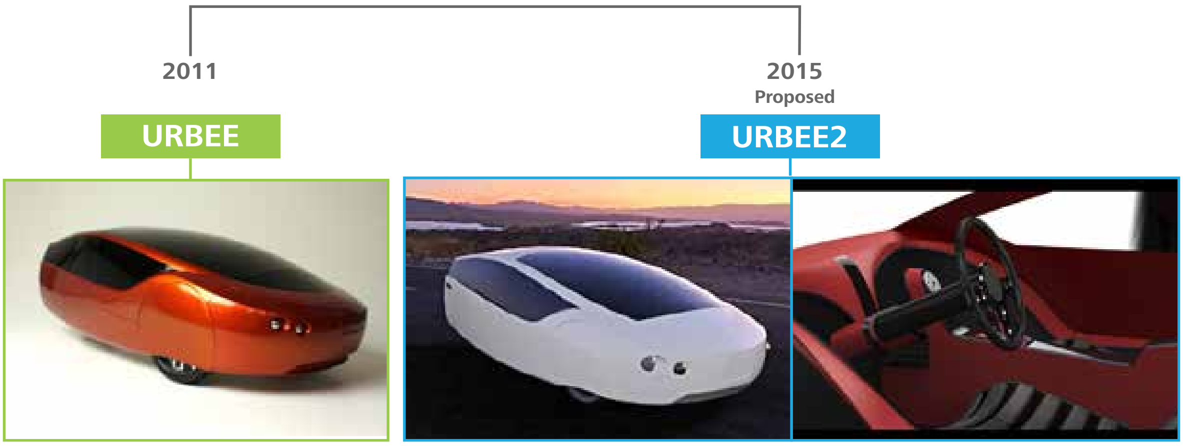


Source: Deloitte analysis.

Graphic: Deloitte University Press | DUPress.com

As the number of additively manufactured parts increases, one company's goal is to use AM as the primary production technique for building vehicles. Urbee 2, an electric car with as many as 50 AM-produced parts, is under development and expected to debut in 2015 (figure 3).[36]

Figure 3. Urbee, the first AM-produced car



- Built external frame comprised of 20 separate panels built through rapid prototyping using fused deposition modeling (FDM)
- Partnered with a major rapid prototyping service bureau in production of the frame
- Used design and simulation software

- CAD modeling begun in 2013
- 3D print interiors in addition to the external body
- More parts—40–50 major body and interior parts will be 3D printed
- Greater complexity of parts which cannot be produced through traditional manufacturing methods

Source: Images used with permission from Kor Ecologic.

Graphic: Deloitte University Press | DUPress.com

Drivers and challenges in AM's adoption in the automotive industry

THE success of AM's future applications in the automotive industry will depend largely on how AM technology evolves over the coming years. We have identified two drivers and four challenges that have the potential to shape the future of AM adoption.

Driver 1: More materials amenable to AM

A wide variety of materials allows a greater number of properties to be embedded into final products. Traditionally, AM applications have been restricted due to the limitations on the materials that can be used. While conventional manufacturing currently uses a wide variety of materials such as metals, alloys, and composites, AM has not been around long enough to see similar developments.[37] With limited application of novel materials in AM so far, these materials remain costly.[38]

However, research has been steadily progressing to expand the portfolio of available materials. For example, researchers at the University of Warwick have developed a low-cost composite material that can be used specifically for additively manufacturing electronic components.[39] In addition, the European FP7 Factories of the Future project is researching methods to reduce production costs of graphene-based thermoplastics for use in the production of high-strength plastic components.[40]

There is also ongoing research on the application of advanced materials that are already available. New processes capable of combining AM with nanomaterials are under development, with the goal of increasing tensile strength, electrical conductivity, hardness, and impact strength.[41] Increases in strength without a corresponding increase in weight could potentially lead to AM even being used to make the body in white for automobiles in the future. Another advanced material of note is carbon fiber. Carbon fiber is used to make lightweight auto components such as fenders, car roofs, and windshield frames through conventional techniques. AM, too, is beginning to take advantage of this material with the launch of the first commercial AM device that can use carbon fiber.[42]

The success of AM's future applications in the automotive industry will depend largely on how AM technology evolves over the coming years.

Apart from new materials, new technologies that produce existing materials in a cost-effective fashion also have an impact on the adoption of AM. Titanium, with its low density, high strength, and corrosion resistance, has strong appeal in the automotive industry for its ability to make lightweight, high-performance parts, yet widespread use is limited because the metal powder produced through current methods is expensive, costing about $200–400 per kilogram.[43] UK-based Metalysis has developed a one-step method to produce titanium powder, with the potential of reducing the cost by as much as 75 percent. Jaguar Land Rover is looking to partner with Metalysis to use the low-cost titanium powder in AM.[44]

Driver 2: Improved AM-manufactured product quality and reduced postprocessing

Parts produced through most AM technologies occasionally show variability due to thermal stress or the presence of voids. This results in lower repeatability, which is a challenge for high-volume industries such as automotive where quality and reliability are extremely important. One way to tackle this challenge is through machine qualification, where companies follow industry standards as well as those of the AM technology providers.[45]

Another concern in using AM is that the dimensional accuracy of final parts produced through AM is not always on par with those made through conventional manufacturing processes. For example, in some cases researchers have found that sand molds produced using AM could lead to reduced dimensional accuracy in metal casting tools.[46] AM processes give a surface finish of the order of 10–100 microns, which is generally not considered to be in the high-precision range.[47] Though high precision is not critical for most automotive applications, finish quality might become a factor for high-performance components. However, AM techniques such as electron beam melting promise to significantly enhance surface finish.[48]

Most components manufactured through AM require some form of postprocessing, which involves removing unused material, improving surface finish, and removing support material.[49] For simple parts, the amount of postprocessing is not significant. However, as the size and complexity of the components increase, it may become necessary to improve postprocessing quality and reliability for AM to be used on a larger scale. We see this as particularly important for companies seeking to use AM in the production of final versions of critical components such as engine manifolds.

Hybrid manufacturing promises a solution for addressing current variability and finish quality concerns. Hybrid manufacturing refers to the combination of AM with traditional techniques such as milling and forging. This transforms the perspective of a product from a "single entity to a series of features" that can be produced through some combination of the techniques.[50] One example of a hybrid manufacturing technique is ultrasonic additive manufacturing, an advanced technology based on AM, using sound, that combines additive (ultrasonic welding) with subtractive (CNC milling) techniques to create metal parts.[51] The use of AM allows these parts to have special features such as embedded components, latticed or hollow structures, complex geometries, and multimaterial combinations, and the use of CNC milling ensures uniform finish quality.[52]

Challenge 1: Economics of AM limited to low-volume production

Profitability in the automotive industry is driven by volume. In 2013, 86 million automobiles were produced globally.[53] Given the enormous volumes, the low production speed of AM is a significant impediment to its wider adoption for direct part manufacturing. This has made high-speed AM an important area of research. Improving build rates through the AM technology of SLM has been an important focus in recent years, yet major breakthroughs have so far been elusive.[54]

Challenge 2: Manufacturing large parts

One of the limitations of AM's utility in the automotive industry is the limited build envelopes of current technologies. Given this restriction, larger components such as body panels that are produced through AM still have to be attached together through processes such as welding or mechanical joining. To overcome this, low-cost AM technologies that can support larger build sizes for metal parts have to be developed. There is already significant research in progress. "Big area additive manufacturing," under development by Oak Ridge National Laboratory and Lockheed Martin, has the potential to manufacture products without any restrictions on size.[55] Another example is the mammoth stereolithography process developed by Materialise, which has a build envelope of 2,100 mm x 680 mm x 800 mm—big enough to manufacture most of the large components of an automobile. It was used to build the outer shell of the race car "Areion," developed by Formula Group T, in just three weeks.[56] However, since it can be used only for building panels made of plastics, broader adoption has been slow.

Challenge 3: Talent shortage

The use of any new technology requires people trained in skills specific to its operation; AM is no exception. AM-specific skills are necessary in the areas of CAD design; AM machine making, operation, and maintenance; raw material preparation and management; analysis of finishing; and supply chain and project management.[57] Currently a significant portion of the necessary training is on the job.[58] With the expansion of AM applications, there will be a greater need for formal and extensive training and skill development programs in the application and management of AM. These programs require concerted action from academic institutions, AM service providers, and end-user industries to standardize training and create a stable and capable workforce.

Challenge 4: Intellectual property concerns

AM products can't be copyrighted but have to be patented on the basis of obvious differentiation. With a lack of clarity on what qualifies for patent protection and what does not, there is a possibility that counterfeit components will proliferate. According to the market research firm Gartner, the global automotive aftermarket parts subindustry, along with the toy, IT, and consumer product industries, could report as much as $15 billion in intellectual property theft due to AM in 2016.[59]

The road ahead

DESPITE the challenges, the fact remains that AM is a versatile set of technologies that can support auto industry companies in their pursuit of the strategic imperatives of performance, growth, and innovation. Considering the breadth of capabilities unlocked by AM, leaders of automotive companies should consider taking advantage of AM technologies to stay ahead of competition.

At present, automotive companies are using AM in the most traditional capacity, along path I, for rapid prototyping. We do not currently see significant product evolution or supply chain applications (with the possible exception of the luxury segment of the market). However, automotive companies should consider exploring the other paths to derive greater value.

As applications evolve, we see AM as a potential game changer for future operations of automotive businesses. With rapidly shrinking life cycles for new vehicles, mass-market automakers should follow the example set by motor sports and ultraluxury segments and continue on to path III. The freeform capabilities of AM and drastic reduction in design-to-final-production time will allow OEMs to produce complex, high-performance parts for end use.

Tier 1 and tier 2 suppliers should look at exploiting AM capabilities along path II to serve consumers at locations closer to end use. Considering how auto consumers are becoming less willing to spend on replacement parts, players in the aftermarket segment can make maintenance and service cheaper by incorporating AM.

Leaders in the auto industry should also closely examine the medtech and A&D industries that are setting the benchmark on how AM can be applied in support of overall strategies. Driven by an industry need for individualized products, medtech began with mass customization. By making use of the reduced minimum efficient scale, it is now leading in the application of AM in mass customization. Automakers can benefit from the medtech model of operation.

A&D, on the other hand, is not just working on how to apply existing AM technologies but is actively participating in solving challenges that AM is facing. A&D companies are pioneering the development of new process technologies and partnering with research organizations to develop new materials that are suited to AM. Like the A&D industry, the auto industry too has needs specific to its model of operation. Instead of waiting for materials and AM process technologies to develop elsewhere and adapt them later, auto companies should ask themselves if they can play an active role in the development of AM as well. This will help them position AM as a differentiator before the competition catches up.

The automotive industry is a low-margin, capital-intensive industry. To sustain profitability and market leadership, OEMs need to relook at their business model. Parts simplification and reduced assembly requirements could have a direct impact on the supply base by reducing the size and complexity of auto supply chains. As product innovations supported by AM increase, OEMs will find that they have the opportunity to enhance their business model by operating a leaner and tighter supply chain.

While it is important to look at the advantages of AM, it is just as necessary to keep track of how the legal environment around the use of AM is evolving. Laws around how intellectual property can be protected and used are yet to be clarified. Simultaneously, auto companies should partner with service bureaus and universities to provide training and build a skilled talent pool that can work with AM.

While traditional manufacturing techniques are deeply entrenched and will continue to hold a dominant position in the automotive industry, additive manufacturing is making inroads. While AM will not become the only manufacturing technique in the future, it will nonetheless play an important role in shaping the global automotive landscape.

Considering the breadth of capabilities unlocked by AM, leaders of automotive companies should consider taking advantage of AM technologies to stay ahead of competition.

Deloitte Consulting LLP's supply chain and manufacturing operations practice helps companies understand and address opportunities to apply advanced manufacturing technologies to impact their businesses' performance, innovation, and growth. Our insights into additive manufacturing allow us to help organizations reassess their people, process, technology, and innovation strategies in light of this emerging set of technologies. Contact the author for more information or read more about our alliance with 3D Systems and our 3D Printing Discovery Center on www.deloitte.com.

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