WATCHING: TRANSPORTATION

A SERIES ON ECONOMIC—DEMOGRAPHIC—CONSUMER & TECHNOLOGY TRENDS IN SPECIFIC PLASTICS END MARKETS

Winter 2019
Winter 2019

The Plastics Industry Association (PLASTICS) sends special thanks to PLASTICS’ Transportation and Industrial Products Division for their input on this Transportation Market Watch Report.

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Plastics Market Watch
Watching: Transportation

A series on economic—demographic—consumer & technology trends in specific plastics end markets

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Plastics in Motion with Today's Trends in Transportation
Plastics in Motion with Today’s Trends in Transportation

In this Market Watch Report, PLASTICS will explore the major trends in the transportation sector, and how they impact plastics and plastics’ contributions to vehicles—whether automobiles, trucks, boats, trains, planes or other modes of transportation used around the world.

Some experts call the sector’s current trends and developments the biggest breakthroughs since the Ford Model T; but they could be even more significant in how they shift the dynamics of all transportation modes, transform cities, disrupt the movement of goods, and positively impact the environment. Further, the role of plastics as a material in transportation vehicles will be solidified, and even expanded, as technologies advance and require engineered plastic parts and polymers.

The four, interrelated trends in the transportation sector are:

1. **Electric vehicles/propulsion:** Electric vehicles (EVs) use electricity as their primary source of propulsion, relying upon rechargeable batteries. EV motors do not emit tailpipe emissions.

2. **Autonomous:** Self-driving or autonomous vehicles (AVs) use cameras, radar, and lidar (laser technologies) to navigate and monitor their environment, moving on roads with no—or little—human interaction.

3. **Connected:** Connected vehicles (CVs) are linked with other vehicles, the Internet, and wireless local area networks or short-range radio signals to obtain information for equipment on board and share information with other vehicles and infrastructure.

4. **Shared:** Shared transportation or mobility removes ownership responsibilities and allows users to access transportation services as-needed or on-demand; shared vehicles include cars, bikes, peer-to-peer ride sharing, App-based ride services, micro-transit services (shuttles/vans), and even scooters.

These trends are interconnected by technology, investments, and industry leaders. First, autonomous and shared vehicles are connected—you cannot deploy a shared network of vehicles without having them linked together. Secondly, AVs will need to be connected with technology to share information with other vehicles and infrastructure. And finally, the trends are related to electric propulsion in that all the world’s vehicle manufacturers are investing in electric technologies—and foresee an EV future—for nearly all vehicles on the road.
Why do engineers and designers turn to plastics for vehicles?

- Lightweight plastics and polymers improve fuel efficiency
- Enhanced prototyping and manufacturing speed gets products to market quicker
- Can be used for interior, exterior, structural, and engine parts or components—and made soft, flexible or hard
- Acoustical and insulating qualities
- Vibrant, scratch resistance colors
- Plastic parts can be recycled—and manufactured from—recycled materials
- Resistant to fuels, chemicals, stains, graffiti—and easier to clean
- Safety advances in bumpers, airbags, seat-belts and designs
- Improved comfort with seats, cushions and restraints
- Design and engineering flexibility with styling and shapes—eliminating joints and parts or combined with other materials
- Can be transparent, translucent or opaque for windows and lighting
- Weatherability and moisture repellence, eliminate rust
- Flammability performance and heat resistance
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Industry and governments are researching the impact and timing of these trends. Will consumer and commercial usage of electric and autonomous vehicles be the “owned” commuting vehicle or a “shared” taxi service or delivery vehicle? Will the vehicles become the futuristic mobile office/meeting room/restaurant envisioned by some, or more utilitarian? How will the changes impact traffic? And how will infrastructure be funded when fewer vehicles are paying gas taxes?

Two additional, continuing trends in transportation that are explored in this Market Watch Report are light-weighting and sustainability. Plastics have played a major role in these developments and they relate to a manufacturer’s commitment to a vehicle’s performance, particularly in terms of mileage and the environment.

All vehicles—on land, sea and air—have been on diets to shed weight and improve fuel economy. Plastics have played a major role with engines and in the interior and exterior of vehicles to shave pounds. Electric vehicles, due to their storage batteries, are heavy, and therefore must be built with an eye toward weight-saving materials. They are also vehicles where heat from the batteries and components are intense—thermoplastics are an emerging material for EVs and the management of temperatures.

Plastics, too, play an important role in the sustainability of resources through the carbon footprint of vehicles during manufacturing and operations—as well as through end-of-life management of resources. Manufacturers have adopted measures to improve the environmental performance of their products—and their manufacturing processes.

With these transportation trends, General Motors CEO Mary Barra sees an era in transportation with “zero crashes, zero emissions and zero congestion.” To achieve these goals, automobiles and other vehicles have a long road ahead of them, but AVs, EVs, CVs, and shared vehicles are here and expanding.

**Did you know...**

A 10-percent reduction in vehicle weight results in an estimated 5 to 7 percent reduction in fuel usage.

Of the approximately 30,000 parts in an automobile—1/3 are plastic.

In 2016, the average light vehicle contained about 330 pounds of polymer composites that accounted for over 50 percent of the total vehicle volume.

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Transportation Trends

Electric Vehicles and Propulsion

To date, no major automotive manufacturer has made electric vehicles profitable. Tesla, with its high-profile market entry, new models, self-driving technologies, and wide-ranging electric/battery and solar businesses, has produced 300,000 vehicles, but has had just two profitable quarters in its history. And Toyota, which had groundbreaking success with its hybrid Prius models, has been historically reluctant to fully embrace long-range, all-electric vehicles due to costs.

But ready or not, incumbent automotive companies and new entrants are aggressively pursuing partnerships and collaborations to tackle electric vehicles. With improved batteries, storage capabilities, range, and power, the move to electric vehicles will reach beyond cars to include buses, trucks, fleet vehicles, boats, off-road, and two-wheeled vehicles. The major turning point for EVs, according to Bloomberg NEF, will be in the mid 2020s when the costs of electric and combustion vehicles become comparable—or trade places.

**EV predictions are being recalibrated:**

The move toward electric is changing how companies operate and view transportation systems. GM is working to transform itself; the company hires a scientist, software designer, engineer, and mathematician every 26 minutes. GM has a goal of making its electric vehicles profitable by 2021.

The International Energy Agency in 2016 predicted there would be 23 million electric cars on roads around the world by 2030—now it estimates 127 million in 2030, and 280 million by 2040.

Oil interests also foresee the growth of EV: BP upped its forecast for 2035 from 72 million to 210 million. OPEC forecasts for EVs in 2040 jumped from 46 million to 253 million.
The move toward electric is changing how companies operate and view transportation systems. GM is working itself the company; the company hires a scientist, software designer, engineer, and mathematician every 26 minutes. GM CEO Barra said “There's so much software that is now on the vehicle, and in many cases, software is replacing mechanical systems. There's going to be a point where we're going to be upgrading and improving cars as opposed to fixing them.” GM has a goal of making its electric vehicles profitable by 2021.

**Plastics Fit into Electric Vehicles**

The scale of transformation within the transportation sector with electric propulsion is unprecedented—and will influence all suppliers, including plastics. "The flexibility of plastics in terms of performance, design, weight and costs could be an advantage as electric vehicles increase market share,” said Kendra L. Martin, Vice President–Industry Affairs, PLASTICS. “Plastics currently available meet the specifications of electric motors; it will be interesting to see new polymers come forth as EV technology takes hold.”

Some plastics industry experts working with automobile companies believe there is an opportunity for breakthrough technologies to manufacture EV platforms. Some designs may be based on "skateboards" that use a flat chassis and power system built atop wheels. "What the electric vehicle allows is for car manufacturers to design their vehicles in a fundamentally different way. That opens up for considerable breakthroughs in terms of design,” Patrick Cazuc, Global Automotive Marketing Director, at DuPont told Chemical & Engineering News.

An advantage plastics provide engineers is the ability to mold form-fitting parts with nylon brackets—eliminating the need for additional assembly that steel or aluminum would require. The shaping with thermoplastic polyolefins and other polymers have already made cars quieter and more ergonomic; for EVs these materials can be used to design a wide-range of parts.

Demand is also expected to increase for plastics needed for electrical connectors and housings. Engineered plastics can be designed to withstand the high heat and electrical currents generated by EVs; an electric motor can reach 400 to 600 volts while a gas engine generates only 12 to 48 volts. Some plastics, like polyphthalamide (PPA), polyphenylene sulfide (PPS), and polyether ether ketone (PEEK) are available and in use, but it is expected that new research and innovation will produce new, higher-performing materials.

DuPont has developed a range of plastics to meet the needs of EV manufacturers, focusing particularly on battery and power needs. DuPont has battery separators that improve insulation, save weight, and offer flame retardant qualities. The company reports its Energain™ battery separators for lithium ion batteries can help boost power up to 30 percent and provide stability at high temperatures, so vehicles can extend their range under a single charge.
With EV power-trains, the overall center of gravity of vehicles will shift from the front as with internal combustible engines, toward the rear. The shift calls for redistribution of weight in the EV and weight reduction in certain areas. Lift-gates in the back of vehicles will need to be lighter given the batteries and motors of EVs. And with the height of SUVs and CUVs—the vehicle’s ride will come into play when electric power-trains and batteries are installed. Weight reallocations and savings will be necessary, as will weight diffusers, to help the vehicle operate efficiently.

“By 2025, more than half the vehicles produced will have a rear liftgate or hatch in the back, whether it’s an electric power-train or traditional power-train. We are poised to offer a thermoplastic liftgate that is 25 to 40 percent lighter than traditional steel offerings,” said Brian Krull, Global Director of Innovation, Magna International.

With EVs, the front end of vehicle designs may also change, providing another opportunity for plastics and thermoplastics. EV cooling requirements are different than internal combustible engines, which may eliminate the need for certain kinds of grills and front fascia, and open the door to EV design differentiation.

Brian Krull, Global Director of Innovation, Magna International
Autonomous Vehicles

2018 was a monumental year for the development—and deployment—of autonomous vehicles, a transportation trend that is uniting new and old companies with multi-billion dollar, global collaborations. The Brookings Institution reports nearly $80 billion dollars was invested in AV technologies between 2014 and 2017. Unless you have been shopping for a new automobile in the past few years, you may not have been aware of the advances manufacturers are making with AV. A number of manufacturers, including Audi, Cadillac and Nissan, already have technologies on the road that allow drivers to take their hands off steering wheels and feet off pedals.

In current models, some Audi vehicles can be equipped with “pre-sense” technologies that monitor areas around the car with front-facing cameras and front/rear-facing radar sensors. The equipment helps prevent accidents, assist with turns and maneuvering, offer adaptive cruise control, stop and go traffic jam assistance, and other technologies. For Audi, the technology platform represents a stepping-stone toward full-AV transportation.

The advancements toward AV stumbled in early 2018 when a pedestrian was killed by an Uber-designed AV in Tempe, AZ. The test vehicle did have a backup safety driver, but she was distracted when a pedestrian crossed in front of the car. Uber suspended its testing, and many cities and companies took a pause to assess their deployments. Much of the American public seemed startled at the news of the accident in that AV was moving beyond test tracks. Further, the promises that AV technology was going to make roads safer were not airtight.

According to the Brookings Institution’s Metropolitan Policy Program Fellow Adie Tomer, the accident showed work still needs to be done to achieve an AV world. Tomer wrote, “The reality is that we’re still in the nascent stages of this new technology and streets are inherently dangerous places. There is no established algorithm for all scenarios. The testing companies don’t share their code, nor is reporting consistent from state-to-state. And we’re just now seeing AVs enter the more chaotic world of cities. It’s one thing to automate driving on a well-striped, high quality, cars-only road. But machine learning is harder when you add ‘unpredictable’ people, poorly striped lanes, low quality pavement, inclement weather, and other inconsistencies. Algorithms thrive on order—and city streets have less of it.”

Despite these challenges Waymo, which started under Google/Alphabet and was one of the first entrants into the self-driving movement, passed its 10 millionth mile of self-driving operations in 2018. In those miles, Waymo’s vehicles operated under all driving conditions from snow, night construction zones, and sand storms to push their systems. Waymo’s technology can electronically analyze and monitor conditions 300 yards in all directions—speed, positions of other vehicles, cyclists and pedestrians, intersections—and anticipate actions on the road in fractions of a second. The always-on technology, with redundancy, sees at night just as well as day, and is never distracted.

Following its successful testing of an app-based ride hailing service in Arizona (with back up, safety drivers), Waymo “soft” launched its autonomous taxi service for a 100 square mile area in December 2018. In its trials, Waymo purports that riders experience a ‘seeing and trying is believing’ mentality with its vehicles. Still, at the national level, a Brookings Institution poll found only 40 percent of Americans would be willing to ride in a driverless car. Among younger Americans, and those in urban areas already using ride-sharing, AV has a higher acceptance. Getting more people willing to use the technology will be paramount to AV’s successes; limited-range taxi services and shuttle services are likely to be the early AV technologies that Americans will experience.
Global, Cross-Industry Alliances with AV

A wide range of companies see opportunities as transportation changes into an era of connected vehicles with artificial intelligence (AI), autonomous driving, information sharing, and electric power-trains. Analysts at the Union Bank of Switzerland estimate self-driving revenue will hit $2.3 trillion by 2030—and that Waymo may have 60 percent of that market.

With this kind of revenue at stake, in just the past few years an array of partnerships and cross-collaborations have been created to leverage the global talents of established firms and start-ups. In some cases, companies have multiple partners around the globe:

- GM Cruise, a leading U.S. AV effort, received a $2.75 billion infusion in 2018 from Honda Motor Co.—a traditional competitor
- Uber is working with Toyota in a tech/automotive effort
- Waymo—a spin-off from Google/Alphabet—is testing Fiat Chrysler vehicles and has ties to rental car giant Avis and other auto manufacturers
- BMW and Fiat Chrysler are in a cross-Atlantic collaboration with Intel and Mobileye
- Daimler AG is working with tech-focused Bosch and NVIDIA, who is developing the Drive Pegasus AI platform in Silicon Valley
- Ford is aligned with Pittsburgh-based start-up Argo AI
- Tesla has been at the forefront of deploying EV and autonomous technologies—becoming early market leaders in battery technology; it now has a partnership with Daimler
- Renault-Nissan have an AV alliance—and is testing vehicles on the road
- VW Group has a number of AV designs underway and is working with Aurora of Pittsburgh as its lead technology partner
- Volvo, which has some AV technology in current models, is aligned with auto supplier Autoliv (now Veoneer) and AV-focused technology company Zenuity
- Aptiv (formerly Delphi) is working with Lyft

Taking a Cautious Route to AV

As noted, several companies, including Audi, Tesla and Cadillac, have AV technologies in current models. Others are taking a slower or more cautious route, either prognosticating the regulatory path and acceptance of AV technologies or revising their plans after the accident in Arizona.

For instance, Mercedes-Benz is working to deploy its first “semi-autonomous system” in the company’s 2020 S-Class sedan. Equipped with “Level-3” autonomy, the car will be able to operate in certain conditions without assistance.

BMW is another automotive company taking a cautious path to semi-autonomous driving systems. The company is collaborating with suppliers on AV, but will not have a “Level 3” system until the iNEXT electric crossover in 2021.

Aurora Innovation, along with partners, Volkswagen, Hyundai and Chinese start-up Byton, have pulled back on the rush to deploy and make timeline announcements. VW and Aurora are testing e-Golf self-driving vehicles in San Francisco, but remain hush-hush on the timeline for taking the technology to the public.

As with many innovations, the technology has advanced and is largely available, but the public, infrastructure and regulatory oversight are not. Industry journalist Pat Toensmeier believes this will factor into the deployment: “The AV industry and conventional auto OEMs seem focused on 2025 and 2030 as...”
the key rollout dates. I believe, however, that rollout will also depend on local rules and regulations and the willingness of the public to accept the safety of AVs, especially since the first fleets will probably be robo-taxis and even fly-and-ride AVs, which Uber, among others, is developing.”

In November 2018, Uber released the findings of its investigation into the Arizona accident and revealed a wide-ranging criticism of not only its management failings in oversight, but also shortcomings in its technologies. Uber recognized a need for “improving” the overall software system design and the speed of its systems in analyzing data. Uber is making changes in its technologies, and has applied to conduct further tests in Pennsylvania. Uber admits it has a ways to go in order to perfect its systems, reporting, “we have frequently demonstrated proficiency on a specific scenario set only to identify a new variation beyond our current capability.”

Ford’s Map Toward AV

Ford, collaborating with Pittsburgh-based Argo AI, is planning to roll out an AV vehicle in 2021, spurred by an initial investment of $1 billion with Argo. Their collaboration has grown to more than 800 people—and plans to invest $4 billion in AV through 2023.

Determining how and who will use AV vehicles—and who will own them—are questions being researched by companies as well as cities regulating and working with companies. Ford CEO Jim Hacket told Axios that while advancing on AVs, the company is also evaluating how customers will need and want to use the technology in a revamped transportation sector.

Hackett believes AV deliveries will be as vital and valuable as the taxi systems Waymo launched in Phoenix in 2018. Ford and Domino’s Pizza have developed a self-driving pizza delivery vehicle with a warming oven in Michigan. In 2018, the vehicle, based upon the Fusion model, has been navigating Ann Arbor, MI offering curbside pizza delivery.

Joann Muller of Axios concluded, “Ford is using its commercial vehicles expertise to develop routing and dispatch technology for fleet management and is building out a transportation-as-a-service platform to integrate with its business partners.”

For AV collaborators, there is also a race in finding a city (with agreeable state regulations) to allow testing or an office park or similar closed community environment that may be willing to serve as a partner. Ford and Argo AI have launched pre-market mapping and data gathering in parts of Washington, D.C. These efforts, along with AV testing on the road, are the lead up to their planned 2021 launch in D.C., Miami and other unnamed urban markets. D.C. is collaborating with Ford in hopes of learning more about AV and anticipating potential impacts to the community, mass transit systems, and traffic.
SAE Defines AV Levels

The Society of Automotive Engineers (SAE) has established six categories to help benchmark technologies and capabilities of autonomous vehicles.

**Level 0—No Driving Automation**

Majority of cars on the road (even those with audible alerts like lane departure) fall in this category; all vehicle operations rely upon the driver.

**Level 1—Driver Assistance**

Vehicles introduced in 2007 began to offer cameras and sensors to help with parking, assisted braking and speed monitoring; but an attentive driver is still essential while operating.

**Level 2—Partial Driving Automation**

Available in luxury cars beginning in 2014, driver assistance technology like lane centering and speed monitoring. Tesla, Cadillac and Volvo offer Level 2 capabilities in some models.

**Level 3—Conditional Driving Automation**

Only available in limited vehicles, and in only some markets, these vehicles steer, accelerate, decelerate and pass other cars without human interaction. While a driver is still necessary for operations, hands can be removed from steering wheels, feet taken off pedals, and eyes can be taken off the road, in certain conditions. Not all companies, like Waymo, are testing Level 3 technologies; they are focused on Level 4.

**Level 4—High Driving Automation**

With internal and external lasers, radar and systems, Level 4 is a vehicle that can drive itself “even if a human driver does not respond appropriately to a request to intervene.” Many companies are aiming for a 2021 Level 4 deployment. These AVs may have a major role in transportation as a delivery vehicle, shuttle, or taxi service.

**Level 5—Full Driving Automation**

The holy grail of AV performance, these cars operate without any human interaction. Futuristic designs and prototypes of Level 5 cars feature interiors looking like a first-class airplane cabin, dining booth or hotel room. Expected to be available in the mid-2020s, these will be the vehicles that usher in the transformation of transportation.
What will AVs do—now and in the future?

The first AVs deployed in 2018 by Waymo are designed to ferry passengers; but just who will buy AV technologies and how will AVs be used in the future?

Boston Consulting Group estimates that by 2030, up to 25 percent of miles traveled by car in the U.S. will be via AV cars.

Toyota Motor and technology giant SoftBank have united together in AV behind “mobility services” to develop on-demand vehicle services, deliveries, and shuttle services for hospitals and other destinations. Softbank has already invested in car-sharing companies like Uber and as well as the GM Cruise (planning its AV roll out in San Francisco in 2019) so the partnership is not out of the norm—or the future.

Given that AVs will not be operated by a driver, the traditional cockpit of the vehicle designs will be different than today’s cars—AVs will be designed for passengers, function, and utility.

One Volkswagen AV prototype, Sedric, is currently designed as a pod or shuttle. VW sees increasing density and worsening traffic in urban areas pushing AV technology with the shared economy. VW believes Sedric could be the ideal shared AV vehicle whether being deployed for deliveries, taxis or as the rolling cafes or classrooms of the future.

But will all consumers be looking to purchase an expensive Level 4 or 5 vehicle, particularly if it sits in a garage or is used just for commuting? As shared vehicles are increasingly being embraced by urban dwellers and millennials, and ownership rates of cars in urban areas fall, there is concern that AV will not be an owned technology for many users in some markets.

Autonomous Vehicles, Usage of Plastics

Given that most AVs will be powered by electric or hybrid technologies, plastics will already have a significant role in their design and manufacturing. Plastics will be called on to potentially house and protect AV technologies that surround the vehicle; connectors to circuit boards that serve as the vehicle’s central nervous system and computer chips that interconnect with sensors throughout the vehicle.

Heat is a real threat to the operation of autonomous vehicles—imagine operating a computer in an oven. “A lot of interference with signals can happen in a vehicle, everything from your GPS to your automatic door opener to your radio to your rear-view camera,” BASF’s Dalia Naamani-Goldman, Market Segment Manager, Transportation told Chemical & Engineering News. Plastics provide good electrical/heat insulation as well as noise insulation.
According to the Society of Plastics Engineers, AVs will benefit from plastics in the cockpit and flexible designs such as seating. One manufacturer, Faurecia, has developed the Advanced Versatile Structure, a seat for AVs that is a hybrid of steel, aluminum and composites that weighs almost 18 pounds less than a similarly sized conventional car seat. The seat swivels and has self-contained safety belts which protect the passenger in an accident no matter in-which direction the seat is facing.

**Connectivity on the Road with Other Vehicles and Infrastructure**

Connected transportation vehicles will enable safe, inter-operable, networked wireless communications among vehicles, infrastructure, and passengers' personal communications devices. Connected cars are on the road today, but understanding of the technology varies. Fleet operators, who may be at the forefront of CVs, see it as a means to offer efficiencies, cost savings, and safety improvements. Mass transit managers foresee synced stop lights, improved time tables, and on-board Internet connections for passengers.

On the near horizon is Vehicle-to-Vehicle (V2V) communication that will allow vehicles to share information and road updates—warning each other of a crash or congestion. Under a longer timeline is Vehicle-to-Infrastructure (V2I) technologies designed to improve traffic flows through synchronized intersection signals and alignment with “smart” infrastructure.

Connectivity is one of the keys to delivering AV success; IEEE Spectrum wrote, “Industry leaders will need to master connectivity to deliver the V2X (vehicle-to-everything) capabilities fully autonomous driving promises.”

AVs will run more like computers and be more technical than today’s mechanical car; requiring always-on, redundant, and real-time systems with high-speed interconnectedness inside the vehicle—and with other vehicles and infrastructure on the road. High speed cables, links, nodes and assemblies will be the connections between different systems that are essential to the car’s safety and reliability in all driving conditions. Additionally, the systems will need to be robust in terms of security and preventing hacking and interference. Protecting these systems from the elements and the vehicle’s heat will be essential—and present an opportunity to use plastics technologies for exterior and interior parts.

The future of connected vehicle technology is coming into focus. The U.S. Department of Transportation’s (DOT) Intelligent Transportation Systems Joint Program Office notes “if connected vehicle technology receives regulatory approval and addresses the public’s concerns about security and personal privacy, the USDOT anticipates widespread deployment of CV technology over the coming decades.”

Deployment of connected vehicle technology may be advanced first by freight operators; by 2045, total CV fleet penetration could reach 95 percent of vehicles according to DOT.
Shared Mobility and Economy

Shared mobility, in urban areas, is growing and diversifying. "Shared" encompasses a wide range of transportation modes—some, like taxis and limousines, have been used for decades while scooter-sharing was introduced in 2017. Shared mobility is transportation services and resources that are shared among users, either concurrently or one after another and includes public transit (taxis and limos), bikesharing, carsharing (round-trip, one-way, and peer-to-peer), ridesharing (carpooling and vanpooling), ridesourcing or ride-hailing (Uber, Lyft), ride-splitting (UberPOOL, Lyft Line), shuttle services, "micro-mobility" (scooters), and "micro-transit" (jitneys and dollar vans).

Clearly, these services are not available—or viable—in all areas, but in many cities and communities (office parks, universities, residential complexes, etc.) ride sharing services are spreading in terms of applications and usage. Millennials and other younger consumers have adopted app-based ride services and sharing technologies.

Shared mobility’s strong linkage to AV, EV and connectivity is demonstrated by the fact that two shared leaders, Uber and Lyft, are involved in all areas of transportation research and partnerships, and most shared transportation services are already connected to some extent. An example of cross-sector partnership is Ford Motor Company’s recent acquisition of Spin, an electric scooter sharing company with operations in 13 cities. Uber and Lyft have investments with scooter sharing companies too. Shared mobility has impacted vehicle ownership; automotive companies recognize this and therefore are exploring shared mobility threats (and opportunities). Rental car companies are testing shared mobility opportunities as part of their offerings as well.

According to the Shared Used Mobility Center, a number of issues and benefits can be addressed through shared transportation services, including:

- Provide more mobility choices
- Offer last mile and first mile solutions
- Reduce traffic congestion
- Mitigate various forms of pollution
- Reduce transportation costs
- Improve transportation efficiencies
- Identify choices for those who cannot afford to buy and maintain a vehicle
- Create accessible mobility options for those with limited physical ability

Based upon the leading examples of Uber and Airbnb, the sharing economy, in its entirety, is estimated to grow from $14 billion in 2014 to $335 billion by 2025. For transportation, sharing is setting the table for profound disruption for providers as well as heavy users. In a study, Deloitte concluded that the sharing economy train has left the station: "Incumbents should identify the new capabilities they need to participate in the evolving transportation ecosystem and start experimenting with how they can be applied...New entrants may continue to redefine how value is created within the sector, but they can't go it alone."
Transportation Modes Using Plastics
Where do plastics fit into today’s transportation trends?

If it moves, plastics are involved—and make it better. Plastics play a diversified role in vehicle manufacturing: under the hood and in the exterior and interior of vehicles, for parts smaller than a thumbprint to the width and length of a vehicle.

Plastic components in vehicles can weigh 50 percent less than counterparts made from other materials such as steel; the reduced weight can improve a vehicle’s fuel economy by 25 to 30 percent. Reduced weight—and better gas mileage—also results in fewer carbon dioxide emissions: one less kilogram in a car translates to a reduction of 20 kilograms of carbon dioxide over the life of the vehicle according to Plastics Europe.

A wide range of plastics are used in vehicles by engineers and designers:

- Polypropylene (PP) is a thermoplastic polymer used for bumpers, tanks, cable insulation, gas cans and carpet fibers.
- Polyurethane (PUR) provides strong, but flexible, properties that can withstand weather extremes and chemicals; it is valuable for foam seating, foam insulation panels, automotive suspension bushings, cushions, electrical potting compounds, and hard plastic parts.
- Polyvinyl Chloride (PVC) can be processed in a number of ways—extruded, injected, blow molded, compression molded into either flexible or rigid parts that are flame retardant and offer good thermal stability. PVC is used for automobile instrument panels, sheathing of electrical cables, pipes, and doors.
- Acrylonitrile Butadiene Styrene (ABS) is used for automotive body parts, dashboards and wheel covers.
- Polyamide (PA, Nylon 6/6, Nylon 6) is used with gears, bushes, cams, bearings, weather proof coatings, and air bag housings and material. It can be engineered with other materials, like steel.
- Polystyrene (PS) is used in equipment housings, buttons, fittings and displays.
- Polyethylene (PE) is shaped into car bodies (glass reinforced) and electrical insulation.
- Polyoxymethylene (POM) is used for interior and exterior trims, fuel systems, and small gears.
• Polycarbonate (PC) is used to design bumpers and headlamp lenses.

• Acrylic (PMMA) is an alternative to glass and is used for windows, displays, and screens.

• Polybutylene Terephthalate (PBT) makes door handles, bumpers, and carburetor components.

• Polyethylene Teraphthalate (PET) is used for wiper arm and gear housings, headlamp retainers, engine covers, and connector housings.

• Acrylonitrile Styrene Acrylate (ASA) makes housings, profiles, interior parts, and outdoor applications.

PLASTICS Transportation & Industrial Plastics Committee Q and A

Kendra L. Martin, Vice President—Industry Affairs and manager of PLASTICS’ Transportation & Industrial Plastics Committee

Q: Is the automotive component growing for plastics?

A: Is the automotive sector growing from an association perspective? Absolutely. We announced the formation of our Transportation & Industrial Plastics (TIP) Committee at NPE2015, and since that time have had individuals from more than 40 companies participate in our committee meetings and projects around sustainability, materials issues, reliability and light-weighting. And we’ve brought new processor, recycler and brand owner members into PLASTICS, recognizing the value of participating in a supply chain effort to collaborate on the plastics product lifecycle, from ideation to finished product to recycling and reuse.

From an automotive industry perspective, the use of plastics in automobiles has increased. Plastics contribute greatly to automotive fuel efficiency and safety. If we look at global automotive production data post-recession, automotive production has increased 26 percent from 2010 to 2017. That tells us that plastics as an input in vehicle production also increased.

According to IHS, “by 2020, the average car will incorporate nearly 350 kg of plastics, up from 200 kg in 2014.” That projection represents a 75 percent increase in plastics use in vehicles. As the automotive industry continues to innovate, which would require more use of plastics, the automotive component of plastics will remain a growth area.

Opportunities related to plastics for manufacturers of vehicles, automotive components and aftermarket parts include:

1. **Make them lighter.** It’s a given. Fuel efficiency regulations require that cars—and everything that goes into them—weigh less.

2. **Make them safer.** Demand for safe cars isn’t new, but when coupled with the concurrent need to make them safer and more technologically advanced, the challenge grows.

3. **Make them more eco-friendly.** Fuel-efficient vehicles are one thing, but consumers want materials and manufacturing processes that are planet-friendly too. Next-generation plastics will play a huge part in building safer, lighter, more eco-friendly vehicles. Demand for new cars is big—and so are the opportunities.
Q: How important will it be for plastics companies to collaborate and work with other materials (steel/aluminum) to meet the evolving needs of the transportation sector?

A: The whole industry is focused on multi-material solutions; it is essential that vehicles and assemblies use the best material for the job in all cases. As a material, plastics are frequently directly competing with a variety of materials for use in innovative technologies, as well as specifically with parts using high-strength steel and aluminum.

This variety of materials presents potential new challenges for the recycling industry, as automotive materials and combinations of materials become more exotic. Cars used to be mainly steel and polypropylene; they can now have six different grades of steel, two or three grades of aluminum, engineered thermoplastics with fiber reinforcement, thermoset resins and structures with dissimilar materials permanently bonded together.

Q: In the transportation sector, what are the breakthrough materials in plastics and polymers that could become sector leaders?

A: There are really too many ‘breakthroughs’ to discuss! The auto industry is demanding lightweight, so anything and everything is being tried: lots of carbon fiber studies (with second generation fibers), lots of new fillers being studied, new ways to use plastics for metal replacement (reducing the coefficient of linear thermal expansion, increasing printability, increasing modulus, etc.) Demand is pushing innovation, and the industry is responding.

Q: Where are the crossovers in plastics technology between automotive and other industries?

A: One notable example of a crossover in plastics technology between automotive and other industries is the use of light-weighting technology between the automotive sector and consumer electronics; technology companies turn to plastics for durable, lightweight and affordable properties.

Consumer technology has been in a constant state of change and development over the past several decades—it is a rapidly innovative industry where next-generation applications are rolled out on a nearly annual schedule. The internal workings of devices have increased in speed and capabilities while shrinking in size and weight; at the same time, wireless services and technologies have transformed how we use applications today. The hand-held mobile phone is one of the best examples of these transformations. But mobile phones are not an isolated example; plastics have been essential to the miniaturization and light-weighting of many consumer electronic products.

The innovation in plastics helps propel the development of consumer electronics technologies. Weight reductions, safety, miniaturization, design flexibility, performance and greater energy efficiency over the course of a product’s life, are all brought to the forefront with plastic.

As next-generation technologies are introduced every year, the consumer technology sector also faces the same challenges that PLASTICS focuses on across end-markets: end-of-life management and recycling of its products and packaging.
Automobiles

Regardless of an automobile’s propulsion, the need for saving weight is critical. Lighter vehicles get better gas mileage, and a lighter electric vehicle has a longer range. Ted Miller, Ford’s senior manager of energy storage strategy and research, told Chemical & Engineering News, “The effect of vehicle weight is even more pronounced in electrified vehicles since we are pushing the limits of vehicle efficiency.”

Over the years, plastics usage in vehicles, on average, has grown from 17.6 pounds in 1960 to 332.8 pounds of plastics and composites in 2016 according to the American Chemistry Council; this accounts for about 8 percent of the car’s weight and about 50 percent of the volume of materials in the car.

Magna International is optimistic about the continued use of plastics in automobiles as OEMs continue to be interested in light-weighting opportunities in their vehicles using plastics, including going to areas of vehicles that plastics may not have historically been used, like body and structural applications.

Technologies under the hood may vary from vehicle-to-vehicle, but the simple principle that weight requires more power applies to the advantages of plastics being used in new vehicles. Slimming down electric vehicles will be a top priority as batteries are heavy, and electronics add weight. Plastics are well suited to

Fleets are investing in plastic underbelly fairings because they provide positive returns on investment. We are also seeing an up-surge in the purchasing of wheel covers, tail wings made of plastic, and gap reducers that make trucks more streamlined.
be connectors between motors, batteries and inverters. Likewise, high voltage power cables that need resistance to temperatures, chemicals and wear are being made with plastic elastomers. For battery seals and cases, manufacturers see plastics and thermoplastic composites as the solution for their vehicles.

For interiors, automotive plastics have increased dramatically over the years, and have contributed significantly to the styling, comfort and safety of vehicles and passengers. Allied Market Research projects that composites (such as glass fiber reinforced plastic and carbon fiber) and plastics (polypropylene, acrylonitrile butadiene styrene, polycarbonate, and others) will be the dominant interior materials over metals, fabrics, and leather.

**Trucking**

The plastics trends in automobiles closely parallel trucking trends—the engineering just scales up for the bigger vehicles. Truck manufacturers have worked to improve the efficiency of vehicles through light-weighting, improved drivetrains, and aerodynamics. Plastics play a role in each of those initiatives—even though that may have been unheard of some years ago.

Plastics first positioned themselves inside trucks, but now can be found throughout a truck, particularly in exterior parts, like those designed to aid aerodynamics, improve safety, reduce noise, and curb roadspray.

“Trucking companies and fleets are buying lots of plastic side skirts because they work and they improve profitability,” said Glen Kedzie, Vice President, Energy & Environmental Counsel, American Trucking Association (ATA).

Manufacturers and fleet operators are united in their belief that improved efficiencies are good—and save money. Aerodynamic improvements—using plastics—are the low-hanging fruit to improving fuel economies and include wheel covers, slotted mudflaps and cab/trailer underbody air-flow treatments. Simply reducing the air gap between the truck cab and trailer can improve fuel efficiency by up to two percent.

The Environmental Protection Agency’s SmartWay greenhouse gas reduction program launched in 2004 and has become the “Good Housekeeping Seal” for fleet operators and the adoption of fuel technologies, light-weighting, and aero technologies. “Today many of these technologies introduced under SmartWay over the years have become standard equipment on tractors and trailers as they have proven to fleet owners that they save fuel, reduce emissions, and provide a positive return on investment—increased profits you can keep in your pocket or reinvest in your company,” Kedzie said.

For instance, Thermo King Northwest uses durable polyethylene plastic for its SmartTruck Aerodynamic System that withstands the weather, rocks, and chemicals found on the road.

According to the DOT, side skirts provide 4 to 7 percent fuel economy improvement, representing an estimated annual fuel savings of $5,000 for a long-haul tractor trailer.
In the past decade, trucking turned to natural gas as a possible fuel of the future, but the energy source did not take widespread hold, particularly for long haul vehicles. Now two new market entrants and energy sources are coming online. First, Tesla and other manufacturers have announced their intent to deliver electric vehicles as early as 2020. Secondly, Nikola, with its hydrogen electric fuel cell system, unveiled its Nikola Tre model and announced its intent to enter the European market in 2020 and deliver trucks in the U.S. in 2023. Freightliner has developed the eCascadia e-truck and Volvo, Cummins, Ford, and Scania are progressing with electric engines for trucks as well.

Electrification is also moving to urban delivery vehicles. DHL and UPS are two companies deploying electric vehicles—and Renault, Nissan, VW, Ford and others are working to roll out electric delivery vans.

Fleet operators see opportunities in AV technologies and shipping. Many of the companies involved in automotive AV also have an eye on trucking AV; for instance Uber is currently testing a self-driving truck on U.S. interstate highways. For the ATA, AV does not mean “driverless”—it is “driver assist,” and that AV’s equally important contribution on the roadway may be reductions in traffic congestion, reduced emissions/fuel savings, and improved driver productivity. ATA draws similarities to airplane autopilot technology with developing AV technology for trucks and believes tiered AV systems will be gradually introduced over time. ATA’s Kedzie said, “Technology won’t be perfect out of the gate. We have a lot of smart engineers and companies investing in new technologies and competing for market share in the industry. They will find the answers, but we can’t rush to find the answers; the logical approach is to gradually stage levels of autonomy.”

Walmart’s WAVE

Fleet owners, like Walmart, have a vested interest in trucks improving their safety, mileage, and efficiency. With 6,000 trucks in the U.S., Walmart has a tremendous upside for savings by improving its fleet. The company’s concept truck of the future, the Walmart Advanced Vehicle Experience (WAVE) combines aerodynamics, hybrid power electrification, advanced control systems, and weight saving materials like carbon fiber and plastics materials. The center console truck offers 20 percent improved aerodynamics which translates into 10 percent improvement in fuel economy. The trailer is made almost entirely of carbon fiber; single-piece roof and sidewall panels are used with advanced adhesives to save weight and reduce rivets. The WAVE trailer weighs approximately 4,000 pounds less than current fleet trailers and rolls on tires with wind-cheating wheel covers.

ATA’s Kedzie believes the appearance of next generation trucks may help in the recruitment and retention of younger drivers as the appearance and performance may be an appeal for entering trucking.
Aviation

Aviation materials are first evaluated with an eye toward safety; weight savings and durability are additional factors, but safety is paramount. Plastic materials check those boxes for aviation uses.

Stringent safety standards must be met for any plastic material to be used in an airplane; MIL (military), BSS (Boeing Safety Standard), and ASTM Standards are applied to plastics usage to ensure their safety. Plastic polymers and materials must perform while being able to resist corrosion, withstand high temperatures, and meet the flame and smoke requirements for modern aircraft.

For airplane interiors, lightweight plastics keep passengers comfortable and protect vital electronics; high-heat plastics with low flammability and resistance to jet fuel and other chemicals are valued in aviation. Plastics offer durability, ease in cleaning, and fire resistance for parts such as cabin partitions, seat backs, tray tables and arm rests, luggage bins, air ducts and systems, instrument panels, bearings and bushings, fasteners, gears and gear spaces, guides and stops, housings, valve seats, slide rails, splines, wear pads, and wire wrap insulation. Cockpit canopies and aircraft windows rely on polycarbonate plastics for their transparency and impact resistance.

According to Assembly Magazine, carbon-fiber composites are growing in the aviation sector, changing the design and construction of many airplanes—and their performance.

Leading plastics in the aviation sector include:

- Polychlorotrifluoroethylene (PCTFE) has tremendous heat/cold resistance—ranging 800 degrees.
- Polyamide-imide (PAI) is known for its flame retardancy and ability to maintain its strength integrity in high heat.
- Polytetrafluoroethylene (PTFE) is a leading plastic for cables and wires, providing insulation, resistance to tears and flame retardancy.
- Polyetheretherketone (PEEK) can withstand a wide range of temperatures and is flexible; pump gears or valve seats are popular areas to use this product.
- Thermosetting Polyimide is used to save weight, provide insulation, and resist chemicals—it is used in threated nuts found in planes.

Alex Curtiss, president of Engineered Plastic Products Corporation, which produces a variety of aerospace parts, told Assembly Magazine, “Each year, more and more plastics are being created with unique performance characteristics that are ideal for specialized uses and replacing metal materials. Plastic is often a first choice due to weight-to-strength ratios and the natural corrosion resistance of many of the modern compounds.”
According to Curtiss, load-bearing, torque handling and gear drive applications in airplanes are also turning to plastic technologies; specialty polymer grades with superior heat, chemical and radiation resistances are key to plastics, role in the aerospace industry.

Gregory Odegard, a professor of mechanical engineering and materials science at Michigan Technological University said, “The use of polymers is increasing in the aerospace industry, particularly for aircraft. Aluminum used to be the material of choice because of its relatively low weight, low cost, corrosion resistance and resistance to fatigue. However, over the last couple of decades, polymer materials have slowly replaced aluminum. The use of polymers is increasing in the aerospace industry, particularly for structural members of aircraft.”

Despite the increased usage of plastics, some aerospace engineers are still reluctant to switch to plastic, in part, according to one aviation engineer, is because of the decades of available performance data comparing aluminum to plastics and composites.

Electric and hybrid-propulsion is also being explored by the aviation sector; with all-electric air shows cropping up in the industry. Regulations, too, have advanced with electric aviation—the Federal Aviation Administration allows electric flight as well as increased automation as part of several aviation safety and technological innovations.

Mass Transit: Rail/Bus

With transit buses, subway cars, and light-rail trains, the mass of these vehicles requires steel or aluminum carriages in their manufacturing but plastics are valued for a wide variety of parts given their strength-to-weight ratio, high wear and corrosion resistance, and fire and flame resistance.

Plastic parts in mass transit vehicles include bins, seats, seatbacks, armrests trays, mirrors, insulation, structural components, interior skins, flooring, partitions, door, wall, and ceiling panels, dashboards and displays, windows, window masks or shrouds, bulkhead components, and luggage racks.

Transparent partitions, found in many buses, subways and railcars, are made from acrylic and polycarbonate sheeting that are lightweight, impact resistant and stylish—by providing openness and transparency—in addition to being resistant to scratches and flames. Hard-coated polycarbonate sheets are also used for vehicle glazing on mass transit windows; the sheets provide durability, transparency and scratch resistance.

Plastic films and sheeting are also being used in conjunction with LED lighting systems for interior lighting—the LED offers higher reliability and energy efficiency while the plastic films diffuse the light to improve a vehicle’s appearance without negatively impacting light transmission or safety.

Thermoforming is used to manufacture a number of mass transit parts as they help meet the Department of Transportation’s Docket 90—a safety specification for flame spread and smoke emissions.

Exterior mass transit applications using thermoformed plastic include front bumper fascias, side fairings, hoods, fender wells, bumper end caps, running boards, and rear panels.

The International Association of Plastics Distribution reported plastic composite panels on Swiss trains led to a 25 percent weight reduction, leading to significant energy savings.
Marine: From Commercial to Personal

Vessels operating in salt and freshwater marine environments need to withstand harsh, corrosive environments; both exterior and interior systems and components must be up to tasks that would be unsuitable to metals or woods. Plastics are uniquely suited as a material for marine uses, providing necessary high strength-to-weight ratios, resistance to corrosion from ultraviolet (UV) light, sea water, abrasive materials and petroleum products, and, very importantly for a vessel, little or no water absorption.

A wide range of plastics are being used on the water, including fiberglass, composites and “sandwich” multi-ply designs, as well as PVC and polyurethane. Technological advancements in composites and carbon fiber have expanded marine applications to a wider range of vessels—and parts.

Fiberglass, in the 1940s, was a breakthrough material for boat construction—quickly overtaking wooden boat construction. It revolutionized construction, performance, and costs of all classes of boats. Fiberglass is frequently used in fishing, ski and pleasure boats as it provides structural stiffness and integrity. Boston Whalers, iconic boats found in all bodies of waters, use fiberglass and polyurethane foams to manufacture their hulls.

At the lower end of boating, polyethylene is a popular, manufacturing-friendly material that is reasonably priced, easy to manage and design boats with—and virtually indestructible for the recreational boater. Polyethylene kayaks and canoes are molded, so shapes can be easily designed and duplicated. Aluminum, a competing material, cannot be similarly molded and will lack the molded-in compartments that plastics have.

Tideman Boats, a manufacturer of workboats—like tenders, patrol, pilot and crew boats—uses high density polyethylene (HDPE) for its vessels, promoting the material’s weight, durability, resistance to chemicals and performance. Tideman notes that HDPE’s density is lighter than water and, at the same time, their boats’ elastic characteristics prevent deformation or cracks.

At the highest-end of boating, carbon fiber is the material changing the design and performance of boats around the world; it is among the lightest, strongest and stiffest of materials. Carbon fiber is lighter than fiberglass, but has about twice the strength-to-weight ratio. Carbon fiber and similar lightweight, strong composites are being used for shells and linings, as well as propeller blades and shafts under water, and helms, consoles and masts above the waterline. A carbon fiber mast on a performance sailboat not only weighs around half the weight of a traditional aluminum mast; it also lowers the center of gravity of the boat, allowing more sail area but also a smoother ride.

Carbon fiber’s performance comes with a price tag: the material can range from $5 to $20 per pound, depending on the material and variables, while fiberglass generally runs from $1.50 to $3 per pound. A carbon fiber mast, for example, typically costs 3 to 4 times more than an aluminum mast.
Electric propulsion is also coming to the water, for work and pleasure craft. Rolls-Royce has provided battery-powered marine engine systems for a number of years for short haul ships, like ferries. Norway-based Corvus Energy is expanding its electric engines, seeking to grow beyond the nation’s ferries to other parts of Europe.

Recreation: Motorcycle/ RV/ATV

Polycarbonate and polycarbonate blends are leading materials for motorcycle, all-terrain, and off-road manufacturers, offering engineers a strong, lightweight, high-performing material that holds colors and improves aerodynamics. These plastics shape interior and exterior panels, bumpers, seating, and instrument panels.

Motorcycles and other two wheel vehicles are also undergoing a change in their motors: the move to electric propulsion in motorcycles is exemplified by Harley-Davidson. Beginning in 2019, H-D will begin selling LiveWire, its first electric motorcycle. The U.S.-manufactured electric motorcycle, like other electric performance vehicles, will have significant acceleration qualities (0–60 mph in under four seconds) and will be clutchless. Other companies, like Zero Motorcycles, have competing e-models in the marketplace.

Plastics company Covestro worked with Alta Motors to develop a battery pack and subframe for one of their electric motorcycles. Their solution was a polycarbonate blend used in conjunction with other materials like aluminum to produce a system that was durable, chemical and impact resistant, for a motorcycle taking the open road.

Bicycles and E-bikes

Every bicycle seen during the Tour de France—and similar races around the world—uses carbon fiber technology not only for the frame, but also other major components on the bicycle—from the wheels and stems to handlebars and water cages.

While manufacturers may also use titanium, aluminum or steel for some models, carbon fiber is the most popular and successful material in cycling for road and off-road bicycles. Carbon fiber filaments, thin as hair, are bound together into ribbons which are woven into fabrics which are layered together to form laminates, or strong but lightweight material that engineers shape into the best bicycles and components.

The process, however, takes time and expertise—including human hands and craftsmanship—which translates into higher costs compared to other materials. A carbon wheel can cost more than $1000 compared to an aluminum wheel that costs $150—but carbon wheels in their weight and design can cheat the wind and propel a rider two to three miles faster per hour. The frames too can be designed to cheat the wind and increase speeds for cyclists as well.

Electric-powered bikes were once clunky and unstylish bikes that most cyclists would forgo. Today’s electric powered bikes are significantly more stylish, powerful and diverse—carrying thrill seekers on e-mountain bikes, 9-to-5ers on their commute to the office, and for deliveries. In China, more than 200 million e-bikes are being ridden on Chinese streets and cities.

The growth and expansion of electric bikes is underscored by New York City’s recent reversal of a long-time ban against e-bikes—once regulated like mopeds. Now, of the estimated 50,000 bicycle delivery workers around New York City, half are on e-bikes.

Delivery companies, like UPS, are running trials on electric assisted tricycles with a protected cargo space for delivering packages in Seattle.
Plastics have been used by NASA and other aviation-related industries for several decades to help astronauts and payloads get into orbit; helmets, visors, internal systems, flight suits, radiation protection, and light-weighting substitutions, like seating, seals, flooring, and panels have all been advanced with plastics.

Space Exploration and Travel

Space exploration may not be a traditional mode of transportation, but SpaceX sold its first ticket for a trip around the moon with a departure slated as soon as 2023. Spurred by growing global economies and private sector prodding and economic infusions, space exploration has returned to the front burner. Over the next 20 years, the space economy will be between $1.1 trillion and $2.7 trillion according to Morgan Stanley and Bank of America, respectively. The international space station is no longer the only game in the solar system.

The X-Prize Foundation helped launch the renewed interest in space with a $10 million award for the first private-sector launch into suborbital space. Since the organization granted their prize in 2004, more and more companies have set their sights on the heavens, including Jeff Bezos (Blue Origin), Elon Musk (SpaceX), and Richard Branson, (Virgin Galactic). Blue Origin is focusing on space tourism and commercial payloads while SpaceX has sent reusable rockets with satellites into orbit.

Countries have also caught space-fever, some attracted by the chance to diversify their economies and others spurred by national pride and political motivations. The United Arab Emirates, Saudi Arabia, India, and Israel have joined established nations like Russia, China, Japan and the U.S. in pushing the space envelope.

With all the renewed enthusiasm and competing interests, U.S. President Donald Trump has called for the creation of a new arm of the U.S. military—the Space Force. The U.S. Air Force and National Aeronautics and Space Administration, which is celebrating its 60th anniversary, have expressed concerns with the potential competing, new agency, but the discussion is a nod to the growing global interest in space.

Plastics have been used by NASA and other aviation-related industries for several decades to help astronauts and payloads get into orbit; helmets, visors, internal systems, flight suits, radiation protection, and light-weighting substitutions, like seating, seals, flooring, and panels have all been advanced with plastics.

Radiation protection, particularly with visions turning to Mars, will be a priority. Exposure to radiation during solar storms that could occur during the months-long trip would be very hazardous. NASA researchers at the Space Radiation Laboratory at Brookhaven have studied the threat of radiation—and methods to protect humans. Most common protections—cement, lead, or water—would be non-starters in space due to weight and other factors. NASA's researchers have developed a new polyethylene plastic that is light and stronger than aluminum but can also stop radiation. RXF1 is 50 percent more effective against radiation than aluminum of similar thickness. Innovations such as RXF1 and other materials will continue to come as more countries and companies invest in space exploration.
With satellites, plastics are used for applications such as solar array deployment systems, cable insulating blocks, and platform systems. Plastics used in the space industry exhibit high strength under severe vibration, insulating qualities for electrical systems, control units, and landing gears, heat and flame resistance, and low/ultra-low outgassing characteristics.

NASA continues to seem confident in its use of polymers; the agency recently invested $15 million to develop the next generation of composites for manned missions to deep space.

Drones and Autonomous Delivery Vehicles

On social media, drones with cameras are a tool for developing visual content, but in a growing number of industries, drones and unmanned aerial vehicles (UAV) have proven to be vital time- and cost-saving tools—sometimes even life-saving. The expansion of drones over the past few years from a hobbyist-toy to industry disruptor has been remarkable. Agriculture, utilities, construction and maintenance, remote search and rescues and firefighting are now all using drones daily.

Drones, which vary in size and capabilities, must be lightweight and strong; carbon fiber and composite plastic technologies for blades, plating and other components are the standard.

New uses for drones (in air and ground) are coming: cargo and delivery are being tested and companies are test-flying drones to transport people. Amazon, which has been testing drone deliveries, was recently awarded a patent for a drone that reacts to human gestures during delivery—such as hands waving or raising in case a drone comes close to a human.

Ground delivery robots are already being utilized for deliveries. Starship Technologies has autonomous food-delivery vehicles that can be dispatched to make deliveries. Postmate, Starship’s partner with the robots, makes more than 2 million deliveries a month with a fleet of cars, bikes, scooters, and by foot. The automated ground drones are six-wheeled vehicles, encased in plastics, with nine cameras, GPS, and ultrasonic sensors to monitor its surroundings at speeds up to 4 miles per hour. To date, the Starship robots have traveled more than 60,000 miles and encountered 12 million people.

Drones designed to carry human passengers will take flight in 2019. Hoversurf is pre-selling the “Hoverbike S3,” a 253-pound, 4-blade, electric-powered vehicle that resembles a cross between a drone and a snowmobile. The vehicle can fly 60 mph and 16 feet above the ground. The Federal Aviation Administration will regulate the vehicle as an ultralight, and therefore not require a pilot license or aircraft certification. Hoverbike’s first designs used aluminum for the body; the vehicle being sold, however, has a monocoque frame made with different types of carbon fiber that reduced the vehicle weight by a factor of two.

Boeing is also working with a number of partners in drone technology and design to develop air taxis, predicting within the next decade air taxis will transport passengers from one city to another. CEO Dennis Muilenburg told Bloomberg TV that engine technology is “in hand” and that a regulatory traffic management system could be established within five years. Uber is also eyeing 2020 for its Elevate flying car system to take flight.
Transportation Sector Economics Impacting Plastics
All modes of transportation have benefited from advancements in engineered plastics and composites—from airplanes and buses to cars and trains. When looking at the widest range of vehicles and modes of transportation, now and into the future, it is hard not to find plastic components, stylings, and engine parts.

Stable Use of Plastics in Transportation Ahead

Perc Pineda, PhD
Chief Economist, PLASTICS

The increasing demand for mobility services is a good indication that the use of plastics materials in transportation will not diminish. For safety, design, and cost reasons plastics materials are widely used in all forms of transportation—land, air and sea. The use of plastics in transportation will continue to be influenced by changes in technology, demographic shifts, and the regulatory environment.

Aggregate personal spending on transportation has been stable in the U.S.—hovering around 7.0 percent of the total personal consumption expenditures (PCE) since 2014 (see Figure 4.1). As the economy remains in a healthy state so too will transportation demand, as mobility is a necessity so if the economy remains stable and healthy it should be expected that demand for transportation will do the same. If history is our best guide, it is fair to say that when the next economic contraction begins, there is potential for a decrease in transportation spending. After the most recent economic contraction in 2008–2009 personal transportation spending as a percent of total PCE decreased from 6.9 percent to 6.3 percent. While all signs point to a stable transportation end-market for plastics, technology, demographics, and the regulatory environment will continue to influence the use of plastics across the sector.
Recent technological innovations have produced greener vehicles. However, the share of electric vehicles in the market has stayed low with demand expected to stay under 10 percent globally until 2020. A more influential factor in the sector that has recently risen are ride-sharing companies.

Ride-sharing has been viewed as a potential cause for a decrease in the aggregate sales of automobiles to some extent. However, there is agreement among industry analysts that auto sales are in the downturn cycle following strong auto sales in 2015 and 2016. The monthly auto and light truck sales forecast, on a seasonally adjusted annual rate, for 2017 and 2018, has been under 17 million units. In December 2017, however, auto and light truck sales were 17.3 million and in October 2018 were 17.5 million units. The pace of automotive and light truck assemblies holds clues on the use of plastics in transportation. Data suggest lower automotive and light truck assemblies since they peaked to 12.6 million in July 2015, on a seasonally adjusted annual rate. In October, assemblies flattened from October 2017—coming in higher than the previous year by 0.5 percent. Looking back further, assemblies fell 8.5 percent from two years ago.

The trend from the monthly data, which is usually quite noisy, shows moderately declining assemblies following a peak in 2015. However, a business-as-usual scenario points to a moderate increase in assemblies ahead to 11.6 million by the end of 2020 (see Figure 4.2), but still below the 2015 high. The pace of growth of the use of plastics in automobiles and light trucks would depend largely on product innovation. The innovations on the use of plastics in autos and trucks (see Section 5) point to more usage of plastics in the future.
While fewer millennials are supposedly obtaining drivers’ licenses as soon as possible and would rather spend their money on other things a decrease in car ownership does not equate to a decrease in mobility needs. Moreover, U.S. demographics point to a higher percentage of Americans over 65 years old than ever before. In fact, by 2020, 56.1 million of Americans will be 65 years and older—17 percent of the U.S. population, according to U.S. Census Bureau projections. Ten years thereafter, it is projected that this age group will comprise 21 percent of the U.S. population. While driving decreases with age, mobility needs, by and large, do not change dramatically. Hence, demand for transportation is not going to decrease significantly, but would shift away from spending on vehicles and parts as a function of ownership to transportation services spending.

In addition to electric vehicles and ride sharing, technology improvements are making auto manufacturers invest in research and development to produce autonomous vehicles. Over ten million miles on public roads have been driven by self-driving vehicles, with public use of the technology just on the horizon. Waymo, a subsidiary of Alphabet, is contemplating buying upwards of 80,000 vehicles to equip with the technology, an example of how the growth of ride-sharing could potentially help sustain auto and light truck sales and not hinder them as some may believe.

Profit maximizing businesses will undertake research and development to innovate. Businesses that are profitable or have access to capital will develop new products and explore new markets to improve their bottom line. Innovations such as autonomous vehicles, which are often designed to be lightweight, would require use of more plastics materials. Cars that communicate with one another using data connectivity will require more plastics in them as well, not to mention the data warehouses which run on networked servers connected by plastic coated or protected by PVC, PTFE and other plastics.

What will the roads be like in the future when autonomous vehicles run up and down the road side-by-side with vehicles driven by humans? For automobiles to talk to each other and to support human needs in a seamless way, a strong information technology infrastructure will be needed. Ford Motor Company is developing a “Transportation Mobility Cloud, an open software platform that could one day allow vehicles, streets and cities to talk to each other and plan the most efficient routes for people. This technology could direct people to use a combination of autonomously driven Ford-built taxis and bicycles to get to their destination.” Such infrastructure would also solve the burgeoning traffic problems in major cities that are cutting into commuters’ productivity.

While auto manufacturers and their suppliers—including plastics manufacturers—are putting their efforts in high gear to leverage technology to address the mobility needs of the future, the regulatory environment plays a pivotal role. Infrastructure—be it information technology or roads—are often dependent on overall changes in public policy that shapes regulation for specific industry (see Public Policy—Section 6).
Aviation has also experienced a large increase in plastics usage and with miles traveled through the air increasing, the plastics industry seems to have a steady partner in aviation. There is no turning back on the use of plastics in aviation—it has quadrupled since 1970. With the increasing number of airline passengers, as shown by revenue passenger miles in Figure 4.3, aircraft building in the U.S. can be expected to remain healthy.

Therefore, a stable supply of plastics materials into aircraft, engine, and parts manufacturing in the U.S. can be expected ahead. In fact, according to Airlines for America, in 2017 the percentage of the U.S. adult population that flew in the past 12 months was 48 percent—more than doubled from 21 percent in 1971—and the percentage that had flown in their lifetimes was 89 percent—growing approximately 1.8 times from 49 percent in 1971. It is unlikely that demand for air travel will revert to the 1971 levels.

**Figure 4.3**

Revenue Passenger Miles for U.S. Air Carrier Domestic and International Monthly, Seasonally Adjusted

The airline industry is a mature industry and its revenue will most likely grow in sync with gross domestic product (GDP) growth. The plastics industry will generate revenue from the products and service segments (see Figure 4.4) of aircraft, engine and parts manufacturing considering its many advantages over metal alloys that have been traditionally employed in the aerospace industry. IBISWorld projects 5.4 percent revenue growth next year and 4.4 percent thereafter—settling to a 1.6 percent revenue growth rate by 2023.
The airline industry is a mature industry and its revenue will most likely grow in sync with GDP. The plastics industry will generate revenue from the products and service segments (see Figure 4.4) of aircraft, engine and parts manufacturing considering its many advantages over metal alloys that have been traditionally employed in the aerospace industry.

The boat building industry in the U.S., which is engaged in motorboat, rowboat, sailboat, personal watercraft, yacht, and dinghy manufacturing uses plastics materials extensively. In fact, one of the key determinants of demand for boats is plastics materials and resin prices as shown in Figure 4.6.
The 10-percent aluminum tariffs imposed by the Trump administration, unless reversed, will negatively affect the boat building industry, which uses a lot of aluminum. Considering that demand for boats is relatively price elastic, a higher cost of materials that translates to higher retail prices will keep demand at bay.

It is obvious from Figure 4.1 that the demand for boats in the U.S., despite the wide-ranging price points, is anchored to the state of the U.S. economy. Unlike cars and airplanes, demand for boats is discretionary, and hence largely dependent on disposable income. With the U.S. personal income rising in recent years, it is intuitive to expect that demand for boats is positive. However, as a discretionary purchase that is most likely financed, high interest rates affect demand negatively. At the time of writing this report, the U.S. prime rate was 5.25 percent—higher from the 4.25 percent a year ago. Although disposable income is poised to improve as the economy grows, short-term interest rates are also expected to increase. With the Federal Reserve raising interest rates to meet its dual mandate of maximum employment and stable prices—with a 2.0 percent inflation target—it is unlikely that interest rates will remain low. With the prime rate 3.0 percentage points above the Fed funds rate, another 25-basis point rate hike by the Federal Reserve would easily put the prime lending rate to 5.50 percent.

The 10-percent aluminum tariffs imposed by the Trump administration, unless reversed, will negatively affect the boat building industry, which uses a lot of aluminum. Considering that demand for boats is relatively price elastic, a higher cost of materials that translates to higher retail prices will keep demand at bay. In addition to high tariffs that are making U.S. boat building uncompetitive, a strong U.S. dollar also affects U.S. exports revenues. The U.S. trade surplus in boats (NAICS 336612) had started to disappear in 2015, due partly to a stronger
In sum, plastics will continue to play a critical role in all forms of transportation—cars, airplanes, and boats. Figure 4.8 summarizes the use of plastics in different forms of transportation. It is based on the detail-level table data on a supply-use framework from the Industry Economic Accounts of the U.S. Bureau of Economic Analysis for the years 2007 and 2012. Technological innovation will keep research and development on plastics materials in sync with the broader innovation that will continue to occur across the transportation landscape. Demographic shifts will continue to offer opportunities in transportation services and will impact the use of plastic materials positively. How soon the U.S. and the global economy can adapt—in terms of infrastructure to accommodate self-driving vehicles, EVs, or smart cars—will continue to depend on public policy that will ultimately determine the pace of changes in regulations to accommodate innovation.

Commercial aircraft products will continue to comply with Federal Aviation Administration regulations on quality, airworthiness, repair procedures, and export airworthiness, and list goes on. The U.S. Coast Guard maintains the federal statute law to manage recreational boat manufacturing. The automotive industry will continue to comply with fuel consumption rules—corporate average fuel economy standards (CAFE)—among the other government regulations regarding safety and pollution control.
### Figure 4.8 Plastics in Transportation

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<th>Description</th>
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<th>326120</th>
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<tr>
<td>336999</td>
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</table>
The light-weighting of cars has been transformative for the industry—and transportation. According to Ford Motor Company, “Few innovations provide a more wide-ranging performance and efficiency advantage than reducing weight. All factors of a vehicle’s capabilities—acceleration, handling, braking, safety, efficiency—can improve through the use of advanced, lighter materials.”

A.T. Kearny, a management consultancy, reported that the average weight of motor vehicles since 2008 has dropped 20 percent—improving gas mileage performance and reducing per vehicle emissions. European vehicles by 2020 are expected to weigh only one ton—down from the peak of 1.5 tons in 2010.

R&D—Innovation—Collaborations
Keep Plastics in Transportation

If the future of transportation is electric, autonomous, and connected, it will be transformative in how we move. Plastics have made significant contributions over the past 50 years to all vehicles, but in the future, plastics may be called on even more to help usher in the era of electric and autonomous vehicles.

In looking at the opportunities for engineered plastics, DuPont’s Patrick Cazuc told Foam Expo, “If you look back over the past decade, the penetration of thermoplastics in vehicles is phenomenal. Yet, when we come to the ultimate light-weighting solutions—for chassis application, structural application—most engineers are conservative in this area. For generations now, metal has been taught in most engineering schools. Thermoplastics in this historical context is much younger and the knowledge we have of thermoplastics is still embryonic. It’s not something that people will jump onto straight away, although the possibilities of the material are almost boundless.”

Thermoplastic advancements in recent years—light-weighting, heat and chemical resistance, manufacturing improvements, and cost savings—have contributed to thermoplastics being used inside and out of cars and with the engine and chassis. For many vehicles, thermoplastics dominate the interior finishes and parts of cars.

Increased heat from engines and electric batteries should buoy the use of thermoplastics which exhibit outstanding performance at higher temperatures.

Mike Chiandussi, power-train market segment specialist at BASF Corporation—Engineering Plastics, told Plastic Technology, “We predict that about 20 percent of all turbocharger applications will require a high-heat resistant plastic as engine temperatures increase.”

Running along with the light-weighting trend of vehicles is the fact that electric power trains and batteries produce heavier vehicles: while combustible engines represent approximately 12 percent of a car’s total weight, electric power trains represent 20 percent of the vehicle’s total weight. Manufacturers are under even more pressure to find spec-meeting materials that are lighter. A.T. Kearny projects in the next 10 years plastics will represent 18 percent of the average vehicle’s weight, a four-percent jump since the 2000 average.
Competing materials are not necessarily letting plastics take their lunch; like any industry or material, steel and aluminum are working to maintain their role in the transportation sector. Innovations are being made within the steel and aluminum industries—and according to Kearny, these materials appeal to manufacturers regarding their price stability and costs, recyclability and performance. Further, some engineers are more familiar with them in vehicles.

DuPont’s Cazuc stated, “The battle is between aluminum or high-strength steel and thermoplastics. And clearly the cost advantage might be playing out for thermoplastics because of all the functional integration you can include through the design.”

Auto manufacturers are expected to continue to take holistic views of their supply chains—from design and manufacturing to performance and end-of-life recycling. Kearny wrote, “Collaborative research and development will be more focused on material properties and technology issues. If involved early enough, plastics can be used to substitute parts like-for-like, and also deliver an advantage by improving aesthetics, and reducing costs and vehicle weight. This latter point, reducing vehicle weight, is accomplished via suppression of sub-assemblies; for example, new thin seats are the result of merging foam, fabric, and structure.”

Magna International, a diversified global automotive supplier based in Troy, Michigan, has stepped up its research and development spending—planning to invest $300 million by 2020. The company is deeply involved in EV and AV technologies, and is serving as a partner to Lyft along with Jaguar on the I-Pace electric crossover vehicle as well as BMW on new vehicles.

“We welcome any challenge from our automotive OEM customers to identify a material application, or co-development opportunity, to help them drive their strategy in terms of mass reduction in a vehicle, and to help them usher in the trends that we are seeing for the future. We have very good collaborative relationships with our OEM partners,” said Magna International’s Brian Krull.

Magna’s collaboration has been recognized by the Society of Plastics Engineers (SPE) Automotive Awards. The company won three SPE awards for body exterior parts, a subframe prototype made with carbon fiber, and a torsional welding joining process. The thermoplastic exterior lift gate made for the 2019 Jeep Cherokee represented a 25-percent savings over steel versions and the carbon subframe achieved an 82-percent part reduction.

Engineered thermoplastics such as PEEK, PMMA and TPV/TPO will likely help to deliver necessary performance in intense operating conditions. DuPont is working with vehicle manufacturers to replace metal— and even plastic components—with high-performance thermoplastics and elastomers. These new materials are suitable for under-hood and power-train applications. DuPont Minlon mineral reinforced nylon resin and DuPont Zytel PLUS nylon resin are used to design components that can withstand the high temperatures, chemicals and intense pressures found in vehicle engines.

**Nylon, Composites, Fiberglass and Polycarbonates Usage Increasing**

A number of materials are competing to become major components for next generation electric vehicles; compared to traditional materials, the lighter alternatives can reduce the weight of a vehicle’s body and chassis by up to 50 percent.

Brendan Dooley, of IHS Markit noted, “There is a little bit of uncertainty about what components will be needed for electric vehicles and what materials will be selected for those components. Nylon will play an important role with the electrification of vehicles because it is strong and lightweight—and very durable and resistant to damage.”

While OEMs are testing a variety of materials today in electric vehicles, Dooley believes nylon will be used for load bearing applications, like battery trays, that have to hold a lot of weight and be exposed under the vehicle. As nylon works well with other materials, such as steel, he foresees a simple steel stamping being loaded into an injection molding tool with nylon molded over-top of steel stamping. Steel provides strength and rigidity, while nylon is easily molded into complex shapes which can lead to parts consolidation and reduce assembly costs with molded-in features like snap-fits and screw bosses.
Carbon fiber and composite plastics can also be vital materials with performance, safety and weight-trimming advantages. When used for bumper and crash systems to absorb impacts, composite plastics can absorb 6 to 12 times the energy of steel, dramatically improving the safety of occupants.

For several years, carbon fiber had been used only in luxury and high-performance vehicles but that is changing. General Motors Co. is now using carbon fiber on its large pickup trucks to compete in the profitable truck category while improving fuel-economy performance. GM Engineer Mark Voss was recognized by Design News as one of 14 engineers transforming the industry. Voss’ breakthrough was a carbon fiber truck box in the 2019 Sierra Denali; the “CarbonPro” is 62 pounds lighter than the box in earlier models, but it is also stronger and more resistant to damage. The GM team’s “CarbonPro” uses short, chopped up carbon fibers rather than long ribbons of fiber that are woven together. The short fibers improve manufacturing efficiencies by eliminating any waste.

Journalist Pat Toensmeier foresees carbon fiber becoming as useful with AVs and EVs as glass reinforcements are to vehicles today. He also believes graphene, a 2D matrix with remarkable strength qualities, could be mixed with other polymers to develop valuable materials for the vehicles of the future.

Fiberglass will continue to have a role in all modes of transportation—on land and water—including mass transit vehicles, cars and trucks, and boats. The properties of fiberglass—and the flexibility molding provides designers and engineers—makes it an ideal material as it is affordable, lightweight, durable, designable, visually appealing, and easily cared for. On heavy trucks, the aerodynamic body panels (fenders, hoods, and rooftops) can be made with fiberglass technologies as well as insulation, interior cabinets and storage.

Polycarbonate and polycarbonate blends in the form of a resin can be used for injection-molding and extrusion, or as extruded sheet for thermoforming, providing opportunities for small- and large-scale productions. Polycarbonate offers mechanical toughness as well as a high level of impact strength and toughness that can meet the stringent flame-retardant requirements of the rail and aviation industries.

Material engineers are exploring new uses for polycarbonate for lightweight, structurally sound and safe vehicles with attractive shapes and lines. Polycarbonate used for automotive glazing is also being used to design sunroofs and panels, tailgates, bezels and side windows. They can also be blended and mixed with other plastics to make everything from radiator grilles and bumpers to headlamps and door panels.

EVs will need to be designed with aerodynamic efficiencies; Magna International offers active aerodynamic technologies, like air deflectors, rear diffusers, underbody panels and spoilers, that deploy automatically based on vehicle inputs and reduce vehicle drag while it is in operation and extend its range.

“Nylon is one of the oldest, most well established polymers in the chemical space, widely used around the world.”

Brendan Dooley, Global Director: Engineering Resins, Chemical Market Advisory Services at IHS Markit
Vehicle Sizes and Designs—Now and in the AV Future

Unlike Europe and Japan, U.S. consumers are currently turning toward light trucks, crossovers, SUVs, and vans for their personal vehicles. The choice—and size of vehicle—is influenced heavily by fuel costs. In the U.S. average fuel costs are $2.99, low compared to other developed nations: fuel economy/mileage represent the 20th consideration of a U.S. consumer when purchasing a new car.

Europe's top selling vehicles are significantly smaller, passenger vehicles like the Volkswagen Golf and Renault Clio—the average fuel cost in Europe was $6.57. In Japan, even smaller passenger vehicles are sold, generally with 3- or 4-cylinder engines like the Honda N-Box and Toyota Prius; in Japan the average fuel cost is $4.99.

Globally, it is estimated that 1 billion cars will be added to roads in developed and developing nations as early as 2030. Many of these new cars will be EV and even AV models. What is most significant about 1 billion cars is that it's double the number of cars on the road today—and many of these electric vehicles will be in China and India. The EVs in these developing markets will be micro-EVs, small two-seaters or e-rickshaws in India and e-tuktuks in the Philippines.

AV designs, according to a number of manufacturers, may be leaning toward flexible, minivan designs. Timothy Papandreou, a former Waymo executive told The Washington Post, “The platform of that minivan is ideal. It’s an oblong block on four wheels. It’s familiar and it’s safe. It’s not scary. It’s not a Mustang or Corvette ... it’s a minivan.” But Waymo isn’t convinced minivans will be the only autonomous model; it is also working with SUV designs, as is Uber, which is working with Toyota Sienna minivans and Volvo SUVs.

Ford Motor Company spokesman Alan Hall indicated the vehicles of the future will be flexible in their usage—able to carry passengers as well as packages for delivery. Hall predicts Ford will build vehicles that are a mix of the minivan, van and truck, “but with some comfort features of sedans.”

Toyota is developing a concept vehicle along these lines; the e-Palette, is an electric, cube-shaped autonomous vehicle that permits ease of entry and exit as well as flexible interiors for different uses.

Environmental Efforts Beyond CAFE—Carbon Footprints, Sustainability and Recycling

Automotive recycling was the focus of a 2016 Market Watch Report—plastics continue to play a major role in the sector in terms of recycling and moving toward zero net waste manufacturing. Environmental stewardship is a priority among transportation companies—the move to electric vehicles and support of CAFE standards demonstrates this point.

Manufacturers see savings in efficiencies, making sustainable choices, and recycling valuable materials. GM’s Lauren Smith, during the SPE 18th-annual Automotive Composites Conference and Exhibition, said waste is viewed as “simply a resource out of place.”

“We’re conscious of our impact that we have on the environment and we also recognize that our output streams have potential for reuse,” Smith said. “This is why we’re looking at an aggressive goal to be a leading auto manufacturer in reducing our waste and having zero waste come from our sites and not going into landfills.”
To address the end-of-life management of vehicles, Toyota developed its Global 100 Dismantlers Project, to establish social systems for end-of-life vehicle treatment by looking at four key areas: 1) use eco-friendly materials, 2) use auto parts longer, 3) develop recycling technologies, and 4) manufacture vehicles from end-of-life vehicles. Toyota is collaborating with dismantling companies to develop systems that are easier to separate and dismantle.

In 2018, several vehicles were built with wire harnesses that can be quickly and safely removed during recycling.

Bioplastics are also a part of the transportation sector’s environmental record—the sector was an early adopter of bioplastics for foams and other parts. Technology advances, and the diversification of sustainable sourcing materials, continue today for plastic automotive and transportation parts.

Plastics ELV Demonstration Project

Kendra L. Martin, Vice President—Industry Affairs, and manager of PLASTICS’ Transportation & Industrial Plastics Committee

One of the ways PLASTICS has engaged automotive companies is with the TIP Automotive End-of-Life Vehicle (ELV) Recycling Demonstration Project. PLASTICS is publishing the final Technical Package results from our ELV project, where we targeted Thermoplastic Polyolefin (TPO) bumpers for recovery, re-claiming those valuable polymers before shredding, and turning them back into post-consumer recycled materials. This project took on an entirely new model for evaluating recovery and end-market opportunities for a stream of materials that is not currently collected, demonstrating the technical recovery of ELV bumpers from a broad range of vehicles, exhibiting properties very similar to post-industrial bumpers reprocessed under the same conditions.

PLASTICS member companies tested those materials and reported their findings, which are contained in a Technical Package, which details the experience of the participants and the physical properties of the recycled TPO material, as well as exploration of the economics of collection based on key cost variables. Some initial end market exploration was also performed for the TPO, ultimately resulting in the TPO material being specified for a non-critical part in a vehicle by a large, U.S. auto manufacturer, marking a very important milestone for this project. Work continues by industry participants to identify and measure end market opportunities for these PCR materials.
Transportation Public Policy Shaping Trends and the Role for Plastics
Transportation Public Policy Shaping Trends and the Role for Plastics

Currently, no standards or requirements are in place from the federal government to regulate autonomous vehicles—it is a self-certifying and third-party testing process. This current standard sets the course for companies to demonstrate their vehicles are road-ready and safe, rather than depending upon government regulations and reviews.

Policymakers shape and guide industry sectors through their laws, incentives, and regulatory oversight; plastics usage in the transportation sector has benefited from government policy. Notably, the federal Corporate Average Fuel Economy (CAFE) standards have spurred manufacturers to improve the gas mileage—and lightweighting was one of the auto industry’s responses. Safety standards also spurred increased plastics usage.

Governments have encouraged the development of electric vehicles through subsidies and tax credits, access to HOV lanes, and recharging stations. Fleet operators have been encouraged to improve their vehicle efficiency and adopt measures to improve environmental performance.

Testing in the transportation sector is stringent with regulators—and among manufacturers and industry groups. Plastics and polymers have proven the ability to meet strict safety standards to be utilized in a wide range of vehicles. For plastics companies, the process involves compounding and processing materials to develop innovative solutions to meet evolving standards. Testing conducted by companies and third-parties are the norm and include functionality testing, perceptivity testing, weathering and environmental testing, physical testing, chemical resistance and flammability testing.

Policymakers also shape the transportation sector in how they promote or encourage services like Lyft and Uber, fund infrastructure like light rail systems, and encourage technologies like autonomous vehicles.

AV Guidance from Policymakers

As with many technology advancements, AV progress has advanced beyond the regulatory framework adopted by government agencies (a case of government playing catch up to private sector innovation). The U.S. government has invested approximately $650 million in AV testing and development; on the road, AV testing has largely been in states where industry participants are based or local governments have shown a willingness to engage.

Currently, no standards or requirements are in place from the federal government to regulate autonomous vehicles—it is a self-certifying and third-party testing process. This current standard sets the course for companies to demonstrate their vehicles are road-ready and safe, rather than depending upon government regulations and reviews.

To date, 29 states have passed some kind of regulation for self-driving cars. Hotbeds for AV-vehicle testing are Atlanta, GA, Austin, TX, Boston, MA, Detroit, MI, Kirkland, WA, Phoenix, AZ, Pittsburgh, PA, San Francisco, CA, Silicon Valley, CA
and Washington, D.C. California has rolled out the red carpet for 57 AV companies to test cars in the state. Long-term, the state and local government regulation of AV technologies will need to be superseded by Federal laws if the technology is to be broad and logistically—conflicting state-by-state regulations would curb the expansion of AVs.

The House of Representatives adopted the SELF DRIVE Act to begin the legislative process of outlining the framework for autonomous vehicle regulations—but that bill stalled in the U.S. Senate. The Executive Branch continues to encourage the technology, but holes remain and consistency will be essential to AV deployment and success.

**AV 3.0 Released by U.S. DOT**

In October 2018, the U.S. Department of Transportation issued its updated guidance "Preparing for the Future of Transportation: Automated Vehicles 3.0" (AV 3.0).

AV 3.0 is an indication that the federal government recognizes comprehensive transportation automation can work—from driverless mass transit and autonomous trucks to cars and delivery vehicles. A key advance in AV 3.0 from earlier versions is autonomous vehicles will not necessarily be burdened with legacy human-driven safety and regulations requiring things like steering wheels, pedals, and side/rear view mirrors.

AV 3.0 identifies best practices from state and local government agencies in testing and operating autonomous technologies. Getting all governments—with their particular traffic, infrastructure, and populations—on the same page is a mandatory hurdle to clear. To spur collaboration, the Federal Highway Administration is updating the 2009 Manual on Uniform Traffic Control Devices for Streets and Highways, which provides standards for road managers to install and maintain traffic control devices on all public routes.

Autoblog described the different groups engaged in AV and the outcome of 3.0: "The public and safety advocates wanted the government to prescribe rules to maximize safety; states and politicians made their own rules in the absence of federal structure; and automakers, startups and investors wanted the government to limit the patchwork rulemaking so the nascent market could find an equilibrium."

AV accidents have caused some safety advocates to take a skeptical eye toward deployment without strict federal guidelines. Bryant Walker Smith, assistant professor of law at the University of South Carolina and a driverless policy expert told the Washington Post, "There's wariness about the federal government's regulatory commitment [and] willingness to police the companies. Even more than the distrust in the technology, it's distrust in the companies ...and it's even a distrust in the administrative ability of government to regulate, to act as a check."
A National League of Cities study indicated 66 percent of cities are already investing in smart city technology—and 25 percent of those without smart city systems are exploring how to move forward. Yet there are still definitional issues in what are smart city technologies and capabilities. The League of Cities reported, “There’s so many different voices, from the business sector to non-profit to cities themselves that are trying to define what a smart city is. And until we can really fully encapsulate what it means to be a smart city, I think that we still have some movement ahead within that space.”

Transportation Infrastructure—Connectivity/SMART City

Connectedness in transportation brings together different skill sets—auto companies working with tech companies and urban planners and engineers are some of the cross-collaborations underway. This connectedness is part of SMART City efforts where a municipality uses information and communications technologies to increase operational efficiency, share information, and improve government services and quality of life for citizens.

An example of SMART City collaboration is Ford’s work with tech company Autonomic to develop an open, cloud-based platform that links together traffic lights, parking spots, and private/public transportation services. The companies’ project, Transportation Mobility Cloud, provides location-based services, route mapping, alerts and warnings, identification and payment processing, and collects data and provides analytics on a community’s transportation network. Ford describes the system as “a box of Legos” assembled and rearranged to tailor to a specific city’s assets—as well as the users’ needs.

Transportation Trends Impact Transportation Funding

All levels of government get revenue from transportation: sales taxes, gas taxes, tolls, registration and licensing fees, public transit fees, user fees. In all, it is an estimated $200 billion revenue source annually.

Electric vehicles won’t pay traditional gas taxes, and shared vehicles may not generate sales and registration fees, or parking revenues. With governments relying upon these revenues, tax changes will be required. In anticipating the loss of revenues, Deloitte, in a study of transportation trends, said alternatives, like taxing “movement” vs. ownership, may be a path forward in the future. Deloitte noted monetization for road usage could be dynamic and based upon time of travel, congestion, routes traveled, and the type of vehicle used.
Transportation Policy Update & Outlook in the New 116th Congress

Scott DeFife, Vice President, Government Affairs, PLASTICS

Legislative and regulatory policy developments could have an important influence over transportation and related markets in 2019. In Washington, the new Congress will have leadership changes, with the House of Representative switching to Democratic control, and with early signals that Congress and the Administration will at least try to work together to fund infrastructure investments to address long-standing needs.

The biggest impediment to a major infrastructure bill will be how to pay for it. Congress is expected to consider legislation that keeps the Highway Trust Fund solvent and relies on formula funding. Increasing numbers of business and transportation groups have signaled that they could support a gasoline tax increase that, at minimum, keeps up with inflation. Others suggest increasing the federal pressure on states to create road usage-based fee systems as the key to reinvigorating the Highway Trust Fund, or privatizing many more roads and bridges. The debate on the Highway Trust fund could evolve to include discussions on new carbon tax concepts that are beginning to emerge.

While major road and bridge projects of national significance will no doubt continue to dominate headlines and political discussion, transit funding is also at risk, and could become a major political issue between Congress and the administration. Many of the projects of national significance at most risk are in major metropolitan population centers, pitting urban and rural politics against each other for funding.

For the plastics industry, there will be continued efforts to advance “open competition” legislation that levels the playing field for pipeline materials in federal projects. PLASTICS supported legislation introduced in 2018 that would require all qualifying materials be considered on infrastructure projects that receive federal funding. The competition alone would significantly drive down the cost of the projects, particularly water pipelines, whether or not plastics is used. Unfortunately, with no major broad infrastructure measure there was no vehicle in place for the legislation to move this Congress. We will work with our industry partners and legislative sponsors to once again advocate for open and fair competition for these projects in the new Congress.

On the freight rail side, PLASTICS continues to advocate for a fully functioning Surface Transportation Board as the most efficient means to address issues like those posed by CSX this past year when they implemented a new management system and chaos ensued. This was recently made possible when the Senate filled two additional seats at the very end of the last Congress in early January of this year. With three of the five positions now filled, the board can truly operate in its oversight role. Nominations to fill the remaining two seats are pending with both the administration and the Senate.

A new area to watch will be the introduction of industry supported legislation aimed at increasing the U.S. domestic investment in recycling facilities, equipment, and collection infrastructure as well as development of end-markets for recycled content. PLASTICS along with a dozen other allied organizations in the recycling and waste management arena are leading an effort to get the federal government to focus on this sector and increase domestic capacity to address market issues such as China’s National Sword policy and increasing environmental concerns about waste leakage into the marine environment.

Major international consumer brands are under pressure to make and increase commitments to the use of recycled content and recycling their packaging, and the industry
Fuel Economy Standards—California v. Trump EPA

While the Trump administration is finalizing its plan to freeze the CAFE standards—and stymie former President Obama (and California’s) approved plan for stricter rules in the coming years—dynamics are in place for continuing forward on improved gas mileage in the auto industry. Most significantly, automotive manufacturers themselves are largely onboard with respect to improving gas mileage performance—and EVs are a cornerstone of meeting CAFE standards.

At a Congressional hearing on CAFE, Alliance of Automobile Manufacturers CEO Mitch Bainwol testified, “We support standards that increase year over year.”

Plastics have been a partner in improving the CAFE performance of vehicles, but work continues to be done.

DuPont Global Automotive Technology Director Jeff Sternberg said, “The industry has made phenomenal improvements to date, but we have miles to go and given our current technologies, we won’t get to the 2025 CAFE standards. Materials are core to successfully achieving greater efficiencies and we know we need transformational change not only in the materials themselves, but in the ways we work with them.”

Sternberg outlines three strategies to help advance efforts to reduce vehicle weight:

- Involve materials suppliers early in the design-brief stage
- Look further than product data sheets for knowledge of materials
- Develop more integrated, multi-material solutions

By 2025, carmakers are currently scheduled to get 54.5 miles per gallon (23.2 km/L) from their fleets on average to meet federal regulations. Today, according to the U.S. Environmental Protection Agency, the average new car gets only 24.8 miles per gallon (10.5 km/L). Automakers will need more hybrid and electric vehicles to hit these 2025 targets.

U.S. Department of Energy: A 10-percent reduction in vehicle weight can result in a 6 to 8 percent fuel economy improvement.
Conclusion
A wide range of global industry sector leaders, notably automotive, technology, and transportation are collaborating to transform how we move people and products. Connected, electric, shared, autonomous transportation vehicles represent the greatest “disruptor” for a number of industries, but even with the capital and innovation behind these efforts, the transformation is not without bumps in the road and uncertainty.

Today’s transportation trends—electric, autonomous, connected, shared—are interconnected and link together vital industry leaders that bring capital, resources, innovation and energy to the transportation space. The trends also deliver synergies for companies involved in the transformation—and their customers.

For electric propulsion, the true tipping point may be as soon as 2025 when the price-point (without government subsidies or fuel cost savings) for EVs is expected to be comparable to combustible engines. Developing markets, like China and India, will be hot spots in the adoption of electric vehicles, whether automobiles or other modes of transportation.

Proponents of AV technologies see all transportation vehicles cross-communicating with each other and the road infrastructure, and monitoring all movements around a vehicle, creating a safer and more efficient system of transportation for people and goods.

The upside of the trends are real, but so too are the obstacles. Unlike the EV timeline, AV adoption is more up in the air. First, technologies in vehicles are more advanced than existing infrastructure and regulations; manufacturers do not want to get too far ahead of their environments whether operational or oversight. Secondly, the promises of improved safety are not being fulfilled right now, and the technology will likely continue to have shortcomings after rollout. Third, much of the public, given safety concerns and the dramatic change driverless vehicles represent, are reluctant to accept the vehicles, and use them. Fourth, driving environments in terms of infrastructure and weather around the world vary—let alone in a county or single jurisdiction. AVs will need to navigate larger environments and changes in order to move beyond limited-range operations. Finally, AV technologies will be expensive; it is an open question whether households will own them—or only use them as a shared vehicle when necessary.

For plastics manufacturers and transportation suppliers, today’s transportation trends represent a long-term opportunity not only in automobiles, but every mode of transportation. The technical requirements of the trends will need plastics to perform: batteries that operate under high temperatures will need advanced polymers and plastics that meet extreme heat specifications. Radar, lidar, and cameras connected to computer processors and communication systems will need to withstand extreme temperatures, provide resistance to chemicals and UV exposure, and address flammability concerns. Designs of vehicles will change given the EV and AV requirements—light-weighting will continue and EV and AV vehicles will need flexible interior designs.

Conclusion

Given that plastics and polymers have already transformed the construction, performance, safety and functionality of cars, the next-generation of vehicles for all modes of transportation will continue to need plastic parts and components that meet performance specifications and have been manufactured to improve gas mileage, enhance safety performance, fight rust and corrosion, and improve driver conveniences and comfort.

All modes of transportation will be disrupted within the next decade; that change represents an opportunity for current generation plastic technologies and next-gen polymers as their qualities will be valued by all engineers and designers. Plastic is too valuable and functional not to be a primary material in coming EV and AV vehicles.
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