Logistics, Robotics & Transportation

Tech trends influencing the future of the supply chain, logistics, robotics, the automotive industry and transportation.
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Macro Forces and Emerging Trends

For nearly two decades, the Future Today Institute has meticulously re-searched macro forces of change and the emerging trends that result. Our focus: understanding how these forces and trends will shape our futures. Our 15th annual Tech Trends Report identifies new opportunities for growth and potential collaborations in and adjacent to your business. We also highlight emerging or atypical threats across most industries, including all levels of government. For those in creative fields, you will find a wealth of new ideas that will spark your imagination.

Our framework organizes nearly 600 trends into 13 clear categories, which are being published as separate reports. Each report includes specific use cases and recommendations for key roles in many organizations: strategy, innovation, R&D, and risk.

Each trend offers six important insights.

1. Years on the List
   We track longitudinal tech and science trends. This measurement indicates how long we have followed the trend and its progression.

2. Key Insight
   Concise description of this trend that can be easily understood and repeated to others.

3. Examples
   Real-world use cases, some of which should be familiar to you.

4. Disruptive Impact
   The implications of this trend on your business, government, or society.

5. Emerging Players
   Individuals, research teams, start-ups, and other organizations operating in this space. Mature organizations are included when they are producing new contributions.

6. Action Scale
   FTI’s analysis of what action your organization should take. Fields include:
   - Watch Closely
   - Mounting evidence and data, but more maturity is needed. Use this trend to inform your vision, planning, and research.
   - Informs Strategy
   - Strong evidence and data. Longer-term uncertainties remain. This trend should inform your strategic planning.
   - Act Now
   - Ample evidence and data. This trend is already mature and requires action.
Scenarios Describe Plausible Outcomes

You will find scenarios imagining future worlds as trends evolve and converge. Scenarios offer a fresh perspective on trends and often challenge your deeply held beliefs. They prompt you to consider high-impact, high-uncertainty situations using signals available today.

1. Headline
A short description offering you a glimpse into future changes.

2. Temporal and Emotive Tags
A label explaining both when in the future this scenario is set and whether it is optimistic, neutral, pessimistic, or catastrophic.

3. Narrative
The descriptive elements of our imagined world, including the developments leading us to this point in our future history.

Scenario sources:
The Future Today Institute uses a wide array of qualitative and quantitative data to create our scenarios. Some of our typical sources include patent filings, academic preprint servers, archival research, policy briefings, conference papers, data sets, structured interviews with experts, conversations with kids, critical design, and speculative fiction.
What’s the new normal? Most of us feel an urgent need to get back to normal, especially as we continue to witness and endure an unprecedented amount of change. Early this year, Russian President Vladimir Putin waged an unprovoked war against Ukraine, which led to a rapid global response. Switzerland broke with tradition and took a side, freezing Russian assets and denying entry to oligarchs. Anonymous, the global hacker collective, waged a cyberwar against Russia, infiltrating government databases and state propaganda websites.

Within the past 12 months, DeepMind solved a 50-year-old problem in biology, opening up new pathways to drug discovery. AI systems proved that they can generate images and text as well as a human. Facebook and Square changed their names to Meta and Block, signaling a digital land grab in the emerging Web 3.0. The biggest streamers—Netflix, Disney+, AppleTV, Hulu—discovered a formidable competitor in social commerce networks like Shein. Seemingly every day, a new set of signals emerge to challenge our existing mental models.

It might feel pointless to forecast the future past a few weeks or months. But strategic foresight results in preparations, not predictions. Trends invite us to consider alternative outcomes from those we previously imagined. They also unlock something invaluable in each one of us: the ability to re-perceive reality. The act of “re-perception” awakens you to the possibility of a future that differs from your current expectations. It helps you understand that you cannot know all things at all times, and that you should be curious, rather than absolutely certain, about what you perceive in the present.

Our 2022 Tech Trends Report is designed to help you re-perceive the world so that you can confront deep uncertainty, adapt and thrive. In this 15th anniversary edition, we have analyzed nearly 600 technology and science trends that impact most industry sectors. We created 14 separate volumes, and each report focuses on a related cluster of trends. You will also find vivid scenarios depicting the unexpected ways in which the future might unfold. In each volume, we discuss the disruptive forces, opportunities and strategies that will influence your organization in the near future.

Now, more than ever, your organization should examine the potential near and long-term impact of tech trends. You must factor the trends in this report into your strategic thinking for the coming year, and adjust your planning, operations and business models accordingly. But we hope you will make time for creative exploration. The new normal is unfolding for those who know how to re-perceive signals in the present.

Amy Webb
CEO
The Future Today Institute
This is volume 09 in the Future Today Institute's 2022 Tech Trends Report. Each volume covers a different set of topics.

To find additional volumes, visit www.futuretodayinstitute.com/trends
Cloud robotics and automation are enabling the rapid scaling of robotic applications, allowing developers to test and learn, simulate, and share code in an efficient platform.

Early attempts at self-assembling robots mostly focused on self-re-configuring modular robots, but new approaches are taking the capability a few steps further.

Soft robotics, made of flexible materials, are capable of moving in fluid ways, adapting to their surroundings, and sensing more effectively than traditional robots—and they’re revolutionizing the kinds of roles a robot can play.

The pandemic exposed the fragility of our global supply chain. From semiconductors to shipping containers, we have seen how a single component can throw an entire supply chain into chaos.

From groceries to vaccines and gene therapies, the cold chain is becoming a larger part of our everyday supply chain. Investment is growing to meet rising demand for temperature-stable transit that delivers products without spoilage.

New significant milestones have been met and funding has increased in the area of drone fleet deliveries. Adapting federal regulations are necessary as the technology continues to make a case for its utility at scale.

During the pandemic, the desire for quick and contactless deliveries steadily rose, and there is little reason to think this desire will change. Consequently, autonomous delivery has become more commonplace, even pushing states to change their legislation around the technology.

Drones aren’t just for air and land. Underwater drones have been around since the 1950s, but in recent years the technology has dramatically improved due to advanced payload offerings; low-light, high-definition cameras; enhanced seabed detection; better batteries; and more advanced sensors.

Accelerating adoption of battery-powered transportation is leading to a rethink of how we provide the energy required to transport people and goods from A to B, forcing our energy delivery systems to adapt to a more battery-powered and less gasoline powered transportation ecosystem.

More data usually results in a better algorithm, and the size of the data for training autonomous cars is accelerating at an exponential rate. In addition to the increase in real-world data from cars on the road, synthetic data is growing in volume as techniques for generating data matures.

The importance placed on roads is decreasing as urban planning with autonomous vehicles, sustainability, and technology is leading the charge for how urban spaces are being designed.
Robots-as-a-Service (RaaS)

KEY INSIGHT

Cloud robotics and automation are enabling the rapid scaling of robotic applications, allowing developers to test and learn, simulate, and share code in an efficient platform.

EXAMPLES

The field of cloud robotics and automation is rapidly expanding, with key players like Amazon Web Services launching new tools and new features on existing platforms. With each release, these platforms become more integrated, easy to use, and efficient for developers. The most recent release on AWS RoboMaker now supports container images, allowing customers to use container tools they are most familiar with. Containerization lets developers package up software code and its dependencies so that it can be run consistently on any infrastructure. AWS also released a new offering in 2021, RoboRunner, which companies can use to connect robot fleets to the cloud, manage robots in the fleet, and develop apps that optimize the operations of an automated fleet using real-time data.

DISRUPTIVE IMPACT

The rise of cloud robotics and automation is likely to drive the development of robotics for more advanced applications, such as medical robotics, which benefits from the rapid learning and improvement possible in a cloud simulation environment, as well as the remote monitoring, management, and maintenance afforded by cloud-based platforms. Expanded applications into new industries are expected to drive billions of dollars of growth in RaaS over the next five years.

EMERGING PLAYERS

- AWS RoboMaker
- AWS RoboRunner
- Cogniteam Nimbus
- Fetch Cloud Robotics
- Google Cloud Robotics
- Nvidia Isaac
- Nvidia Jetson
- Robot Operating System (ROS)

AWS RoboMaker's Small Warehouse World is ideal for companies building and testing robot applications for warehouse uses.

Logistics, Robotics & Transportation

Watch Closely Informs Strategy Act Now

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Collaborative robots—or cobots—have been in use across various industrial settings for years. But recent advancements in their sensors and weight limitations are enabling their use in a widening range of applications.

**Examples**

Cobots are intended for use alongside humans, enhancing productivity and speed and reducing risks such as error or injury. Increasingly, top cobot producers such as ABB are enhancing cobot features, making them capable of more. ABB’s new GoFa CRB 15000 can handle heavier payloads, has a longer reach, and is faster than its predecessors, making it ideal for myriad applications, such as picking, packing and placing, kitting, and product handling. Universal Robots’ new UR10e is similarly improved, able to handle 25% more payload, and featuring a significantly longer reach.

**Disruptive Impact**

Today, collaborative robots are primarily used in warehousing and logistics, and in manufacturing where very precise placements are required. Over the course of the pandemic, cobots were widely leveraged to overcome supply chain challenges, rapidly increasing online order and delivery demand, and staffing shortages. Universal Robots alone saw 75% growth year over year as of Q4 2021.

**Emerging Players**

- ABB
- Fanuc
- Festo
- Omron
- Rethink Robotics
- Robotiq
- Universal Robots
- Vecna Robotics

The e-Series family from Universal Robots has four members—the UR3e, UR5e, UR10e, and UR16e, which each offers a different reach and payload.
That’s a 25% increase in payload and a 0% increase in the price of the cobot, giving a significant boost to palletizing applications at no additional expense. That means you can move more per pick, use heavier tools, and process heavier parts, supported by the 1,300-millimeter reach (51 inches) and small footprint that makes the UR10e our bestseller.

— Joe Campbell, senior manager of applications development at Universal Robots
Autonomous Robot Swarms

KEY INSIGHT

Autonomous robot swarms are coordinated and distributed to perform complex tasks with the benefit of herd dynamics. There are a rising number of applications for this technology, mostly for environmental and agricultural purposes.

EXAMPLES

Several autonomous robot swarm startups have enjoyed strong funding rounds over the past year. Many of these companies are focused on the potential to revolutionize agriculture. Robot swarms are also uniquely suited to meet rising environmental needs, such as oil spills, endangered species monitoring, or marine emergencies, due to the quiet, noninvasive nature of drones, and the fact that they do not require a human on-site to operate them. Countless use cases for this technology abound—other startups promise swarm applications for commercial cleaning, GPS mapping, manufacturing, and completing tasks in harsh or hard-to-reach environments and underwater environments. In one recent test, part of the Defense Advanced Research Projects Agency (DARPA) OFFensive Swarm-Enabled Tactics program, an operator-directed swarm of 130 uncrewed planes, quadcopters, and ground vehicles scouted a set of mock buildings and shared information with the operator.

DISRUPTIVE IMPACT

A University of Arizona team has received a NASA grant to create a new technique called the Human and Explainable Autonomous Robotic System, which leverages neuromorphic learning to train a fleet of robots on mining, excavating, and building, and enhances the robots’ collaboration over time. This technique could enable the mining of materials on the moon. Undersea applications are promising as well—in 2012, Virginia Tech helped the U.S. Navy develop undersea robots that moved like jellyfish. More recently, Berkeley Marine Robotics received an innovation research grant from the National Science Foundation to conduct research and demonstrations of an autonomous underwater robot swarm system, which will perform inspections under ships. In a very different type of use case, agtech startup Aigen recently raised a $4 million seed round for its solar-powered robotics platform, and is working to build robot swarm technology to revolutionize farming.

EMERGING PLAYERS

- Aigen
- Apium
- Avidbots
- Berkeley Marine Robotics
- DARPA
- Exyn Technologies
- Locus Robotics
- SwarmFarm Robotics
- Unbox Robotics
- University of Arizona
- Virginia Tech

Moe Mamoyez (left) and Jekan Thanga, faculty members at the University of Arizona College of Engineering, have received $500,000 from NASA to develop space-mining methods that leverage autonomous robot swarms.
Self-Assembling Robots

Key Insight

Early attempts at self-assembling robots mostly focused on self-reconfiguring modular robots, but new approaches are taking the capability a few steps further.

Examples

Self-reconfiguring modular robot innovations include Roombots, created by EPFL (Swiss Federal Institute of Technology Lausanne), and SMORES-EP from the Modular Robotics Laboratory at the University of Pennsylvania. Now attention is turning to the newest area of discovery in the field of self-assembling robots. Martin Nisser, at HCI Engineering Group at MIT’s Computer Science and Artificial Intelligence Laboratory, has partnered with the MIT Space Exploration Initiative to explore methods of using 3D printing with shape memory polymers and other smart materials to create a mechanism that will fold into its intended shape when desired. Researcher Wei Feng at Tianjin University in China, along with his team, designed a robot made of 3D-printed liquid crystal elastomer, which self-assembles by rolling into a tubular form when heated. Researchers at the University of New South Wales are developing PolyBricks, small units of DNA programmed to take a certain shape when they come together.

Disruptive Impact

Self-assembling robots have significant potential for the health care field. Self-reconfiguring modular robots can be used in health care settings or eldercare facilities to take the shape of needed furniture—such as a chair or a support to help someone move throughout a space. Smaller scale systems, such as nanobots, could be used in therapeutics or regenerative medicine, or to enable a targeted treatment, such as clearing buildup from an artery. Smart materials and 3D printing will enable new applications of self-assembling robots for space exploration, allowing the robots to be transported in a collapsed format, and take their needed shape upon landing. Still other applications abound for emergency response and disaster relief—self-assembling robots can take the shape of a needed escape—a shelter, bridge, or ladder—in instances such as a wildfire, flood, or earthquake.

Emerging Players

- MIT Computer Science and Artificial Intelligence Laboratory
- MIT Space Exploration Initiative
- EPFL
- Tufts University
- University of New South Wales
- University of Vermont
Because every system launched into space has to fit within the confines of a rocket firing, space agencies are interested in structures that can self-reconfigure between smaller and larger shapes. I saw a great opportunity to build on what I’d learned about self-folding robotics. I developed algorithms that would allow large numbers of spacecraft modules to move together, attach to one another, and then reconfigure together into a target shape.

— Martin Nisser, PhD candidate, HCI Engineering Group, MIT Computer Science and Artificial Intelligence Laboratory
Robot Compilers

KEY INSIGHT
Robot compilers help non-engineers to conceptualize and fabricate robotic solutions, and soon they'll offer efficiencies, cost savings, and increased productivity for every industry.

EXAMPLES
We will soon tell computer systems what tasks we need completed, and they will automatically fabricate new robots for the job. The process of designing, programming, and building robots is time-intensive, and typically only achievable by engineers and robotic specialists—until recently. Institutions including the MIT Computer Science and Artificial Intelligence Laboratory and the Laboratory for Embedded Machines and Ubiquitous Robots at the University of California, Los Angeles have been working for years to develop robot-compiling solutions that make rapidly fabricated custom robots available to non-engineers. Montreal-based Vention, founded in 2016, makes it possible for users in various different industries to design robotic equipment that suits their exact needs and specifications. Users of Vention’s tool can build from scratch or customize from a set of designs that cater to a number of capabilities, including inspecting and testing, machine tending, material handling, and material processing.

DISRUPTIVE IMPACT
As robot compilers continue to advance and become accessible to the average person, limited specification offerings may become less attractive to users, shifting demand to custom robots for a large proportion of the market. Robots may also be designed for an increasing number of uses, beyond where they are leveraged today. Fabricating programmable robots may not exactly be a simple, DIY weekend project, but promising research indicates that robot compilers could soon enable people with limited technical knowledge to sketch, design, fabricate, and control a robot drawn straight from their imagination.

EMERGING PLAYERS
- Laboratory for Embedded Machines and Ubiquitous Robots at UCLA
- MIT Computer Science and Artificial Intelligence Laboratory
- Vention

Users of Vention MachineBuilder can design and order custom robotic equipment by choosing from modular parts and using smart design tools.
Soft robotics mimic living organisms. Made of flexible materials, they are capable of moving in fluid ways, adapting to their surroundings, and sensing more effectively than traditional robots.

**Examples**

Meta AI researchers have created a new kind of electronic skin and fingertip called ReSkin, a deformable elastomer with embedded magnetic particles. This soft robotic solution has enhanced tactile senses, and can perform delicate tasks more effectively than a device without the skin. Researchers at the University of California, Riverside have developed a type of light-powered soft robotic film that can be trained to remove oil spills at sea or contaminants from drinking water. A team at Linköping University took an alternative view of soft robotics opportunities, creating a soft robot that can serve as a possible bone replacement, entering the body in soft form to allow for accurate placement, and then hardening when properly arranged. Soft robots that have the ability to morph and reshape are also being developed at Southeast University in China, where researchers are modeling a soft robot after the camouflaging and self-healing properties of a starfish.

**Disruptive Impact**

Soft robots have significant advantages in handling and sensing, and are also able to mold into needed shapes that would be difficult for rigid materials to achieve. Over the coming years, soft robots may also be able to regenerate, regulate their own temperature, frequently change shape, or change level of rigidity depending on the environment. These machines could allow humans to explore previously hard-to-reach environments, take images inside of our bodies, or other extremely small areas, deliver medication in a targeted way, or take samples of their environment.

**Emerging Players**

- Linköping University
- Meta AI
- MIT Computer Science and Artificial Intelligence Laboratory
- National University of Singapore
- Princeton University
- Southeast University
- University of California, Riverside

A soft tough robot developed by the National University of Singapore is able to handle small, delicate items with care.
EMERGING PLAYERS

• Bosch
• Broadcom
• Goertek
• Google
• HP
• Honeywell
• Infineon Technologies
• Knowles Electronics
• Microsoft
• NXP
• Qorvo
• STMicroelectronics
• TDK
• TE Connectivity
• Texas Instruments

In May 2021, engineers from Columbia University published a study in the journal Science Advances, demonstrating their achievement of creating the world’s smallest single-chip system ever developed, shown here resting in the tip of a hypodermic needle.

SMART DUST

KEY INSIGHT

Smart dust, also known as microelectromechanical systems or MEMS, represents a new method of atomic-level materials engineering.

EXAMPLES

MEMS are already used today in common applications, including drone control, game controllers, digital cameras, smartphones, wearables, and pressure sensors and displays, to name a few. While these devices are not new, and have been in development for decades, recent advancements in the reduced size of computing chips as well as enhanced manufacturing methods have revealed many more purposes for MEMS.

MEMS collect data on aspects such as acceleration, altitude, and pressure, but in the coming years, the most important aspect of MEMS won’t be what they collect, it will be what those devices do with the data. It’s likely that in the coming years, we will see enhanced capabilities around AI/ML/DL on the edge embedded within smart dust, making it capable of not just capturing information about the environment that surrounds it but also making decisions about how to respond.

DISRUPTIVE IMPACT

Several major tech players are actively studying ways to apply microelectromechanical technology to increasingly microscopic microphone and speaker systems. Over the next several years, microphones, and inertial and optical MEMS will be the most critical devices to keep an eye on.

A subset of this field, called BioMEMS, refers to the application of MEMS in biological or health care–related applications. Several use cases are being developed that explore the use of MEMS in microscopic devices or treatments that can significantly enhance the efficacy of treatment and diagnosis while reducing the invasiveness of such procedures. Some such examples include devices that control irregular heart rhythms, enhanced microneedles for micropump drug delivery systems, “airway-on-a-chip” devices to assist in lung repair, and noninvasive methods of detecting the presence of disease or certain substances.
Essential Robot Workers

During the pandemic, robots became essential workers. Fleets of automatons were deployed worldwide to assist with important tasks: They autonomously sanitized hospital rooms, remotely monitored patients, picked up and delivered prescriptions, took our temperatures, made pizzas and salads, and assisted front-line medical workers. Some robots required direct supervision, but many of them worked alone. Across North America, factories and other industrial companies hired 37% more robots than last year, valued at $1.48 billion, according to the Association for Advancing Automation. The rush to expand the robot workforce has to do with companies struggling to keep up with demand and the enduring challenge of hiring workers for jobs that perform repetitive tasks.

Commercial Quadrupedal Robots

A number of companies now offer quadrupedal robots, including Boston Dynamics, Ghost Robotics, and ANYbotics. MIT is also developing a smaller version of the machine called Mini Cheetah. These robots have already been implemented by companies such as National Grid, Merck, BP, and Petrogas. Most quadrupedal robots in service today are used for security, monitoring, and inspections; to take readings; or for collecting images or data. Due to their agile nature, these robots can access areas that could be unsafe for human employees to enter, such as small caves or mines. They are also increasing efficiencies for businesses, which can have the robots capture images and send them to remote specialists for analysis, rather than sending specialists to various locations.

Mars Dogs

Current robots designed for off-planet exploration have wheels. While they’re designed to roll over rugged terrain, they’re limited to generally flat surfaces or gentle slopes. Scientists from NASA’s Jet Propulsion Laboratory and Ames Research Center and McGill University are developing a modified version of Spot, the quadrupedal dog created by Boston Dynamics. Au-Spot, as it is known, is built for Mars: It has artificial intelligence to learn about surfaces, a communications module, and an array of sensors (thermal, visual, motion). Au-Spot should be able to climb over rocks, up steep hills, and into underground caves. These biomimetic robots will work as teams, much as human explorers do. Au-Spots, traveling in packs, will assist each other as they climb, jump, and descend on unfamiliar terrain on Mars.

Robot Workers

Spot, a Boston Dynamics quadrupedal robot, has been implemented in a wide variety of use cases.
Robots and AI-enabled chatbots cannot feel, but this is still an important area to explore. If we are teaching machines to think, and to learn from us humans, then what moral codes are we programming into our future generations of robots? How will children’s interactions with robots affect the way they treat other humans around them? And perhaps, most confounding, but also most important—what drives humans to mistreat humanoid machines, and what does it mean for other interactions?

Robot Rights

As robots are leveraged in an increasing number of settings, questions around their treatment and rights have naturally arisen. The first involves a robot’s right to operate. Several states, including Pennsylvania, Virginia, Idaho, Florida, and Wisconsin, are passing rules that permit robots to operate on sidewalks, a key allowance for delivery robots. These are early signals of municipalities making legal allowances for robots to operate, but more will be needed as the machines are more widely used. The second, more disturbing concern being addressed is that of the right of a robot not to be harmed. Disturbing stories now abound of people kicking, hitting, or otherwise harming or abusing robots in public settings. In a slightly different example, many users are admitting to engaging in verbal abuse when using the AI chatbot app Replika, which simulates a human conversation.

Quadrupedal robots can be implemented in many ways, such as situations involving a dangerous or hard-to-reach location.
Logistics & Supply Chain
## Supply Chain Fragility

### KEY INSIGHT

The pandemic exposed the fragility of our global supply chain. From semiconductors to shipping containers, a single component can throw an entire supply chain into chaos. In its World Economic Outlook, the IMF showed that shipping issues reduced global economic growth from half to one percentage point.

### EXAMPLES

While chip shortages constrained traditional carmakers, Tesla was positioned to rewrite software so that it could use available chips. The electric car company could hold off many of the early impacts because much of its expertise remained in-house. However, even Tesla is beginning to feel supply chain constraints. In February 2022, sources confirmed that an electronic control unit in Chinese-built steering racks was excluded due to chip shortages. In October 2021, Amazon was reported to be acquiring refurbished long-range cargo planes so that it could better control imported products.

Companies are developing solutions to tackle these challenging conditions. Oracle has developed a new logistics management system that incorporates intelligent transit time predictions, enhanced shipment capabilities, multilingual digital assistants, and advanced global trade analytics. Attabotics provides a 3D robotic warehouse system that can help organizations to store the same amount of goods in a fraction of the floor space.

### DISRUPTIVE IMPACT

For decades, business operations have focused on leaning on supply chains and incorporating just-in-time practices to reduce inventory levels. The result is a brittle supply chain with little ability to respond to fluctuations. In the U.S., the Department of Commerce issued a report highlighting that median inventories of semiconductors had fallen to less than five days in 2021. The implication is clear. In a Capgemini survey, two-thirds of organizations believed they would need to make significant changes to their supply chain strategies to adjust to a post COVID-19 world. Many were looking to add resilience back into supply chains, with 68% reporting they were actively investing in diversifying suppliers. While adding resiliency may add cost now, with rising potential for disruptions due to extreme weather and pandemics, those with the most adaptable supply chains will be best positioned to thrive.

### EMERGING PLAYERS

- Attabotics
- European Chips Act
- Leaf Logistics
- Oracle

Shortages of workers, equipment, and space coupled with skyrocketing demand have exposed significant vulnerabilities in the global supply chain.
Supply Chain Verification

**KEY INSIGHT**
Tracking and verifying provenance in supply chains is becoming a critical component for supply chain operations. Consumer demand for transparency combined with the need to quickly locate recalled products means companies will need to ensure they have a solution in place to meet shifting compliance requirements.

**EXAMPLES**
Singapore-based Zuellig Pharma launched a blockchain-based system to track and trace products like vaccines. A mobile app provides instant verification of expiration, storage conditions, and provenance. Toray Industries will launch a proof-of-concept trial of its traceability system later this year. The company seeks to provide transparency into its use of recycled materials and biomass resources. Russia's Chestny Znak (“Honest Mark”) system provides details of a product's manufacturer and supply chain journey to reduce flow of counterfeit goods. To provide verification down to the individual item, luxury brands like Prada and Gucci have created unique NFTs (non-fungible tokens) that enable the end customer to view a specific product's history from creation to sale. Supply chain verification isn't just for products. Codenotary allows organizations to identify and track software components across development to make it easier to identify where code libraries are being used when vulnerabilities are identified.

**DISRUPTIVE IMPACT**
Supply chain verification is becoming much more mainstream since early initiatives like IBM’s Food Trust. The U.S. Food and Drug Administration plans to complete a rule around food traceability in November 2022 requiring the food industry to maintain records tracking data around growing, preparation, and shipping. With a rise in cyberattacks, software provenance tracking will also become critical to quickly locate known vulnerabilities in vast applications.

**EMERGING PLAYERS**
- Codenotary
- FDA Food Safety Modernization Act
- Gucci
- Mastercard Provenance Solution
- Prada
- TextileGenesis
- Zuellig Pharma
You’re eco-conscious, but you still want to travel. We get it.

Why not leave your suitcase at home? You’ll lighten airplane weights and significantly reduce CO2 emissions. Plus, you won’t have to worry about buying environmentally-damaging clothes.

Before you start your trip, scan your body using the Repurposeful augmented reality app. We’ll capture your exact measurements and select garments that match your style, destination and itinerary.

Once you arrive at your final destination, you’ll receive a customized box with one-time-use garments. When you’re done wearing our clothes, drop them and the box into a Repurposeful composting bin where they’ll begin their transformation into organic fertilizer for local soil production.

It’s easy. It’s affordable. It’s the right thing to do.
**KEY INSIGHT**

Regulations and shifting market expectations are pushing companies to improve sustainability of their supply chains. From apparel to food to construction, calls for action mean companies not only have to transform supply operations but provide reporting that verifies claims.

**EXAMPLES**

In January 2022 Fashion for Good launched the D(R)YE Factory of the Future, a project to accelerate the shift from wet to mostly dry material processing. The program claims that innovations including plasma and laser treatments, spray dyeing, and foam dyeing have the potential to reduce emissions by up to 89% and cut water consumption by up to 95%. The Roundtable on Sustainable Palm Oil developed a set of environmental and social criteria that companies must comply with for certification and has over 5,000 members, including General Mills and Kellogg. Cargill invested $200 million in a new refinery in Indonesia that guarantees traceability to the plantation where raw palm oil is sourced.

Many companies are leveraging QR codes on their packaging to connect consumers with easy-to-access information about the product’s provenance and history. These codes provide buyers with information about the item’s sustainability-related information.

**DISRUPTIVE IMPACT**

Sustainability regulation is shifting. Across the European Union, the proposed Corporate Sustainability Reporting Directive seeks to reduce variability in reporting practices and require all large EU and EU-listed companies to report on sustainability. The first set of standards would be adopted by October 2022. In Germany, a new law was passed in June 2021 that fines companies directly if their suppliers breach human rights or environmental rules, making companies responsible for their entire supply chain, from raw materials to finished products. If passed, The Fashion Sustainability and Social Accountability Act would require global apparel and footwear companies operating in New York to set binding targets to reduce environmental impact, map their complete supply chain, and comply with mandatory reporting. It won’t be enough to sign onto sustainability pledges; companies will need to prove they are acting and producing results.
We believe that we must protect the planet and the future of sport, by creating, testing, and building momentum around consumer and operational solutions that address the issues we face relative to carbon, waste, water, and chemistry.

— Andrew Campion, Nike chief operating officer
**KEY INSIGHT**

Sustainability commitments by governments, combined with emerging customer expectations, are driving growth of startups and investment by brands in the area.

**EXAMPLES**

Adidas’ Choose to Give Back program rewards people for donating old apparel, accessories, and shoes in any condition and from any brand. The sports brand resells items in good condition and reuses remaining materials. Nike takes damaged shoes and refurnishes them by hand for resale in selected markets. The EU has been leading many efforts around the circular economy. The EU-funded Circular System for Assessing Rare Earth Sustainability uses blockchain tokens and digital passports to track rare earth metals and certify compliance with global standards. With the increased electrification across the continent, securing this supply chain is critical for the economy. In France, an anti-waste law aims to recycle all plastics by 2025, introduce a "repairability index" that rates the ease of repairing products before they are purchased, and plans to hold makers of goods responsible for their products when they are thrown away.

**DISRUPTIVE IMPACT**

Investment in circular economy startups is accelerating as brands invest in their own entry into resale. New models are emerging like subscription-based clothing company Circos, which lowers the environmental impact of apparel during the first few years of a child's life by providing larger sizes as the child grows and recycling the items that no longer fit. As countries begin to hold manufacturers responsible for product waste at end-of-life, product designs and business models will need to adapt. Dubai recently increased the cost of waste disposal to drive greater reuse and recycle of materials. Renault’s circular economy factory Re-Factory is part of the company’s strategy to achieve zero impact by 2050. All companies will need to consider their entire value chain and how they can make changes to manufacturing practices and product use that extends end-of-life through repair, reuse, and recycling.

**EMERGING PLAYERS**

- Resortecs
- Circulor
- The Ellen MacArthur Foundation
- Circularise
- Mercari
- ThredUP
- Circos
- Vietnam’s revised Law on Environmental Protection
- Mediolanum Circular Opportunities fund
Rethinking the Cold Chain

KEY INSIGHT

From groceries to vaccines and gene therapies, the cold chain is becoming a larger part of our everyday supply chain. Investment is growing to meet rising demand for temperature-stable transit that delivers products without spoilage.

EXEMPLARY

UPS leveraged vaccine experience gained during the pandemic to develop a permanent end-to-end offering through its health care division. The logistics company tracks temperature diversions from its command centers and touts 99.9% on-time delivery. UPS also worked with Atrium Health Wake Forest Baptist to deliver vaccines using its Flight Forward drone service while maintaining cold chain requirements. Research led by the University of Hawaii at Manoa demonstrated use of supercooling to extend the shelf life of asparagus without damaging it, an innovation that may be used with other produce to keep it fresh for longer periods. Passive thermal packaging introduced by World Courier maintains low-frozen temperatures for up to 168 hours. These Cocoon shipping containers are also 30% lighter than traditional containers. A personal cooler-size ultra-low temperature freezer created by Stirling Ultracold maintains temperatures while using a third of the power required by compressor-based containers.

DISRUPTIVE IMPACT

Global spending on biopharma cold-chain logistics is expected to reach $21.3 billion by 2024, according to the 2020 Biopharma Cold Chain Sourcebook, and we are already seeing this rise in investment today. American Airlines Cargo doubled its cold-chain capacity while UPS launched a permanent service offering and expanded its global cold chain network. DHL announced plans to invest $400 million in 2022 to expand its pharmaceutical and medical supply capabilities in the U.S. Results from the 2022 Third-Party Logistics Study found that both shippers and third-party logistics companies are accelerating growth plans to develop more cold chain capacity. Part of that may include automating pallet storage and retrieval as well as order picking to increase efficiency and eliminate the need for employees to work in harsh conditions. Reusable thermal packaging and passive packaging are other areas of innovation being explored to drive down costs while improving performance and sustainability.

EMERGING PLAYERS

- UPS Cold Chain Solutions
- World Courier
- Stirling Ultracold
- DHL

Making the cold chain more efficient and effective is a challenge many logistics companies are rising to meet.
EMERGING PLAYERS

- 3D Systems
- Alquist 3D
- BioLife4D
- Carbon 3D
- ExOne
- Stratasys
- Formlabs
- ICON
- Lund University
- Materialise
- Mighty Buildings
- NScrypt
- University of Toledo Institute of Applied Engineering Research
- World Economic Forum’s Industrializing Additive Manufacturing Initiative
- Xi’an BLT

KEY INSIGHT

Once constrained to simple polymers, additive manufacturing (AM)—or 3D printing—has expanded to use metal, ceramics, and biological materials. New technologies are pushing the field beyond geometric, surface quality, and material limitations to create optics, shape-morphing materials, and self-healing components.

EXAMPLES

Advances in AM are opening new possibilities in medicine and off-planet manufacturing. In 2021, 11% of NASA’s Small Business Innovation Research and Small Business Technology Transfer grants leveraged additive technologies. NASA’s focus on in situ resource utilization makes additive a key enabling technology. But there are other advantages to zero-gravity environments—such as printing large delicate structures, like chambers of a heart. Researchers at Tel Aviv University are using 3D printing to replicate brain tumors from a patient’s tissue to optimize drug treatments and target proteins and genes for that patient’s tumor. The next-generation bioprinter in development by nScrypt is a bioreactor that integrates spinning, shaking, and oxygen infusion to achieve similar results outside of low-gravity environments. Additive is gaining traction in home construction where it is used to print exterior walls that reduce time and cost compared with traditional wood-frame homes.

DISRUPTIVE IMPACT

AM is rapidly growing, in part, due to a global focus on sustainability and reshoring initiatives. It is powering the rise of microfactories that localize production while offering remanufacturing techniques that create seamless repairs for damaged components. Outside of traditional applications in aerospace, automotive, and heavy industry, medical applications are growing. As of 2021, the U.S. Food and Drug Administration had cleared over 100 devices manufactured using additive technologies. As the technology grows, organizations should consider Design for Additive Manufacturing practices that move beyond traditional manufacturing constraints. Regulation has been slowly developing but will need to address key issues in intellectual property and quality assurance while organizations like the Pacific Northwest National Laboratory are exploring national security implications.

Experiments on the International Space Station demonstrated the feasibility of bioprinting organs in low gravity environments.

Image credit: NASA.
Capturing IIoT Metadata

**KEY INSIGHT**

The industrial internet of things (IIoT) deploys sensors that monitor the conditions of industrial machines and systems. Metadata provides additional context to the data collected such as sensor functionality, placement, and relationship within the network. It’s this metadata that holds the key to unlocking value from massive amounts of data.

**EXAMPLES**

Large troves of data are being generated by sensors and connected devices in industrial settings. Industrial operations look to that data to provide insights around cost savings, efficiencies, and process deviations. With the rise of cloud-based AI, metadata enables multipurpose solutions that can adapt to the operational context of the data without having to be familiar with an equipment’s specific operation. Today’s solutions offer live, real-time dashboards so that leaders can monitor production process and machine condition, to identify opportunities for predictive maintenance or process optimization.

**DISRUPTIVE IMPACT**

The Open Platform Communications Unified Architecture attempts to provide a standard for data exchange between machines and platforms. This standard was broadened in the late 2000s to cover more of the machinery landscape, and is still in use today. Data management has gone from a voluntary nice-to-have to an absolute requirement on manufacturing and warehouse floors. Enhanced metadata management in industrial settings enables businesses to improve their margins, decrease scrap, reduce downtime, increase the quality of their output, and become more efficient. As AI capabilities expand into this space, deeper and less obvious insights will emerge, allowing organizations to truly leverage their machinery to the fullest extent.

**EMERGING PLAYERS**

- Amper
- Augury
- MachineMetrics
- Plataine
- PTC ThingWorx
- Uptake
**Emerging Players**
- ArcBest
- AutoStore
- Einride
- Exotec
- Flock Freight
- Loadsmart
- Ocado Group
- Phantom Auto
- Project44

**Key Insight**
Rising inflation and labor challenges are accelerating adoption of automation. Less than a tenth of U.S. warehouses are heavily automated, but as supply chain velocity increases, robotics can increase productivity and lower costs. Artificial intelligence provides more accurate predictions of demand while wearables bring intelligence to logistics workers based on context.

**Examples**
Automated technology is bringing expanded capabilities while lowering implementation costs. In December 2021, Tyson Foods announced it would spend $1.3 billion over the next three years to automate its production lines. Struggling to keep its production plants staffed, the meat giant plans to invest over $500 million in this next fiscal year alone and expects to recoup $450 million in cost savings by 2024. Tyson isn’t alone. Logistics company ArcBest modified Phantom Auto forklifts for autonomous operation with remote human operators looped in for complex tasks. Nike is investing in demand-sensing AI to predict, plan, and shape individual consumer demand. The company has added over 1,000 collaborative robots to its distribution centers that sort, pack, and move inventory. Walmart announced it is installing automated material handling systems in its regional distribution centers. Grocer Kroger opened its third automated fulfillment center in February 2022 to support expansion of e-commerce initiatives.

**Disruptive Impact**
The National Bureau of Economic Research reported that the pandemic left almost 600,000 logistics jobs unfilled just in the U.S. As companies continue to face logistics worker shortages, automation is becoming much more attractive. Retail operator Fast Retailing plans to open an automated warehouse in China by August 2022. It was able to reduce its workforce by 90% after automating one of its Japanese facilities in 2018. Across China, automation is accelerating to adjust for an aging population. By 2025, the country expects to have at least 500 smart manufacturing factories. Globally, money is flowing into supply chain automation. PitchBook reports that supply chain technology startups raised $24.3 billion in venture funding in the first three quarters of 2021. The expectation is that by injecting automation, AI, and machine learning, lean supply chains will develop greater resiliency.
By 2025, 52% of current workplace tasks will be automated.

—DHL’s “Future of Work in Logistics” report
Drones
**KEY INSIGHT**

The global drone market continues to see unprecedented rise, and is expected to grow from a $15 billion market in 2020 to more than $90 billion by 2030, bolstered by its wide-ranging applications in defense, public safety, agriculture, weather monitoring, and enterprises.

**EXAMPLES**

Drones, or unmanned aerial vehicles (UAVs), carry out tasks that range from the mundane to the extremely dangerous, including firefighting efforts. Other types of drones are not limited to aerial activities but travel across terrain or below the ocean. Japanese telecommunications operator KDDI, in partnership with Prodrone and Qysea, has developed the first “sea-air integrated drone.” This drone is capable of aerial navigation, and it is equipped with an underwater drone payload that can be released once the craft has made contact with water. The Pentagon’s Defense Advanced Research Projects Agency (DARPA) raised the stakes for UAVs by equipping an UH-60A Black Hawk helicopter with Sikorsky’s Matrix technology. This technology allows preexisting aircraft to be equipped with individualized autonomous systems from scratch. This breakthrough could allow the military to operate aircraft at all times of the day or night—and begin to redefine what has the potential to be operated remotely or autonomously.

**DISRUPTIVE IMPACT**

Adoption of drones will continue to expand over the coming years, allowing companies and organizations of all types to access hard-to-reach areas for uses such as search and rescue, optimized and speedier delivery, increasingly efficient warehouse and agricultural operations, and climate monitoring.

While drone technology has been around for sometime, regulators have not found a way to safely integrate the technology. However, in June 2021, the U.S. Federal Aviation Administration announced that it had created a new rulemaking committee focused on UAVs that operate beyond visual light of sight. This committee is made up of 86 organizations, including six drone manufacturers. This collaboration between the drone industry and regulators will result in recommendations that will take effect in two to three years. The impact could result in the implementation of drones at scale, providing a broad range of services.

**EMERGING PLAYERS**

- 3D Robotics
- AgEagle
- Alpine 4
- Ambarella
- Autel Robotics
- Boeing
- DJI
- DraganFly
- GoPro
- Hubsan
- Lockheed Martin
- Parrot SA
- Red Cat Holdings
- Vuzix
- Yuneec
Drone Swarms

**Key Insight**
Drone swarms, or fleets of networked drones capable of coordinated operations and communication, are expanding the capabilities of a single operator. As this technology advances, swarms will be able to operate with no human interaction, allowing the collective functionality of the entire network to take precedence over any single drone.

**Examples**
Raytheon has developed a system that lets a single user operate a swarm of 130 physical drones as well as 30 simulated drones at the same time. With this technology, an operator could control these drones in air-based or land-based situations, inside or outside, with minimal training. The Israel Defense Forces used a swarm of small drones to attack Hamas militants. While drones have been used before in combat, this is believed to be the first instance involving a swarm. The drones supplied by Elbit Systems enable a single user to operate the craft almost silently to provide persistent observation or deliver explosives. Drone swarms have been used in other unique ways: India used drone swarms to decorate the night skies with formations of the national flag and Mahatma Gandhi. In China, Bilibili flew a fleet of 1,500 drones to create a QR code advertisement promoting the video game Princess Connect! Re:Drive.

**Disruptive Impact**
Semiautonomous drone swarms, such as the ones highlighted by Raytheon and Elbit Systems, drastically expand the capabilities of single users, equipping them with the power of more than 100 drones that can work in concert to achieve a unified task or goal. As semiautonomous drones become more fully autonomous, the implications grow even more significantly, with AI being able to complete tasks, even if drones are lost during a mission, by calibrating other drones in the swarm to cover the slack. While the swarm remains minimal, only consisting of four separate drones, Korean Air has implemented the use of drone swarms to conduct inspections on aircraft. Collision-avoidance systems and geofencing enable such tasks and result in a 60% reduction in time spent by human inspection. As the technology scales, fully autonomous swarms will grow in size of fleet and level of application.

**Emerging Players**
- Raytheon
- Elbit Systems
- Korean Air
- Northrop Grumman
- Israel Aerospace Industries
- Lockheed Martin
- China Aerospace Science and Technology Corp.
- BAE Systems
- Boeing

Raytheon is working under a contract for the Pentagon’s Defense Advanced Research Projects Agency to build unmanned aircraft system platforms that work together in formations, enabling swarms of drones that can overwhelm adversaries and fly into dangerous locations.
**NEW INSIGHT**

New significant milestones have been met and funding has increased in the area of drone fleet deliveries. Adapting federal regulations are necessary as the technology continues to make a case for its utility at scale.

**EXAMPLES**

While early applications of possible drone fleets were tied to pizza deliveries, the idea is coming full circle as Domino's Pizza has partnered with Skydrop to advance drone delivery trials in New Zealand. 7-Eleven is an unexpected candidate for adopting drone deliveries, but the convenience store has partnered with All Nippon Airways to really expand its convenience offerings to be available 24 hours a day, 365 days a year. Alphabet's drone fleet service, Wing, has reached a new milestone of completing over 100,000 deliveries, operating in Australia, the U.S., and Finland, as the technology still aims to prove its utility at scale. The Israeli startup Flytrex, which has partnered with Walmart to target suburban consumers, has raised $40 million in funding while it waits for expanded regulatory permissions to expand to new markets. Retailio has piloted the technology to deliver medicine to Indian hospitals, while Nebo conceptualizes using it to create a fleet of hovering remote charging stations for electric vehicles.

**DISRUPTIVE IMPACT**

Drones offer the promise of truly meeting end users wherever they are. Demand for contactless deliveries stemming from the impacts of COVID-19 have caused projections for global drone package deliveries to grow from $0.68 billion to $0.99 billion with a compound annual growth rate of 44.5%, with the market expected to raise to $4.4 billion by 2025. Drones are merely the conduit between service provider and end user. As regulations adapt and the technology improves, fleets will provide more than just the delivery of products but will also be used to offer various services, such as health-related assistance to distressed individuals in remote locations.
Every breakthrough business idea begins with solving a common problem. The bigger the problem, the bigger the opportunity. I discovered a big one when I took apart an IBM PC. I made two interesting discoveries: The components were all manufactured by other companies, and the system that retailed for $3,000 cost about $600 in parts.

— Michael Dell, founder, chairman and CEO of Dell Technologies
As applications for drones become more pervasive, aviation guidelines and regulations for operating these vehicles will become increasingly necessary. Essentially, a system of “air lanes” will establish a guide for both piloted and autonomous low-flying aircraft. Managing the number of flying drones will be important to ensure safety and minimize noise pollution.

Traditionally, air traffic control measures for drones have relied on government agencies. This remains largely the case, as the U.S. Federal Aviation Administration has made regulatory developments over the past year including the BEYOND program, the Operations Over People program, and remote ID regulations. The FAA is not the only organization to develop mobile applications to inform recreational users where they can and cannot operate drones. Alphabet Wing has also developed its own drone safety and navigation app called OpenSky. Airbus is another commercial operator with plans to impact this domain by collaborating with regulators, manufacturers, service providers, and consumers to build air traffic management tools and solutions for air taxis and delivery drones. Israel has taken even more progressive measures by becoming the first country to allow large, high-flying drones in civilian airspace.

Currently, regulations related to the management of unmanned aerial vehicles are piecemeal. At present, there are no rules that all countries agree on relating to the operation of drones. Development of international drone rules and regulations would be an expedient, albeit challenging measure to be taken, such as how the International Civil Aviation Organization rules global air traffic now. Regulators still have the opportunity to take preemptive measures to minimize congestion, ensure safety and privacy, manage community perception, and learn from road and air travel; however, that timeline is quickly shrinking as more commercial and noncommercial drone applications develop. Partnerships among government agencies and private companies will be required to keep air lanes operational and safe.
Flying Taxis

KEY INSIGHT

While vertical take-off and landing (eVTOL) aircraft may only result in the transportation of small groups of individuals over short distances, the positive impacts on traffic congestion, civic design, and city planning are paramount. As concepts have moved to the testing and prototyping stages, the true potential of this technology will be more fully realized.

EXAMPLES

Joby Aviation is conducting a series of eVTOL flights over San Francisco Bay, according to documents filed with the U.S. Federal Communications Commission. Tests of its prototype, the S4, would be the first in an urban environment in full view of the public. Such tests naturally follow other milestones the company reached this past year, setting the record for the longest flight (155 miles) the fastest flight (205 mph) and the highest flight for an eVTOL aircraft. The Japanese company Aix has preordered 50 units of Ehang’s EH216 AAVs. As Ehang emerges as a significant player in the urban air mobility (UAM) sector, its air taxis will be operational by 2025 or the World Expo in Osaka. Networks of flying taxis will require more than just the eVTOL technology required to power the flights. Australian based Skyportz is seeking partnerships with underused parking garages to build infrastructure for vertiports for these eVTOL air taxis.

DISRUPTIVE IMPACT

While the viability of flying taxis still comes into question, as the industry gains momentum and investors designated $4.3 billion for electric air taxi startups last year, city, regional, and state officials will be forced to make concessions for such new ways of transportation. And that is not to say that public agencies have not already made movements in this area. NASA launched its Advanced Air Mobility National Campaign with the objective of partnering with other government and state agencies as well as industry leaders. The city of Los Angeles is particularly interested in air taxis to assuage local transportation issues and has developed programming from the mayor’s office to develop a policy toolkit to advance such operations. As public agencies invest more time and energy in this space, this new mode of travel could have impacts on civic design and infrastructure.

EMERGING PLAYERS

- Joby Aviation
- Ehang
- Autonomous Flight
- Skyportz
- Lilium
- Airbus
- Tetra
- Urban Aeronautics
KEY INSIGHT
“Follow-me” functionality allows a drone to detect and pursue a moving subject, and has myriad applications ranging from photography and videography to security and safety.

EXAMPLES
Many photo- and video-enabled consumer drones available today have “follow-me” and crash-avoidance functionality, enabling semiautonomous flight, where a subject is kept in the frame of the camera without the need for a designated pilot. These drones rely significantly on two types of technology: vision recognition and GPS. Vision recognition provides the most advanced version of obstacle detection and avoidance. Qualcomm is integrating 4K and 8K cameras into its drones, greatly enhancing this skill of obstacle avoidance. GPS allows drones to follow a transmitter signal of an associated remote control. Jeep is planning to incorporate a follow-me function into its platform, enabling a drone to follow the vehicle for the purpose of capturing photos of the subject or providing additional lighting for navigating dark, off-road trails. Piaggio Fast Forward has released the Gitamini, a robot that uses cameras, sensors, and radar to follow its users on land.

DISRUPTIVE IMPACT
As vision recognition for drones improves, the ability to automatically avoid crashes and reroute around obstacles will also improve, greatly increasing the drone’s safety and versatility. Autonomous conflict avoidance and follow-me functionality reduce stress and sensory demand on the remote pilot, allowing him to concurrently operate other tasks. These factors also make indoor flight easier and expand the range of circumstances in which drones can be safely operated. While follow-me functionality has primarily been used for capturing photos of a subject, the technology could be used for other situations, such as providing auxiliary light, making it possible for the Glowglobes represented in “Dune” to become a reality.

EMERGING PLAYERS
- DJI
- Gitamini
- Jeep
- Yuneec
Inspection Drones

KEY INSIGHT
As natural disasters and extreme weather become more common, drones will not only provide more insight and advanced detection of destructive weather events but also help with the rapid inspection and analysis of critical infrastructure.

EXAMPLES
Industries that require visual inspections are increasingly turning to drones to perform such tasks. More recently, power utilities have moved in this direction, equipping drones with zoom lenses, thermal sensors, and lidar to capture more information about power lines and infrastructure. Researchers from the University of Kentucky are exploring the possibility of using unmanned aerial vehicles to assist cattle producers by remotely locating cattle and assessing herd health. Drones and machine learning are being used by NOAA’s National Centers for Coastal Ocean Science and Oregon State University to identify marine debris that has accumulated along coastal regions. In a partnership with Black Swift Technologies, NASA is using rugged drones to monitor active volcanoes and warn of potential eruptions.

DISRUPTIVE IMPACT
As extreme weather events become more frequent and destructive, additional strain will be placed on existing infrastructure. Inspection drones will not only be used to monitor and inspect natural disasters, but they will also be used to gain access to difficult-to-reach, at-risk infrastructure such as gas pipelines and power lines.

EMERGING PLAYERS
- NASA
- Black Swift Technologies
- University of Kentucky
- NOAA’s National Centers for Coastal Ocean Science
- Oregon State University
- Buzz Solutions
Cognitive Active Safety Features

KEY INSIGHT
Car manufacturers are racing ahead to develop proactive safety functions and semiautonomous capabilities to satisfy both consumer and regulator demands.

EXAMPLES
The Insurance Institute for Highway Safety announced in early 2022 that it would release its first ever safeguard ratings for partial automation technologies later in the year. The ratings, which will score capabilities as good, acceptable, marginal, or poor, are meant to provide drivers with greater clarity around these safety features’ effectiveness. This announcement comes as safety features such as Front Automotive Emergency Braking, Blind Spot Warnings, and Rear Cross Traffic Warnings are increasingly common in new vehicles.

While autonomous vehicle frontrunner Tesla continues to improve its self-driving capabilities, key auto players including Nissan, Chrysler, Toyota, Mazda, Honda, and Hyundai have implemented top-of-the-line safety systems. Other companies are making strides in the space as they develop new cutting-edge technologies. Netradyne specializes in AI-powered dash cameras while Comma.ai created Openpilot, an open-source software driver assistance program.

DISRUPTIVE IMPACT
Despite these safety features, car accidents have continued to spike over the past two years, owing to increased speeding as drivers take advantage of the decreased traffic congestion during the pandemic. Cars on U.S. roads are also fairly outdated, and likely don’t have many of these safety systems installed, as the average age of U.S. vehicles reaches a peak of 12 years. As more individuals buy newer cars, and a greater number of vehicles on the road have such cognitive safety features embedded, road safety will likely increase significantly.

Vehicle manufacturers will continue to implement and tout active safety features to attract safety-minded consumers and appease regulators, as software drives the next wave of advancements. Car manufacturer development cycles, which historically span about 10 years, will naturally accelerate as platforms and vehicles become increasingly software driven and technologically complex.

EMERGING PLAYERS
- Chrysler
- Comma.ai
- Honda
- Hyundai
- Insurance Institute for Highway Safety (IIHS)
- Mazda
- Netradyne
- Nissan
- Tesla
- Toyota

Backup cameras and blind spot monitoring have gone from luxury accessories to safety staples.
Partial automation systems may make long drives seem like less of a burden, but there is no evidence that they make driving safer. In fact, the opposite may be the case if systems lack adequate safeguards.

— IIHS President David Harkey
**Autonomous Last Mile Delivery**

**KEY INSIGHT**
During the pandemic, the desire for quick and contactless deliveries steadily rose, and there is little reason to think this desire will change. Consequently, autonomous delivery has become more commonplace, even pushing states to change their legislation around the technology.

**EXAMPLES**
Starship Technologies, the autonomous delivery company consisting of a fleet of small six-wheeled robots, experienced impressive growth during the pandemic. By early 2021, the company had already achieved 1 million deliveries, experiencing a 900% increase in deliveries from where it had been mid-2019. By late 2021, Alibaba Group’s autonomous delivery robot program had achieved the same milestone in China; however, this happened only a year into its operation. The efficient system employs 200 robots carrying parcels to 200,000 consumers in 52 cities spread out over 22 provinces. As companies look to improve this technology in an effort to safely reach more customers, the Polytechnic University of Catalonia and CARNET have developed delivery robots that are capable of going up and down stairs. Autonomous delivery company Nuro announced its next-generation vehicles will be equipped with an external airbag for protecting pedestrians.

**DISRUPTIVE IMPACT**
As autonomous last mile delivery gains momentum, legislation has already adapted accordingly. The state of Pennsylvania has gone as far as recognizing delivery robots as pedestrians. They can weigh up to 550 pounds and drive up to 12 mph to maintain this designation. Proponents of these measures suggest that they will bring about a future where household items are delivered in no time, reducing the amount of bulky delivery vans that block sidewalks and produce harmful emissions. The consultancy MarketsandMarkets projects that this industry will grow to $4.9 billion by 2030 and could reduce delivery costs for the retail industry by up to 90%. As autonomous deliveries become more commonplace, they will serve as a reliable, data-rich, and cost-effective solution for last-mile transportation. Additionally, they could create conditions that lead to autonomous vehicle systems for transporting people becoming more palatable to the general population.

**EMERGING PLAYERS**
- Starship Technologies
- Alibaba Group
- Nuro
- Wayve
- Loggi Tecnologia
- StreetDrone
- DroneUp
- Tiny Mile
- Coco

Small road-based autonomous drones are enabling faster and more efficient last mile delivery, especially of small items like meals or groceries.

*Image credit: Starship Technologies.*
**Autonomous Underwater Vehicles**

**KEY INSIGHT**

Drones aren’t just for air and land. Underwater drones have been around since the 1950s, but in recent years the technology has improved dramatically due to advanced payload offerings; low-light, high-definition cameras; enhanced seabed detection; better batteries; and more advanced sensors.

**EXAMPLES**

Some of these underwater craft remain tethered to external inputs or are remote operated, others are becoming more autonomous and independent. Autonomous underwater vehicles (AUVs) can now accommodate a range of payloads. They can be equipped with underwater cameras, sonars, and even sniffing sensors capable of detecting chemicals and other particles. While Anduril, the startup operated by Oculus’ co-founder Palmer Luckey, has primarily focused on above-ground drones, it is shifting its focus to AUVs with the acquisition of Dive Technologies. These services can already engage in anti-submarine warfare, mapping of seabeds, and oceanographic sensing. Notilo Plus’ AUV, the Seasam, uses acoustic and computer vision technologies to wirelessly follow and capture HD video of its scuba-diving user. The technology recently gained recognition after being featured in the horror film “The Deep House.”

**DISRUPTIVE IMPACT**

Various driving factors are contributing to this market’s estimated $3.71 billion worth by 2026. These include the rising demand in the defense sector, the increased demand for search and discovery of ship wreckage and air crashes, advancing capabilities for seabed mapping, and its application for coastal protection, intelligence, and surveillance. Additionally, AUVs have the potential to lessen the environmental impact of operations at sea and the ability to produce sustainable offshore data acquisition services. As military bodies seek to expand both offensive and defensive capacities and enhance intelligence, network infrastructure, and port security, AUVs will provide cost-effective solutions for such endeavors.

**EMERGING PLAYERS**

- Anduril
- Dive Technologies
- Notilo Plus
- Monterey Bay Aquarium Research Institute
- Woods Hole Oceanographic Institution
- DOF Subsea
- Ocean Floor Geophysics
Autonomous Ships

KEY INSIGHT

Autonomous, AI-powered ships are moving from concepts to reality as two separate companies have completed successful maiden voyages of their respective autonomous technology. As legal frameworks are shifting to accommodate the authorized operation in international waters, the ships have also been equipped to adapt to navigational rules and regulations.

EXAMPLES

In November 2021, Yara, a Norwegian fertilizer producer, sent its highly anticipated Yara Birkeland on its maiden voyage, marking the world’s first demonstration of an electric and autonomous containership. After traveling from Horten to Oslo, Yara plans to put the containership into operation, projecting to cut CO2 by 1,000 tonnes and replace up to 40,000 trips by diesel-powered trucks a year. The ship relies on the Leclanché high-energy lithium-ion battery system, radar, lidar, an automatic identification system, and infrared cameras to operate. Despite the maiden voyage of the Yara Birkeland, the Japanese shipping company Mitsui O.S.K Lines claims to have operated the world’s first sea trial of an uncrewed autonomous containership. In order to complete the voyage, the vessel took a number of variables into account including ship location, wind, tides, currents, ship handling elements, and navigational rules and regulations.

DISRUPTIVE IMPACT

Large autonomous ships could transform shipping by reducing environmental impacts, increasing efficiency, reducing costs, and reducing human error. Unmanned electric ships could result in cost savings along the supply chain and resiliency against potential labor shortages. When the notorious Ever Given blocked the Suez Canal in early 2021, environmental factors like heavy winds and a low water level contributed to the incident—elements that an AI-enabled navigation system could have potentially detected and compensated for. Interestingly enough, the very day before the Ever Given got stuck, its parent company, Evergreen, signed a deal with Samsung Heavy Industries for 20 new ships equipped with SVESSEL smart technology, including fuel-economizing features and intelligence systems. Autonomous ship technology could provide added protection from such incidents happening in the future.

EMERGING PLAYERS

- Yara International
- Mitsui O.S.K. Lines
- Samsung Heavy Industries
- Shone
- IBM
- Marine AI
Transportation
EMERGING PLAYERS
• Tesla
• Volvo
• Philips
• Geely Healthy Car program

KEY INSIGHT
Vehicle manufacturers are expanding their definition of safety to include protection from the elements whenever we are in or around a vehicle. As a result, vehicles are becoming mobile biospheres that enable people to move through the world with increased safety from the outside world.

EXAMPLES
Tesla began installing and marketing HEPA air filters in its Model X cars beginning in 2015 but now includes them in its Model S and Model Y vehicles. These oversized air filters are part of a safety feature known as Bioweapon Defense Mode as they can filter particles as small as 0.3 micrometers, hence “military-grade biological contagions.”

In 2020 Volvo introduced Advanced Air Cleaner technology, which combines air filters and ionization with an interior air quality sensor. As a result, drivers can compare the air quality in their car versus outside.

DISRUPTIVE IMPACT
The pandemic has made people more sensitive to potential environmental hazards. While vehicles have always enabled people to create a semi-controlled environment on the move, the concept of what a vehicle can protect you against is expanding. Making personal safety cover more types of threats while also being mobile could change how we move from one safe space to another and how we view the time in between safe places.

In 2015 Tesla began to manufacture cars with HEPA filters to improve the air quality within the car cabin.

Vehicular Biospheres
EMERGING PLAYERS

• Ford
• GM
• VW
• Tesla
• BMW
• Rivian

KEY INSIGHT

Battery-powered transportation now extends beyond cars, trucks, and buses to motorized bicycles, hoverboards, skateboards, and scooters. These electric-powered forms of transportation are not going away and will be an increasing part of the transportation landscape going forward.

EXAMPLES

The increased transportation on non-gasoline powered vehicles will affect fossil fuel demand and the resulting energy distribution networks.

Volkswagen, the largest global automotive manufacturer, has announced plans to stop selling new fossil fuel powered vehicles in Europe by 2035. The majority of mainstream auto manufacturers have also set lofty objectives for electric cars with many first generation cars coming to market recently including vehicles from VW, BMW, Ford, and GM.

Battery-powered transportation is not limited to private travel either as Amazon has demonstrated keen interest through its strategic investment in Rivian. Rivian has reprioritized its business from consumer vehicles to commercial delivery vehicles to focus on delivering 100,000 electric Amazon delivery vehicles by 2024.

DISRUPTIVE IMPACT

Energy prices, reliable and safe batteries, and convenient, affordable recharging infrastructure will drive adoption of electric transportation. Utility providers will be pressured to improve grid resiliency as demand grows for domestic charging. Those first movers of charging infrastructure along travel routes will shift traffic patterns and create new networked economies—similar to how the interstate system created an economic boon for certain towns and hurt cities that were bypassed.

Incentives from federal and state governments to install charging stations along even less-traveled routes will drive adoption of electric vehicles over the coming years. As electric vehicles become more efficient and longer range, and drivers are assured that charging stations will be there when they need them, “range anxiety” is likely to lessen, removing one very significant psychological barrier from the embrace of electric vehicles.

Batteries need to come in all shapes and sizes to accommodate the increasing ways we want to get around.

Demand for Battery-Supported Transportation

4TH YEAR ON THE LIST
You’re out of charge and stranded.

Spin the wheel to discover why!

- Grid is overloaded
- No adapter
- Power outage
- EV station is in safe mode
- 3-5 hour wait to use the EV station
- Corsing (EV stations for parking)
- Not charging
- Wrong adapter
- Hot day — your battery is in safe mode
EMERGING PLAYERS
- Tesla
- ChargePoint
- Electrify America
- PlugShare
- U.S. Environmental Protection Agency
- National Electric Highway Coalition

KEY INSIGHT
Accelerating adoption of battery-powered transportation is leading to a rethink of how we provide the energy required to transport people and goods from A to B. How will our energy delivery systems need to adapt to a more battery-powered and less gasoline-powered transportation ecosystem?

EXAMPLES
Charging infrastructure outside the home has begun to standardize with the development of standardized plugs, units for measuring recharge rates, and interoperable charging points across multiple vehicle manufacturers. While “range anxiety” with electric cars still exists, the stress around the ability to charge along road trips and at what rate is beginning to decrease as fast chargers and standardized metrics become more readily available. Charging infrastructure along travel routes is not without its growing pains as it tries to rapidly scale up to the increasing demand from early adopters of the ever increasing number of plug-in electric vehicles. Tesla is in the process of opening up its charging network to other manufacturers but has been making very slow progress. It is piloting 10 supercharger stations in the Netherlands where non-Tesla vehicles can also use the charging infrastructure, but not all cars will be compatible due to short cables, stall layouts, and connector compatibility issues.

DISRUPTIVE IMPACT
Robust and reliable electrical grids become increasingly critical when transportation becomes dependent on the ability to charge batteries. In the U.S., the National Electric Highway Coalition includes 50 utilities and plans to address infrastructure gaps along major travel corridors by the end of 2023. By bringing utility companies into the effort, the coalition hopes to leverage better information on the existing grid capacity for deciding new station locations.

While fueling transportation with electrons from the electrical grid is of significant importance, other energy sources like hydrogen, natural gas, ethanol, and biodiesel will also need to be taken into consideration as we transition to energy delivery beyond mostly gasoline.

The Department of Energy tool helps people find charge points across the U.S.
EV Charging Levels

Access control
For more than 100 years, we’ve relied on gasoline to fuel our cars and trucks. At the pump, there are different choices: regular, mid-grade, premium, and diesel. Most cars can get by on regular gas, but some require premium, which has a higher octane rating and helps the engine perform better.

With electric vehicles, there are also an array of choices for recharging. Like other electronics, the levels (indicating the type of charge) depend on how much power a vehicle can accept, the power outlet it can use, and the amount of time it takes to fill up the battery.

There are three levels of charging, and the higher the level, the less time it takes to reach a full battery.

Level 1
These charging stations use a standard 120v outlet. The time to charge a vehicle’s battery can take 60 or more hours.

Level 2
These are the most commonly available charging stations and are used most often for home charging. The time to reach a full battery is around 11 hours.

Level 3
These charging stations are known as rapid charging stations, and there are two standards: DC Fast Charging and Supercharging. Level 3 stations can fully charge a battery in under 30 minutes and most closely resemble the customer experience of gasoline-powered cars. Tesla’s standard is Supercharging, and the company has the largest network of Level 3 charging stations in North America.

“It’s no longer a matter of if, and it’s no longer a matter of when, it’s now the question is how fast? Because we know that the automakers have put the money into the retooling.”

— Jonathan Levy, Chief commercial officer of EV charging company EVgo
Car OS

KEY INSIGHT
Platforms are building operating systems for smart cockpits, initially using the phone as an interface.

EXAMPLES
The majority of new cars include the ability to control your phone through the built-in infotainment screens by either plugging it into a USB port or through a wireless adapter. Apple, Amazon, and Google are competing to expand their reach into the car by working with manufacturers to incorporate their software directly into driving interfaces. These systems are powered by a mobile phone’s smart assistant and the specific apps consumers have installed on their phones. So, the experience can be updated, replaced, and refreshed at a much faster rate than when a new car is purchased.

DISRUPTIVE IMPACT
As driving assistants increase in ability, people will spend more and more time in their car without having to pay as much attention to driving. Consequently, the major platform players increasingly view the car ecosystem as prime real estate not only for customer attention but data collection. Volvo’s new Polestar electric vehicles use Android Automotive OS, which was custom-built by Google to integrate its services in the infotainment experience. Simpler integrations include manufacturers like Volkswagen/Audi that utilize the built-in LTE internet connection to provide navigation with Google Maps instead of a proprietary offline maps file that is not regularly updated. By extending the reach of their smart assistants and software to the automotive environment, these companies are able to keep consumers within their ecosystem and collect ever increasing data with increasing specificity.

EMERGING PLAYERS
- Apple
- Google
- Volvo
- Volkswagen
Transportation-as-a-Service Business Models

KEY INSIGHT

The concept of transportation-as-a-service is gaining popularity as more companies use platform business models like ride-sharing to provide transportation without customers having to pay large upfront costs like when they buy a car or scooter.

EXAMPLES

Part of the appeal to consumers of transportation-as-a-service is that they do not need to make the large purchase to own a vehicle outright. Instead, customers can pay per use of a vehicle with all the costs of things like insurance and maintenance included.

The concept of transportation-as-a-service is extending beyond just pay per minute of electric bike rentals with rental car providers and even vehicle manufacturers piloting subscription-based systems for their vehicles. Hertz, Sixt, and Porsche offer some of the most celebrated subscription packages. The subscriptions aren’t limited to cars either, with NetJets providing private airplanes and Carefree Boat Club providing access to boats.

DISRUPTIVE IMPACT

High upfront costs for purchase, maintenance, insurance, and rapid depreciation associated with traditional vehicle ownership will continue to dissuade people from purchasing vehicles when all they want to do is get from A to B. Subscription and per use models alleviate much of the downsides of traditional asset ownership for an increasing segment of the population who seek to limit commitment, while maximizing flexibility and cost-efficiency.

EMERGING PLAYERS

- Hertz
- Sixt
- Porsche
- NetJets
- Lyft

Transportation-as-a-service is not limited to bikes. Cars, jets, and even boats are adopting the business model.
Exponential Growth in Autonomous Driving Data

**KEY INSIGHT**

More data usually results in better algorithm performance, and the size of the data for training autonomous cars is accelerating at an exponential rate. There is an increase in real-world data from cars on the road, but synthetic data is being used to fill in the gaps.

**EXAMPLES**

In 2018, Tesla reached its first billion miles driven with autopilot engaged after four years of testing. Then, Tesla added 2 billion more miles’ worth of data, indicating the exponential rate of increase of real-world testing miles. The problem for the ecosystem is that Tesla’s data isn’t used by other car manufacturers.

New techniques are being developed and perfected in order to generate simulated testing miles, thus feeding the data-hungry algorithms without needing humans to drive physical cars around. Synthesizing data allows designers to train algorithms to better adapt and respond to situations that might be uncommon but have potentially catastrophic consequences. The fusion of synthetic and real world data is helping to accelerate the training of next-generation driver assistance and autonomous driving algorithms.

**DISRUPTIVE IMPACT**

The stakes are incredibly high for the group that creates the best driving assistance algorithms with the quality and size of the training dataset being an instrumental component to achieving the best possible product. Convention-al wisdom suggests that the algorithm with access to the most data will have a competitive advantage over all other algorithms. The fusion of real-world data and synthesized data for training algorithms has tightened the race to generate as much training data as possible, as there are multiple paths to large training datasets.

**EMERGING PLAYERS**

- Waymo
- Tesla
- GM
- Ford
- Nvidia

Autonomous cars rely on algorithms trained on enormous real-world driving data, but that could be changing soon.
Regulating Autonomous Vehicle Testing

KEY INSIGHT

The legislation around how, where, and under what conditions autonomous vehicles can be tested has yet to be set at a national level.

EXAMPLES

In June 2020, the U.S. National Highway Traffic Safety Administration created the AV TEST Initiative to provide the public with information about testing of autonomous vehicles. The objective is to raise public awareness to help the safe development, testing, integration, and education of autonomous vehicle technology in the U.S. The program includes information that states and companies self-report about the status of their various autonomous vehicles development initiatives. Arizona, California, Florida, and Nevada (along with some federal initiatives) lead in testing autonomous vehicles on public roads, with other states and countries catching up. Since 2012, at least 41 states and Washington, D.C., have considered legislation related to autonomous vehicles. More than 50 self-driving companies are testing their technologies in California.

DISRUPTIVE IMPACT

Creating learner’s permits or driver’s licenses for AI-enabled autos will help socialize the technology and establish expectations for experiences and protocols on the road. For autonomous vehicles to become safer, they must be tested in conditions similar to those where they will be deployed. Because of this dynamic, autonomous car services will likely arrive soonest in areas with existing testing sites. The fragmented regulatory environment, which will remain until federal laws and guidelines are imposed, will result in conditional and situational rules, such as how Cadillac centrally designates sections of road compatible with Super Cruise, its AI-enabled hands-free driving assistance product. If the regulatory framework around the use of autonomous vehicles on public roads remains fragmented, there could be a delay in the development of safe autonomous vehicles.

EMERGING PLAYERS

- Moral Machine
- Focus Group on AI for Autonomous and Assisted Driving
- U.S. National Highway Traffic Safety Administration
- National Conference of State Legislators
- International Telecommunication Union

Regulating how autonomous vehicles are tested is still in progress.

Regulating Autonomous Vehicle Testing
KEY INSIGHT
Historically mechanical systems are increasingly built in an electric-only format without a fallback strategy if they fail. Electrical systems are usually more fragile than their analog counterparts, meaning failures are likely to become harder to assess, repair, and recover from.

EXAMPLES
Many car locks today depend on electricity and become inoperable when the car battery dies. Tesla's Model 3 has a mechanical system for the front doors but not the rear doors. Such vulnerabilities can cause life-threatening scenarios: A failed car battery locked the doors of an Ohio man's Cadillac and trapped him in the car for 13 hours, and, in another case, a Texas man and his dog died in his Corvette as a result of the same problem. Both vehicles had manual door release mechanisms as a fallback for when electrics failed, but neither person could find the release. To make matters more tragic, one of the victims had the vehicle owner's manual yet was still unable to activate the manual release mechanism. These problems will be exacerbated when cars no longer come with physical user manuals or when firmware updates change a car so drastically that the original physical manual is no longer accurate.

DISRUPTIVE IMPACT
As vehicles become more automated, manufacturers must design for the appropriate level of redundancy for a population of people with limited understanding of how the underlying systems work. Communication of these designs increases in importance as digital systems enable firmware updates that can drastically change what and how a car does what a user wants it to do.

EMERGING PLAYERS
- Cadillac
- Tesla
- Range Rover

How do you get out of your car if it's frozen shut and you have no door handle?
Unashamedly, this is a high-end product. It’s an awesome machine. It’s a true luxury electric car...We’re able to charge nearly 300 miles of range in just 20 minutes. No one else is even close to that.

— Peter Rawlinson, CEO, Lucid Motors
China produces more cars than any other country in the world. While their manufacturing volume leads globally, Chinese brands have not yet reached saturation in overseas markets. China’s ambitions to dominate the global car industry are buoyed by its manufacturing sector, work in AI, and global competitiveness.

**Examples**

Chinese domestic brands are starting to make headway with a global audience. During the 2022 Super Bowl, a little-known Volvo spinoff called Polestar took a dig at Tesla, bragging that it had no plans to conquer Mars, and highlighting “no Dieselgate” as a key feature. Polestar is a joint venture between Zhejiang Geeling Holding Group, which also owns Volvo. NextEV launched its Nio EP9 hypercar, and the company has plans to bring mainstream sports car models into production this year. Chinese companies including HAAH and Chery, which make more affordable passenger cars, hope to break into the U.S. market.

**Disruptive Impact**

China is leading the charge for the future ecosystem of mobility with manufacturing, electric vehicles, apps, communications systems, AI, and data at its center. The advances in manufacturing technology from Tesla’s Giga Shanghai factory are already starting to form the basis for higher efficiency production methods for other domestic Chinese manufacturers, like advanced casting machines developed by LK Group for Tesla. Baidu’s Apollo is another leading example of a ready-for-export technology where a collaboration of international and domestic companies are developing an open-source self-driving system.

**Emerging Players**

- China Association of Automobile Manufacturers
- Zhejiang Geeling Holding Group
- Li Auto
- Xpeng Motors
- Tesla
- Apollo Committee
- LK Group
## China Electric Vehicle Sales — July 2020

<table>
<thead>
<tr>
<th>Model</th>
<th>Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tesla Model 3</strong></td>
<td>11,575</td>
</tr>
<tr>
<td>Wuling Hong Guang Mini EV</td>
<td>7,348</td>
</tr>
<tr>
<td>GAC Aion S</td>
<td>3,685</td>
</tr>
<tr>
<td>SAIC Roewe/SAIC E-Series</td>
<td>3,416</td>
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<tr>
<td>BYD Qin Pro EV</td>
<td>3,400</td>
</tr>
<tr>
<td>Great Wall Ora R1/Black Cat</td>
<td>2,771</td>
</tr>
<tr>
<td>NIO ES6</td>
<td>2,610</td>
</tr>
<tr>
<td>Chery eQ</td>
<td>2,521</td>
</tr>
<tr>
<td>Li Xiang One EREV</td>
<td>2,445</td>
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<tr>
<td>BMW 530Le PHEV</td>
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<tr>
<td>Weltmeister EX5</td>
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<tr>
<td>BYD Yuan/S2 EV</td>
<td>1,801</td>
</tr>
<tr>
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<tr>
<td>BYD Tang PHEV</td>
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<td>BAIC EU-Series</td>
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<td>BYD Song Pro EV</td>
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<tr>
<td>VW Passat PHEV</td>
<td>991</td>
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<td>Buick Velite 6</td>
<td>521</td>
</tr>
<tr>
<td>SAIC Roewe Ei5 EV</td>
<td>410</td>
</tr>
</tbody>
</table>

**Bold:** Fully electric  
**Chart:** CleanTechnica  
**Source:** EV Volumes
New Cityscape Designs

KEY INSIGHT
The importance placed on roads is decreasing in urban planning with autonomous vehicles, sustainability, and technology leading the charge for how urban spaces are being designed.

EXAMPLES
Saudi Arabia is developing a futuristic new approach to urban planning and city design through its ambitious NEOM project. Its centerpiece is a 106-mile-long belt of connected communities which is being called The Line. The linear city will stretch from the Red Sea to the mountains in northwest Saudi Arabia. The goal is to be a city of 1 million people using clean energy where daily needs like schools and shops will be within a 5 minute walk and no journey will be longer than 20 minutes. The Line plans to achieve its transportation design objectives by using a multilevel spine that will include local and high-speed transit, a service layer, and a pedestrian layer. Construction has already begun with earth being moved and creations for tunnels taking shape for a city that hopes to have its first residents in 2024.

DISRUPTIVE IMPACT
With climate change accelerating, more and more is being asked of urban planning with greater considerations for sustainability, flexibility, and future adaptability. These large-scale, interconnected urban planning projects are an approach toward redesigning how we live and how we consume resources. We may have little choice, as sea levels rise and extreme weather events force us indoors or even underground.

EMERGING PLAYERS
- Bjarke Ingels Group
- Arquitectonica
- Rockwell Group
- NEOM CEO Nadhmi Al-Nasr

The Line is a linear city proposed in Saudi Arabia.
Decarbonizing Flight

Key Insight
Airplane travel accounts for 2.5% of global carbon dioxide emissions, and efforts are underway to decarbonize travel.

Examples
NASA has been working on using electric planes to help solve aviation carbon pollution for the past decade through the development of the X-57 Maxwell, an all electric plane. The experimental two-seater plane will have a range of 100 miles. The technology NASA is working on will hopefully help scale electric planes from 20 person planes to 100 person commuter planes.

While the energy density of batteries is improving, other options include hydrogen as a zero-emission fuel source. ZeroAvia is developing hydrogen-electric powertrains to replace traditional fossil fuel engines. Their projected timeline is 2024 for commercial planes of 10–20 seats going up to 50+ seats by 2026 and 200+ seats by 2040.

Disruptive Impact
Aviation contributes 3% of the world’s total carbon emissions. When flights stopped during the COVID-19 pandemic, there were noticeable changes to air pollution. As air travel returns to pre-pandemic levels over the next few years, there will be increased calls to reduce emissions. Hydrogen-powered planes, while still under development, could be a viable alternative.

Emerging Players
- ZeroAvia
- Airbus
- NASA
EMERGING PLAYERS
• European Commission
• European Investment Bank
• Asian Infrastructure Investment Bank
• New Development Bank
• National Development and Reform Commission

KEY INSIGHT
The governments and companies that lead international infrastructure projects have powerful influence on setting regional, global and geopolitical standards.

EXAMPLES
China’s multibillion-dollar Belt and Road Initiative began in 2013, focusing primarily on investment in infrastructure, education, construction, rail, highway, auto, and electrical grids. The program has provided the motivation for new trade links and diplomatic ties through financing and development expertise.

The European Union has announced a competing initiative of $340 billion called Global Gateway. The European alternative will focus on financing to support digitization, clean energy, transport, health, education, and research. The group aims to increase investments promoting democratic values and high standards, good governance and transparency, equal partnerships, green and clean, secure infrastructures and that catalyze private sector investment.

DISRUPTIVE IMPACT
The balance of geopolitics may be significantly impacted by large infrastructure initiatives that have the ability to create new trade relationships with mutual self-interest and aligned approaches to tackling large problems.

Critics of the Belt and Road Initiative worry that Chinese financing will create unsustainable debt especially among the developing nations that are most in need of these large infrastructure projects.
In the distant future, people may outlaw driving cars because it’s too dangerous. You can’t have a person driving a two-ton death machine.

— Elon Musk, CEO, Tesla
Robotics, drones, supply chain technologies, and evolving transportation are coming together to transform operations for businesses of all industries in the near future. Companies and their organizations should begin to evaluate their value chain, and identify areas that are manually intensive, dangerous, or easily repeatable. These tasks could be good candidates for enhancement through technology, and create renewed opportunities for human workers to work on enhancing and transforming organizations.

Multiple forces are coming together to disrupt and challenge company operations, including growing consumer demand for transparency and sustainability, continued supply chain pressures, worker shortages, and expectations for rapid turnaround times. Companies can address some of these challenges by evaluating areas of their operations where inefficiency is greatest, and streamlining activities, leveraging technological solutions where possible.

Robotics, drones, supply chain technologies, and evolving transportation are coming together to transform operations for businesses of all industries in the near future. Companies and their organizations should begin to evaluate their value chain, and identify areas that are manually intensive, dangerous, or easily repeatable. These tasks could be good candidates for enhancement through technology, and create renewed opportunities for human workers to work on enhancing and transforming organizations.

Several technologies in the fields of robotics and drones are still relatively nascent, such as self-assembling robots, drone swarms, and microelectromechanical systems (smart dust). These technologies exist today but require real-world trials and tests to reach their maximum potential. Businesses, likewise, are best suited to identify unique use cases for these tech solutions based on their greatest needs or barriers. Safety, security, health, and connection are four key driving forces behind the development of these capabilities, showcasing their potential to positively impact both company and worker experiences and consumer outcomes in the near future.

We anticipate sustained growth in all of these areas, particularly in robotics and drones. Current adoption of these technologies has been on a consistent rise over several years, and decreasing cost and increasing efficiency of these solutions will only serve to drive further growth. While companies have a huge opportunity to benefit from these improved solutions, governments likewise could leverage these systems to support U.S. agriculture, battle climate change, improve countrywide infrastructure, and unlock new potential in existing supply chain systems.
Key Questions

We recommend using this report to support your strategic foresight activity in the coming year. Every executive team should begin by asking these questions:

1. What parts of our business model and value chain are experiencing the greatest inefficiency?
2. How are we addressing the rising consumer demand for greater sustainability?
3. What entirely new ways of doing business might be possible in the next few years as these technologies improve?
4. What new types of data might we unlock by implementing more technological solutions into our processes?
5. How might we use that data to reach new markets or enhance our offerings?
6. How might we get our products to customers differently in five years?
Benefits of Strategic Foresight

33% Higher Profitability
Companies using a dedicated strategic foresight process outperformed the average by a 33% higher profitability.

200% Growth
Companies using a dedicated strategic foresight process outgrew their competitors by 200% in desired areas.

25% Improvement
Companies say that strategic foresight improves business objectives and planning, helps define new markets, and builds flexible mindsets among executives, even in times of deep uncertainty.

The Future Today Institute Supports Executive Leaders and Their Teams

The Future Today Institute works closely with executive leadership and management teams to transform their strategic thinking on the future.

We leverage these and other trends and use applied foresight to develop deep (20+ years), long-range (10+ years) and near-term (2+ years) scenarios and strategic plans.

FTI’s advisory services include signal mapping, trend identification, scenario development, risk modeling, visioning, and strategic planning.
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About the Future Today Institute

Founded in 2006, the Future Today Institute researches, models, and prototypes future risk and opportunity. As the leading strategic foresight and futures management consultants to executive leadership teams worldwide, FTI’s data-driven applied research reveals trends and calculates how they will disrupt business, government, and society.

Together with our clients and partners, FTI is helping leaders achieve their preferred futures. Our pioneering, data-driven forecasting methodology and tools empower leaders to make better decisions about the future, today.

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