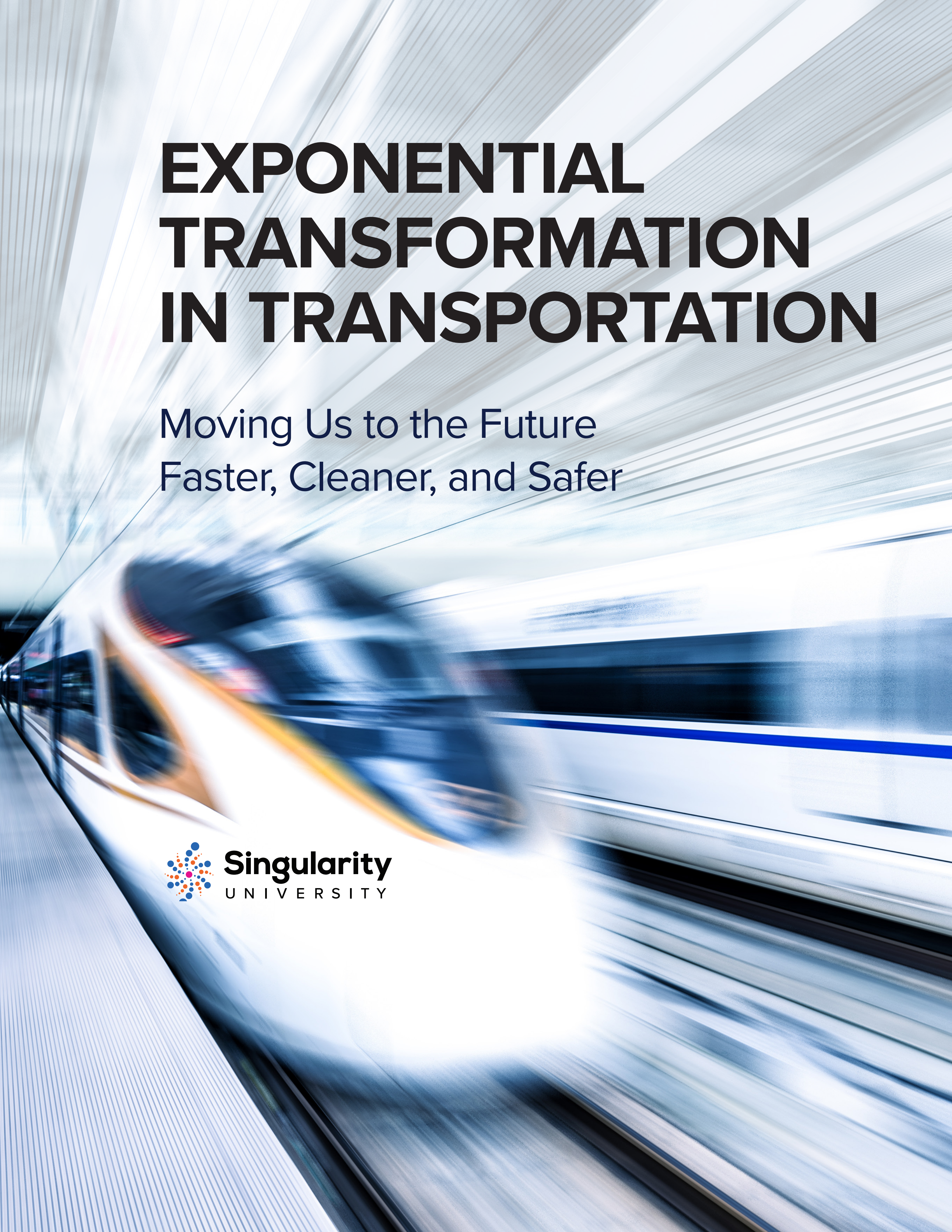
EXPONENTIAL TRANSFORMATION IN TRANSPORTATION

Moving Us to the Future Faster, Cleaner, and Safer



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Introduction

Though we didn't ring in the 21st century with flying cars, as popularized in sci-fi movies and media, we've definitely gotten closer to this milestone in the past two decades. The idea of fully electric automated vehicles operating across land, air, and sea has come much closer to reality.

In 2019, transportation companies large and small are investing in exponential technologies to keep pace with fierce competition. Electric vehicles may see wireless charging in the near future, and could even evolve into hybrid vehicles that can operate in the air or on the ground. The first launch of automated, 100 percent remotely-operated, 100 percent electric container ships is also on the horizon.

In this ebook, we'll explore the state of the transportation industry and look ahead to the future of the transportation sector's exponential growth opportunities, focusing on:

- The future of electric vehicles
- Legal, ethical, and financial considerations of autonomous passenger vehicles
- Drones that will switch between ground and air travel, and those that will live at sea
- Active hyperloop prototypes on multiple continents

No matter what sector your organization operates in today, the exponential changes to the world's transportation infrastructure will affect your business profoundly. Let's look at some examples of where this transformation is already under way.

Electric Vehicles Are Charging Ahead

The struggle for electric vehicles to gain legitimacy in a world dominated by supersized SUVs and overbearing big rigs is something of a David and Goliath story. Tesla has had its recent challenges, but in 2017, the company landed a blow right between the eyes of manufacturers, when it became the most valuable automaker in the U.S., passing General Motors in total market value. GM later regained the lead by a slim margin, edging Tesla in market cap by a little more than a billion dollars.

Still, the ability of a 15-year-old company to stand shoulder-to-shoulder with the venerable Detroit automakers is extraordinary. It's a reflection of the broader picture of how alternative energy and renewables have risen to prominence. It would seem to be no coincidence that at a time when electric vehicles appear poised for widespread adoption, solar and renewable energy have become cheaper than coal. The following are ways that the industry can sustain its anticipated growth trajectory.

Strong regulatory policies are needed

There is potential for the number of electric vehicles on the road around the world to hit 125 million by 2030, the International Energy Agency forecasts, but that will require radical shifts in environmental and regulatory policy; that figure could reach 220 million if the world adopts a more aggressive approach to addressing climate change and reducing emissions than currently planned.

According to John Axsen, an associate professor at Simon Fraser University in British Columbia who studies green technology, consumer behavior, and environmental policy, "As long as gasoline vehicles are able to belch pollutants and greenhouse gas emissions 'for free,' then EVs will have a disadvantage. Economists call this a market failure. So nearly all the good research out there shows that strong policy is responsible for any success we've seen so far, and that we'll need more strong policy to see any real success going forward."

There are very few places where such policies exist. For example, Norway has reached 25 percent market share for EVs because it has huge taxes on fossil fuels, huge taxes on conventional vehicles, and very substantial financial and non-financial incentives for EVs, according to Axsen.

California is leading the way in North America. Its zero-emissions vehicle (ZEV) mandate requires automakers to sell a certain percentage of electric vehicles. Quebec has recently followed suit with its own ZEV mandate. "I believe that if California did not have this policy, Tesla would never have existed (and Toyota probably never would have developed the Prius, for that matter)," Axsen says.

Earlier this year, California's utilities submitted plans to collect up to $1 billion from customers to expand the state's EV infrastructure. If approved, California would add more than 10,000 new charging stations, as the state pushes to put a million EVs on the road by the end of the decade. The Guardian reported last year that the European Union has created a draft directive requiring every new and refurbished home in Europe to be equipped with a recharging point.

Supply must meet demand

Another impediment to EVs reaching a tipping point is supply, according to Axsen. There are relatively few makes and models available, particularly in truck and van classes. "And then, many car dealerships are not carrying these EVs in their inventory, and research shows that many dealers in Canada and the U.S. are not even trying to sell the EVs to customers," he notes.

> "The electric vehicle market reached the $1.2-million sales mark for the first time, with more than 165 models available for sale. EVs now have a market potential of about 25 million units that will be sold by 2025; more than 400 models will be made available."
>
> —Frost & Sullivan Global Electric Vehicle Market Outlook, 2018

Most of the major U.S. automakers manufacture EVs or hybrids, with more than 55 models on the market. There are also a number of emerging startups vying to become the next Tesla. Some of the best-funded are in China, while a company called Lucid Motors in California has been touted as a potential challenger to Tesla. Its luxury model, still not in full production, boasts 1,000 horsepower and can go 400 miles on a single charge.

Elon Musk and Tesla, meanwhile, are not satisfied with just building the world's most advanced EV compact cars and sedans. The company recently announced it would next tackle a mini-bus, pickup truck, and even semi truck. The latter would be a particularly disruptive technology, especially if Tesla outfits it with the company's Autopilot system.

Of course, there are quite a few technological roadblocks the company will need to address, not least of which is developing a battery system that can handle a heavy, long-haul 18-wheeler rig. The Nikola Motor Company thinks it has the answer: using hydrogen fuel cells to power a fully electric 18-wheeler. Nikola claims its Nikola One will have a range of 800 to 1,200 miles, while delivering 1,000 horsepower. Toyota also announced plans for a hydrogen cell-powered big rig, in a new race to produce the first zero-emission 18-wheeler.

Wireless charging on the go must be enabled

While the global auto industry is estimated to be worth about $2 trillion, electric and hybrid cars currently make up less than one percent of that figure. However, experts are predicting an explosion in electric car adoption. China saw a 53 percent increase in electric car sales from 2015 to 2016, and India is aiming to sell only electric cars by 2030. Even though they'll be affordable, and they'll keep the air cleaner, electric cars will still have one major limitation: the fact that they're electric. Electric things run on batteries, and if batteries don't get recharged every so often, they die.

Researchers at Stanford University just took a step toward solving this problem. In a paper published in *Nature*, the team described a new technique that wirelessly transmits electricity to a moving object within close range.

Magnetic resonance coupling

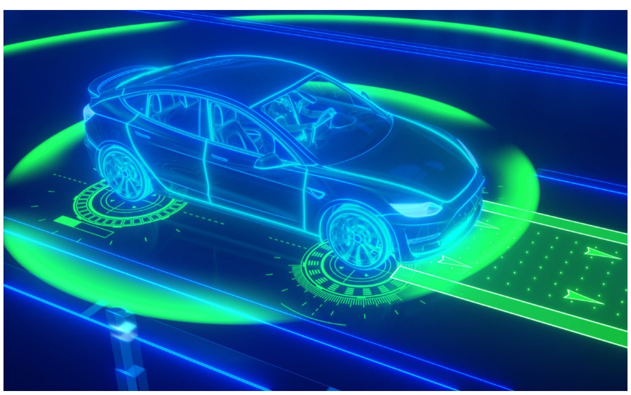
Wireless power transfer works using magnetic resonance coupling. An alternating magnetic field in a transmitter coil causes electrons in a receiver coil to oscillate, with the best transfer efficiency occurring when both coils are tuned to the same frequency and positioned at a specific angle.

That makes it hard to transfer electricity while an object is moving, however. To bypass the need for continuous manual tuning, the Stanford team removed the radio-frequency source in the transmitter and replaced it with a voltage amplifier and a feedback resistor.

New amplifier technology needed

The system calibrates itself to the required frequency for different distances. Using this system, the researchers were able to wirelessly transmit a one-milliwatt charge of electricity to a moving LED light bulb three feet away. No manual tuning was needed, and transfer efficiency remained stable.

One milliwatt is a far cry from the tens of kilowatts an electric car needs. But, now that they've established that an amplifier will do the trick, the team is working on ramping up the amount of electricity that can be transferred using this system. Switching out the amplifier itself could make a big difference—for this test, the team used a general-purpose amplifier with about 10 percent efficiency, but custom-made amplifiers could likely boost efficiency to over 90 percent.



When roads are car chargers

It will still be a while before electric cars can get zapped with energy infusions while cruising down the highway, but that's the future some energy experts envision. "In theory, one could drive for an unlimited amount of time without having to stop to recharge," says Shanhui Fan, a professor of electrical engineering at Stanford. "The hope is that you'll be able to charge your electric car while you're driving down the highway. A coil in the bottom of the vehicle could receive electricity from a series of coils connected to an electric current embedded in the road."

Embedding power lines in roads would be a major infrastructure project, and it wouldn't make sense to undertake it until electric car adoption was widespread—when, for example, electric cars accounted for at least 50 percent of total vehicles on the road, or more. If charging was easier, however, more drivers might choose to go electric.

Tesla has already made electric car ownership a bit easier by investing heavily in its Supercharger network. In 2019, there are 1,441 Supercharger stations around the world with 12,888 chargers, and hundreds more are in the works. The stations recharge Tesla vehicles for free in about an hour, instead of multiple hours.

Ripping up roads to embed power lines that can charge cars while they're moving seems unnecessary as technologies like the Superchargers continue to proliferate. But as electric vehicles also proliferate, drivers will likely want their experiences to be as seamless as possible, and that could include not having to stop to charge your car.

AI Drivers Are Safer than You

Future car owners may not even have to bother with driving, according to the experts.

Artificial intelligence (AI) is proving to be safer behind the wheel than human drivers, who caused 37,133 deaths in the U.S. alone in 2017. Bart Selman, a Cornell professor, has predicted driverless cars would be 10 times safer than those driven by humans within three years, and 100 times safer within a decade. The potential savings in human lives and damages are evident, and significant.

Even so, the European Union suggested creating a type of insurance fund to compensate those injured by AI-driven vehicles. According to a Boston Globe survey of experts across fields ranging from philosophy to robotics, there seems to be a consensus on one thing: the legal status of smart robots will require a "balancing act."

While many may worry about the risks involved in mass adoption of AI drivers, registered patent attorney and board-certified physician Ryan Abbott appears to be the first to suggest that tort law treat AI machines like people when it comes to liability issues. And, perhaps more radically, he suggests people be judged against the competency of a computer when AI proves to be consistently safer than a human being.

Currently, the law treats machines as if they were all created equal, as simple consumer products. In most cases, when an accident occurs, standards of strict product liability law apply. In other words, unless a consumer uses a product in an outrageous way or grossly ignores safety warnings, the manufacturer is automatically considered at fault.

"Most injuries people cause are evaluated under a negligence standard, which requires unreasonable conduct to establish liability," Abbott notes in his paper, Allocating Liability for Computer-Generated Torts. "However, when computers cause the same injuries, a strict liability standard applies. This distinction has significant financial consequences and corresponding impact on the rate of technology adoption. It discourages automation, because machines entail greater liability than people."

Turning thinking machines into people—at least in a court of law—doesn't absolve companies of responsibility, but allows them to accept more risk while still making machines that are safe to use, according to Abbott. "I think my proposal is a creative way to tinker with the way the law works to incentivize automation without forcing it," Abbott said.

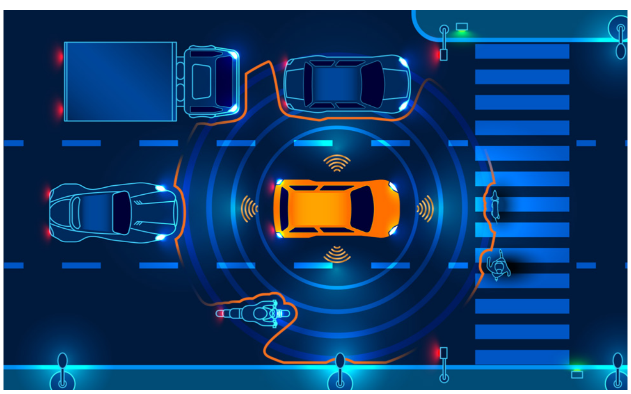
"Self-driving cars are here among us and going to be all over the place very soon," notes Abbott, adding that shifting the tort burden from strict liability to negligence would quicken the adoption of driverless technology, improve safety, and ultimately save lives.

"Ultimately, we're all consumers and potential accident victims, and I think that is something people could support," Abbott says. "I think when people see the positive impact of it, it will change attitudes."

The moral dilemma

An enduring problem with self-driving cars has been to find a way to program them to make ethical decisions in unavoidable crashes. A new study has found it's actually surprisingly easy to model how humans make decisions, opening a potential avenue to solving the conundrum.

Ethicists have wrestled with the so-called "trolley problem" for decades. If a runaway trolley is about to hit a group of people, and by pulling a lever you can make it switch tracks so it hits only one person, should you pull the lever?



But for those designing self-driving cars, the problem is more than just a thought experiment, as these vehicles will at times have to make similar decisions. If a pedestrian steps out into the road suddenly, the car may have to decide whether to swerve and potentially injure its passengers or knock down the pedestrian.

Previous research had shown that the moral judgments at the heart of how humans deal with these kinds of situations are highly contextual, making them hard to model and therefore replicate in machines. But when researchers from the University of Osnabrück in Germany used immersive virtual reality to expose volunteers to variations of the trolley problem and studied how they behaved, they were surprised at what they found.

"We found quite the opposite," Leon Sütfeld, first author of a paper on the research in journal Frontiers in Behavioral Neuroscience, said in a press release. "Human behavior in dilemma situations can be modeled by a rather simple value-of-life-based model that is attributed by the participant to every human, animal, or inanimate object."

The implication, the researchers say, is that human-like decision making in these situations would not be that complicated to incorporate into driverless vehicles, and they suggest this could present a viable solution for programming ethics into self-driving cars.

"Now that we know how to implement human ethical decisions into machines we, as a society, are still left with a double dilemma," Peter König, a senior author of the paper, said in the press release. "Firstly, we have to decide whether moral values should be included in guidelines for machine behavior and secondly, if they are, should machines act just like humans."

There are clear pitfalls associated with both considerations. Self-driving cars present an obvious case where a machine could have to make high-stakes ethical decisions that most people would agree are fairly black and white. But once you start insisting on programming ethical decision-making into some autonomous systems, it could be hard to know where to draw the line.

Should a computer program designed to make decisions on loan applications also be made to mimic the moral judgments a human banker would likely make in a face-to-face client meeting? What about one meant to determine whether or not a criminal should be granted bail? Both scenarios represent real examples of autonomous systems operating in contexts where a human would likely incorporate ethical judgments in their decision-making. But unlike the self-driving car example, a person's judgment in these situations is likely to be highly colored by their life experience and political views. Modeling these kinds of decisions may not be so easy.

Even if human behavior is consistent, that doesn't mean it's necessarily the best way of doing things, according to König. Humans are not always very rational and can be afflicted by all kinds of biases that could feed into their decision-making. The alternative is hand-coding morality into these machines, and that is fraught with complications.

For starters, the chances of reaching an unambiguous consensus on what particular ethical code machines should adhere to are slim. But even if you could, a study in *Science* suggests it wouldn't necessarily solve the problem. A survey of U.S. residents found that most people thought self-driving cars should be governed by utilitarian ethics that seek to minimize the total number of deaths in a crash even if it harms the passengers. But it also found that most respondents would not ride in these vehicles themselves or support regulations enforcing utilitarian algorithms on them.

In the face of such complexities, programming self-driving cars to mimic people's instinctive decision making could be an attractive alternative. It would prevent a situation where programmers are forced to write algorithms that could potentially put people in harm's way. By basing the behavior of self-driving cars on a model of our collective decision-making we would, in a way, share the responsibility for the decisions they make.

Drones Are on the Rise Over Land, Sea, and Air

Whether over land, sea, or air, the delivery of goods from factory to front door is becoming increasingly automated, as witnessed in particular by developments at Amazon and at Matternet, an SU Portfolio Company.

Amazon is known for its logistical aptitude, such that its acquiring Whole Foods for $13.7 billion is largely understood to be a move to further embed its logistical tendrils into the consumer realm. The company also has its own automated drone delivery service in the works, Amazon Prime Air. Other participants include Tesla and its upcoming autonomous big rigs, which would automate shipping by road.

Matternet, founded at SU's Global Startup Program in 2011, is pioneering a new industry with point-to-point autonomous drone delivery. The company is deploying drones that fly five times faster than traditional transport, saving time for patients and healthcare professionals. After 1,800 drone flights with a perfect safety record in Switzerland, Matternet has been approved to use its system to deliver blood and other diagnostics between hospitals and clinics in Switzerland.

It's no surprise that delivery drones are finding a home in healthcare. Large hospital systems often need to move blood and pathology samples back and forth between labs and peripheral facilities with great urgency, perhaps dozens of times a day.

Matternet provides this example of the benefits of autonomous drone delivery: A patient that arrives bleeding out in the ER requires a blood

transfusion of a type no longer in stock. Today, a hospital may hire a courier to retrieve blood bags from a different facility, or literally put those bags of blood into a taxi for transport. Matternet wants to simplify this process and take traffic and delivery personnel out of the equation by autonomously flying in a straight line between pickup and delivery points.

The drones hop from station to station at a little over 40 miles an hour at distances of up to 12.4 miles. At each station, they can pick up packages and freshly charged batteries. Because failure is a possibility mid-flight, all Matternet vehicles are equipped with a parachute and flight termination system that would allow them to fall to the ground at a speed that shouldn't cause anyone harm.

While Matternet's drones will begin regular flights between hospitals, the startup's vision extends beyond just healthcare.

Mobile Matternet stations

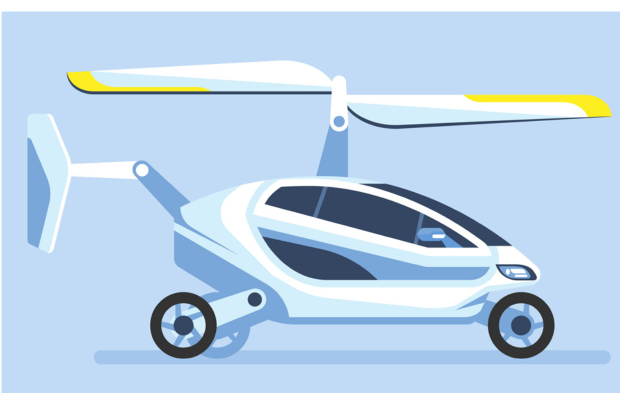
Matternet has launched a program with Mercedes-Benz Vans to test a drone-based delivery system for e-commerce goods, whereby vans would drive to "rendezvous points" in Zurich, and drones would autonomously deliver packages to them for the final leg of their journey.

Matternet has other promising long-term goals, including using drone delivery networks to move healthcare supplies that save lives around rural, less developed parts of the world that don't have reliable roads or transportation systems. CEO Andreas Raptopoulos believes Matternet's systems will become autonomous and affordable enough to leapfrog current systems in the near future, according to his TED talk.

Hybrid air-ground drones

Further learnings from drones are also giving hope to those who wish for flying cars. The MIT Computer Science and Artificial Intelligence Laboratory (CSAIL) added wheels to a fleet of eight mini-quadcopters to test-drive and fly them around a tiny toy town made of cardboard and fabric.

Adding the ability to drive ended up reducing the distance the drone could fly by 14 percent compared to a wheel-less version. But while its driving was slower, the drone could travel 150 percent further than when flying. The result is a vehicle that combines the speed and mobility of flying with the energy-efficiency of driving.



Who's driving?

The fact that cars may soon take flight doesn't mean drivers are ready for the pilot's seat. The aforementioned MIT research team and other groups are more focused on autonomous, flying passenger vehicles than enabling drivers to pilot their own personal vehicles.

Volocopter recently announced its plan to perform a set of urban air taxi flight tests in Singapore in 2019. The flight tests will seek to verify the ability of Volocopter's eVTOLs—emission-free, electrically powered aircraft that take off and land vertically—to operate safely in Singapore's densely populated urban environment.

There has been significant progress in developing technology and regulations needed to integrate autonomous drones into our airspace that future driverless flying cars can most likely utilize. Safety requirements will inevitably be more stringent, but adding more predictable and controllable autonomous drones to the skies is likely to be more attractive to regulators than trying to license and police thousands of new amateur pilots.

Remote-operated, zero-emissions cargo ships

> "Cargo transported by the liner shipping industry represents about two-thirds of the value of total global trade, equating each year to more than U.S. $4 trillion worth of goods."
>
> —World Shipping Council

Do self-steering, fully-electric ships which can avoid obstacles and dock independently sound too far-fetched? The Yara Birkeland, with an expected launch date in 2020, is a joint project of agricultural firm Yara International and technology specialists Kongsberg Gruppen.

The ship will have GPS and various types of sensors, including lidar, radar, and cameras—much like self-driving cars. "The Norwegian maritime cluster has taken a leading position within technology, design, legislation, testing and all other aspects of the development," says Geir Håøy, CEO of Kongsberg.

A small ship that will carry about 150 containers—average ships carry about 3,000 containers and the largest ships about 19,000—the first Yara Birkeland will cost $25 million, roughly three times the cost of a similarly-sized conventional ship, according to the *Wall Street Journal*.

The ship's cost-savings will kick in once the ship starts operating, since it won't need traditional fuel or a big crew. Its autonomy will be phased in. At first, "a single container will be used as a staffed bridge on board. Then the bridge will be moved to shore and become a remote-operation center," according to the *Wall Street Journal*.

Hyperloop: Meet Your Next-Generation Transportation

The hyperloop first hit headlines with a 2012 tease from Elon Musk and a 2013 paper by engineers at SpaceX and Tesla. Skepticism was, perhaps, warranted. Accelerating pods 700+ miles an hour through a low-pressure tube sounds amazing, but there's a fair distance between feasibility and a finished product. Since then, a number of companies and groups have taken up the cause, and at a recent Singularity University Global Summit in San

Hyperloop One DevLoop test track in Nevada desert. Image Credit: Hyperloop One.

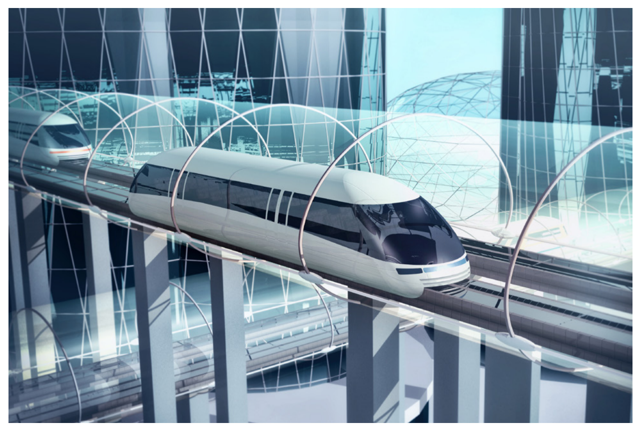
Francisco, we got a progress update from one of them: Rob Lloyd, CEO of Hyperloop One.

In three years, Hyperloop One has raised $160 million and gone from whiteboard strategy to a hyperloop prototype outside Las Vegas. According to Lloyd, the startup has accomplished quite a bit already and have even bigger dreams for the next few years. What is Hyperloop One building? Lloyd described it as a handful of basic components:

- **The pod:** This is the aerodynamic vehicle that will carry people and cargo. The exact design of the pods will vary a bit depending on what's being ferried.
- **The tube:** The tube will be depressurized to a partial vacuum to reduce resistance between pod and air.
- **The motor:** The pod is propelled by a linear electric motor. It works on the same principle as a circular electric motor, only one in which the static, electromagnetic part of the circle has been unfurled linearly along a track.
- **The magnets:** The pod won't touch the tube because it's being levitated by magnets. This further reduces friction and, combined with the low-pressure, allows the pod to coast.
- **The controls:** The system will be mostly automated. Software will send pods hurtling along in close proximity, joining and diverting them as traffic and destinations dictate.

Bringing these components together at scale yields a mode of land transportation theorized to travel over 600 miles an hour. The team installed the first section of tube on their 500-meter-long DevLoop test track and began testing in May 2016. In mid-2017, the company unveiled the carbon fiber and aluminum aeroshell for their XP-1 test pod, then accelerated it to 190 mph.

"The XP-1 performed as designed, handling high speeds and levitating in a vacuum tube depressurized to the equivalent of flying at 200,000 feet above sea level," the team wrote. Testing will continue, but Hyperloop One has much bigger plans for the future.



The company's stated goal was to have three production hyperloops completed by 2021, though Lloyd admitted it was "a bit of a moonshot." But, he said, he's been continually impressed by the dedication and smarts of his team of 280 engineers, citing their 10-month prototype as a testament to the speed at which they can work. Since then, the team has signed partnership agreements with India and Spain, and conducted feasibility studies in Missouri and Texas.

Critics suggest maintaining the required low pressure will prove an impossible task over hundreds of miles. Others say seismic activity, or subsidence, could push the tube dangerously out of alignment. It'll also be difficult to protect the system from attack. And, in case of emergency, how easy will it be to evacuate? Then there's the cost to build and maintain what amounts to a brand new and simply massive infrastructure. These challenges, especially cost, get relevant when you go from prototype to scale. Moving from paper to prototype is a leap forward, but going from prototype to production may be a bigger one.

Lloyd suggests the first production hyperloops won't be 1,700 miles long. They'll start over shorter distances. Such intermediate steps would address concerns and allow for better cost estimates. If all checks out, momentum could take over from there, and a more comprehensive hyperloop network may sprout from the first few.

Lloyd sketched out a vision of what success looks like, and why he's inspired to make it happen. For one, he said, the concept of commuting would change dramatically. People could live hundreds of miles from work and still take advantage of the many opportunities offered by a bustling-but-costly city. Cities within a half hour of each other might link up. U.S. connections could include San Francisco and Los Angeles, Portland and Seattle, or New York and Washington.

> "People priced out of Brooklyn could move to Baltimore. Congressional aides would commute to Philadelphia. Whole cities—and labor and housing markets—would fuse together,"
>
> —Emily Badger, writing in *The New York Times*

Lloyd also said Hyperloop One thinks its system has to be more than just a people transporter. There will be pods that carry people and small packages, but there will also be pods designed for cargo as big as shipping containers. "It's all about throughput," he said. "Very rapidly moving containers away from our ports and not using the world's most valuable land in city centers to store steel cans. Then, what about connecting factories and supply chains and an on-demand environment of Alibaba or Amazon with smaller, package-based hyperloops?"

This vision of a branching network of nodes and conduits connecting the physical world of people and packages at high speed resembles that of broadband telecommunication networks. And the vision is clearly inspiring a lot of talented people and urging momentum. Even Elon Musk is back in the game, after previously saying he needed to focus on other projects and open-sourcing the idea. It's only a matter of time before someone takes it past the prototype stage.

The Future of Transportation Has World-Changing Potential

Today's transportation infrastructure is aging, crowded, and inefficient. One study of global vehicular traffic by INRIX, a transportation consulting firm, estimated that traffic congestion cost $305 billion in 2017. In addition to lost productivity, there's the cost of wasted fuel, air pollution, and traffic injuries and deaths.

But exponential technologies and innovative organizations are driving transformational change. The disruption of traditional transportation will bring challenges, but also business opportunities we have not yet imagined.

Traffic-choked, dirty, and dangerous is giving way to better, faster, cheaper, and safer. The future of transportation is filled with massive potential and mind-bending technologies, as well as nearly limitless ways to travel more efficiently across the land, sea, and through the air.

At **Singularity University**, we're laying the groundwork for exponential change. With our learning and innovation platform, proven tools and methods, and world-class faculty, Singularity University helps transform companies of all sizes into adaptable organizations that can get out in front of market disruptions and achieve exceptional business results.

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