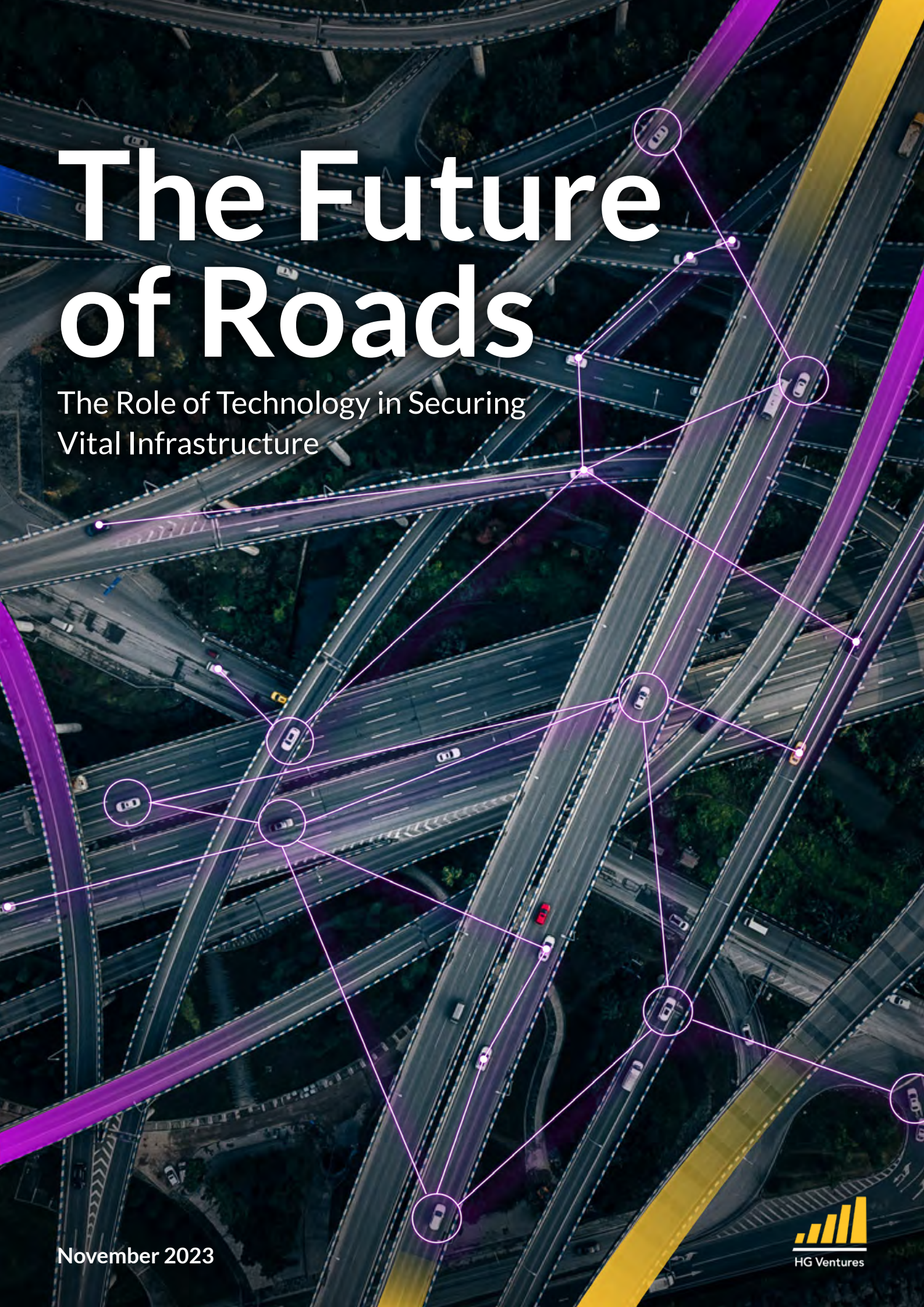

The Future of Roads

The Role of Technology in Securing Vital Infrastructure

November 2023

HG Ventures

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Introduction

Introduction by John Glushik Managing Director, HG Ventures

I am fortunate that my chosen career brings me into contact with scientists, engineers and other visionaries who are working at the leading edges of their respective fields, developing new technologies that have the potential to transform our world for the better.

Whether they are working in materials science, chemical engineering, electrical engineering, software development or any one of a dozen other fields, these entrepreneurs are designing and building new systems and processes that not only keep industries, and therefore our economy, moving, but do so in ways that reduce or minimize our impact on the environment.

One of the areas in which we see a lot of exciting innovation is road technology.

Roads are an essential part of our infrastructure. Whatever else may change about our world in the next half-century, the need to move goods and people from point A to point B, and to connect communities, will be a constant. But with more people in the world, and more vehicles using our roads, that infrastructure is under intense pressure.

This is where technological innovation has a role to play.

Across the United States and throughout the world, we see examples of new technologies emerging that can solve challenges around capacity, congestion, safety, sustainability and more.

This report collects together some of the key technologies that are being developed, piloted, and in some cases implemented, that have the power to keep our roads moving.

This is such a wide-ranging field that there are limits on what we are able to include. For example, the United States has more than four million miles of road, the highest level of vehicle ownership in the world, and challenges maintaining a uniformly high quality road infrastructure, so much of the content of this report is inevitably weighted towards the US, but there is an enormous amount of important work happening all over the world.

And in many instances, the real innovation is taking place not only in the R&D centers of established technology giants, but in the laboratories and rented offices of startups. This is what excites me the most: That the potential for positive change can be fueled by individuals and small teams with a singular vision.

At HG Ventures, we are proud to back this spirit of innovation, and have invested in a number of startups working in this field. Indeed, as part of The Heritage Group, which has a diverse set of heavy-duty construction and materials operating businesses, we work alongside colleagues with unsurpassed knowledge and expertise of road building and maintenance. The Heritage Group has decades of experience in this market, and customers that have relied on them to help them innovate, and I appreciate being part of that.

I believe that the required transformation of our roads infrastructure will only be possible with an increased and expanded vision of public-private partnerships, and that venture capital has a vital role to play in this - enabling those entrepreneurs to bring their concepts to market and become part of the mix of solutions that will keep us all moving.

I hope you enjoy this report and that it contributes to the ongoing conversation about the future of roads.

John Glushik
November 2023

Executive Summary

Executive Summary

Roads infrastructure is at a crossroads

- Roads are vital infrastructure, connecting communities and contributing to the global, national and local economies by allowing for the efficient transportation of goods and people.
- The way roads are constructed and operated has remained largely unchanged for a century, yet demographic, economic, environmental and other factors have pushed them to and even beyond their capacity.
- Not only does the global population continue to increase, it is becoming more urban and more mobile, with more people living in more, ever-larger cities; the number of vehicles on roads is increasing, as is the volume of goods transported by road.
- In the US and other parts of the world, many roads are in poor condition, and the effects of climate change are adding billions of dollars to the cost of maintenance.
- For 70 years or more, the default policy has been to build more roads, or widen existing ones, to cope with increasing demand; but the challenges of safety and congestion evident in the 1950s are as pressing today, exacerbated by legitimate sustainability concerns. What got us here will not get us to where we want to be in the future.

The solution is not more roads, but better, smarter roads

- Throughout the world, there is a wealth of innovation taking place that addresses the issues of safety; capacity and congestion; sustainability; and efficiency. Exciting technologies are emerging from multinational companies and entrepreneurial startups alike.
- These technologies range from the theoretical to others that are actively being piloted and rolled out.
- In addition to electrification and autonomy, with their well-documented benefits, advances are taking place in materials science; the Internet of Things (IoT); software with AI capabilities; sensors, cameras and other hardware; wireless charging; energy recovery and storage; sustainable fuel alternatives; and many other fields, all with the potential to transform our roads and secure this vital infrastructure.

A roadmap to the future

- Advancements in technology are out-pacing the way we think of our roads. The future of roads will need to look very different, if our vital infrastructure is to keep the global economy moving and address the longstanding issues of safety and the environment.
- The technologies outlined in this report will need to be adopted, to create better, smarter roads.
- Adoption comes with the challenges of financial investment; a willingness to adopt new and sometimes unproven technologies; the lag in realizing the benefits of such changes; and benefits that are uneven based on geography and other factors.
- The way forward requires a broad consensus that the societal, economic and environmental benefits of transforming our roads outweigh short term concerns, and this effort should be seen as a 25-year endeavor.
- We also need to embrace innovative new funding models, including a reimagining of what business and government interactions can be. The transformation of our roads will not be possible without embracing innovation from startup businesses backed by venture capital, a type of firm with which governments and road operators are unaccustomed to partnering.

Where Are We Now? The Challenges Faced By Our Roads Infrastructure

Where Are We Now? The Challenges Faced By Our Roads Infrastructure

Roads are a vital aspect of our infrastructure. They make it possible to transport goods and people from the Pacific Northwest to the Florida Keys, from Oslo to Athens, and Bangkok to Bangalore; they keep our towns and cities moving; they connect rural communities to larger commercial hubs, making vital services and amenities more accessible to millions of people. Despite their significance, we largely take roads for granted.

The United States government began funding road construction a little over 100 years ago, with a recognition that the country's ability to become a global economic power largely depended on our ability to move the goods being produced. However, our roadway system remained relatively unchanged. There certainly have been innovations in the construction materials and methods used to build our roads, but the Interstate Highway System that is the legacy of the Eisenhower administration would look quite familiar to a time traveler from the 1950s.

Today demographic, economic, environmental and other factors have pushed our roads system to and even beyond its capacity:

- **The population continues to increase:** The world's population is more than three times larger than it was in the mid-twentieth century, reaching 8 billion in mid-November 2022 up from an estimated 2.5 billion in 1950. Furthermore, the world's population is expected to increase by nearly 2 billion people in the next 30 years, reaching 9.7 billion in 2050.[1] In 1956, when the Interstate Highway System was approved, the US population was 168 million; according to US Census Bureau data, by 2022 it had almost doubled to 333.2 million.[2]

Our roadway system has barely changed. The Interstate Highway System would look quite familiar to a time traveler from the 1950s.

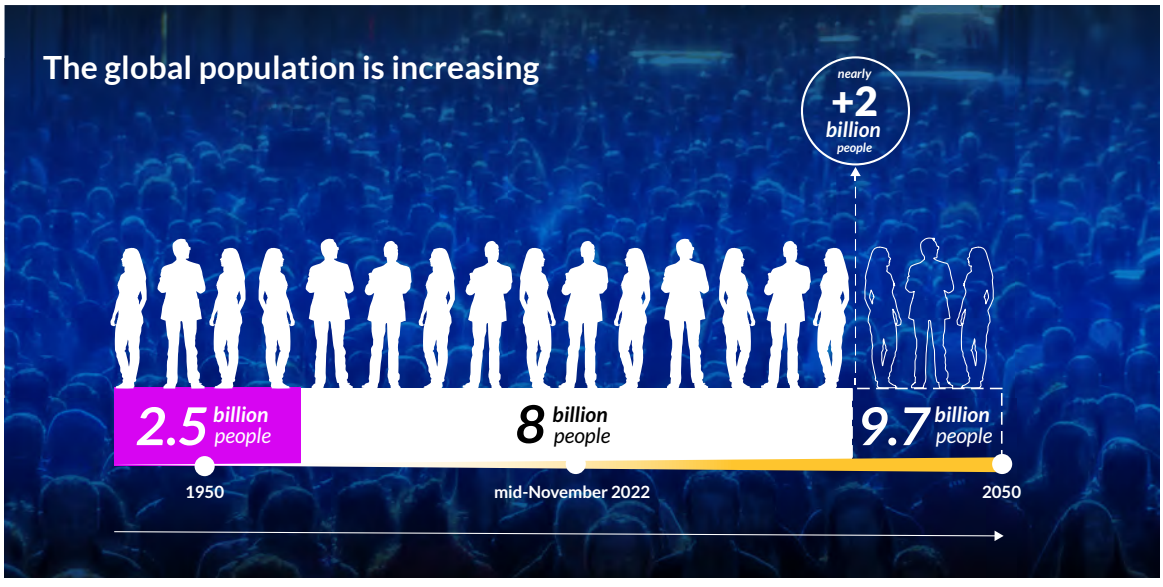


Fig 1: Projected global population growth

Economic, environmental and other factors have pushed our roads system to and even beyond its capacity.

- **More people than ever are living in cities:** Today, some 56% of the world's population (4.4 billion people) live in cities. This trend is expected to continue, with the urban population likely to more than double its current size by 2050, at which point around two-thirds of people will live in cities.[3]

Fig 2: Projected proportion of global population living in cities

- **The number of cities with populations of more than one million is increasing:** In 1950, there were just 83 cities in the world with populations exceeding one million; there are now more than 600, and this trend is continuing.[4]

- **There will be more 'mega-cities' over the next 25 years:** A mega-city is a very large city, with 10 million or more inhabitants. In 1950, New York City was the only urban area in the world with a population of this size; today there are at least 33, with more expected to achieve that status in the next decade.[5]

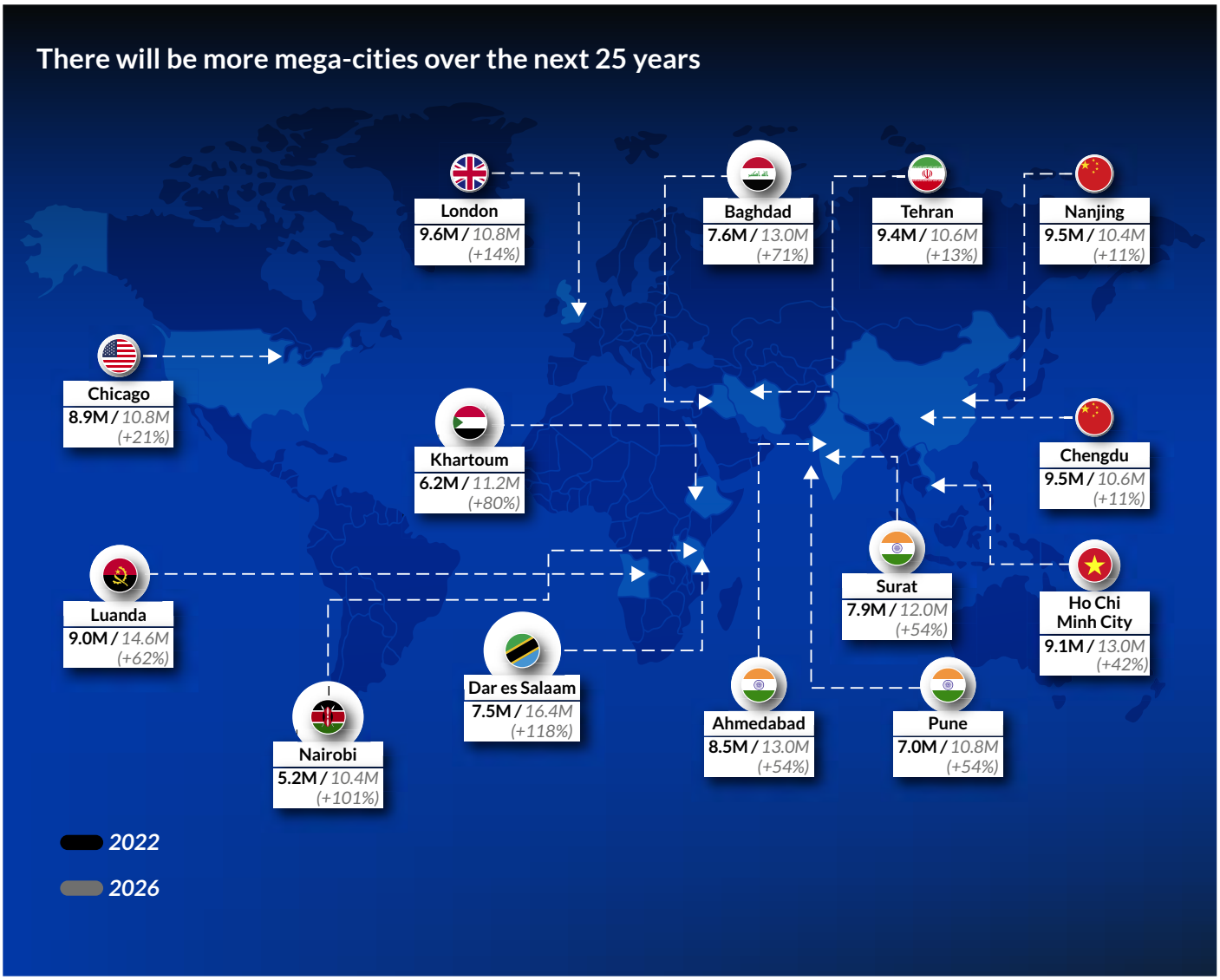


Fig 3: Projected mega-cities with populations of 10M+

- **More of us are mobile:** The number of vehicles on the road continues to increase as car ownership becomes within the reach of more and more parts of the world. In 2015 there were an estimated 1.1 billion cars on the road, while by 2040 this is expected to be two billion.[6] In the US, the number of vehicles increased from 65 million in 1956 to 278 million in 2023, a four-fold increase.[7]

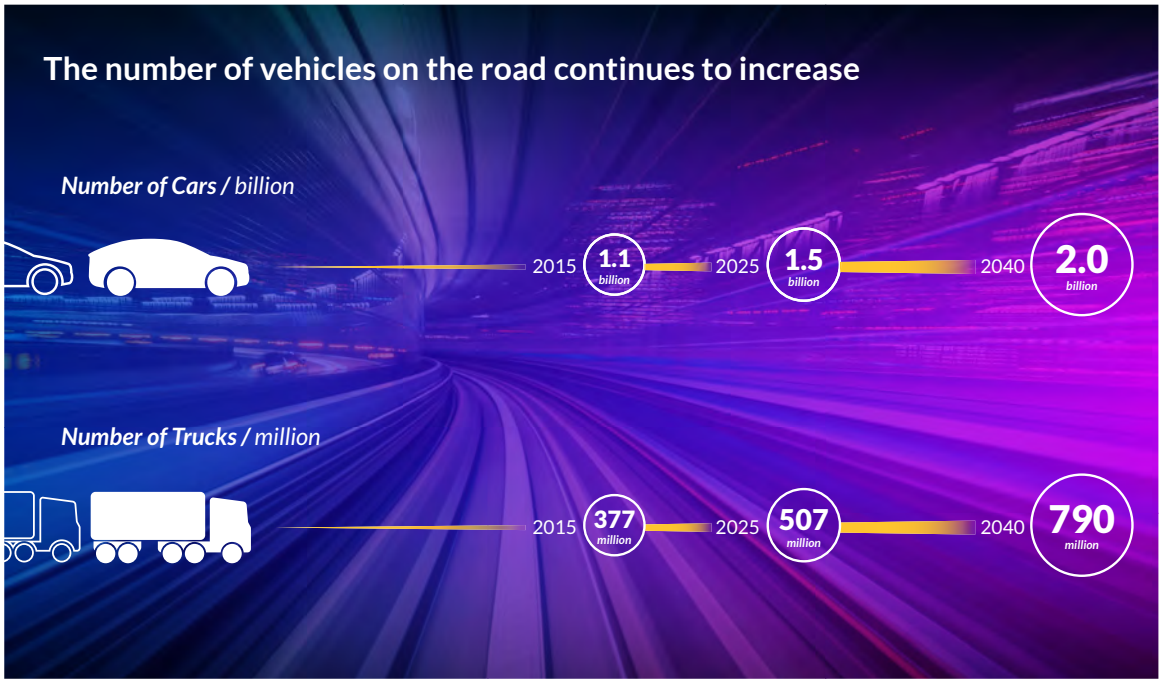


Fig 4: Projected increase in vehicles on the road

- **The volume of freight transported by road continues to increase:** The World Economic Forum reports that the number of trucks on the road is likely to increase from 377 million in 2015 to 790 million by 2040.[4] In the US, the Federal Highway Administration (FHWA) estimates that freight tonnage will grow by 40% in the next 25 years, and the value of that freight could double.[8]

All of this puts pressure on our roads infrastructure, and the cracks are beginning to show. In the US, specifically:

- **Our roads infrastructure is aging:** The most recent large innovation in American road infrastructure was the Interstate Highway System, initiated in the 1950s, and the fundamental elements of the 1950s highway system remain unchanged.

- **The condition of many of our roads is poor:** In its most recent 'report card' for US infrastructure, the American Society of Civil Engineers gave US roads a 'D' rating, stating that "over 40% of the system is now in poor or mediocre condition".[9] Those roads in poor and mediocre conditions tend to be urban and rural, and the non-interstate system; Interstate highways tend to be in good condition, despite accounting for just 2.6% of US road lane miles. The Heritage Construction & Materials group of companies has been involved in the construction and maintenance of roads in the US for decades; CEO, Geoff Dillon says: "In spite of innovations in the materials and processes we use, with four million miles of roads, maintenance inevitably comes down to questions of budget. Every day, my colleagues and I see

the hard choices that those responsible for the stewardship of our road infrastructure must make; the choices of which roads' repairs will be prioritized, and which communities will have to wait for their turn".

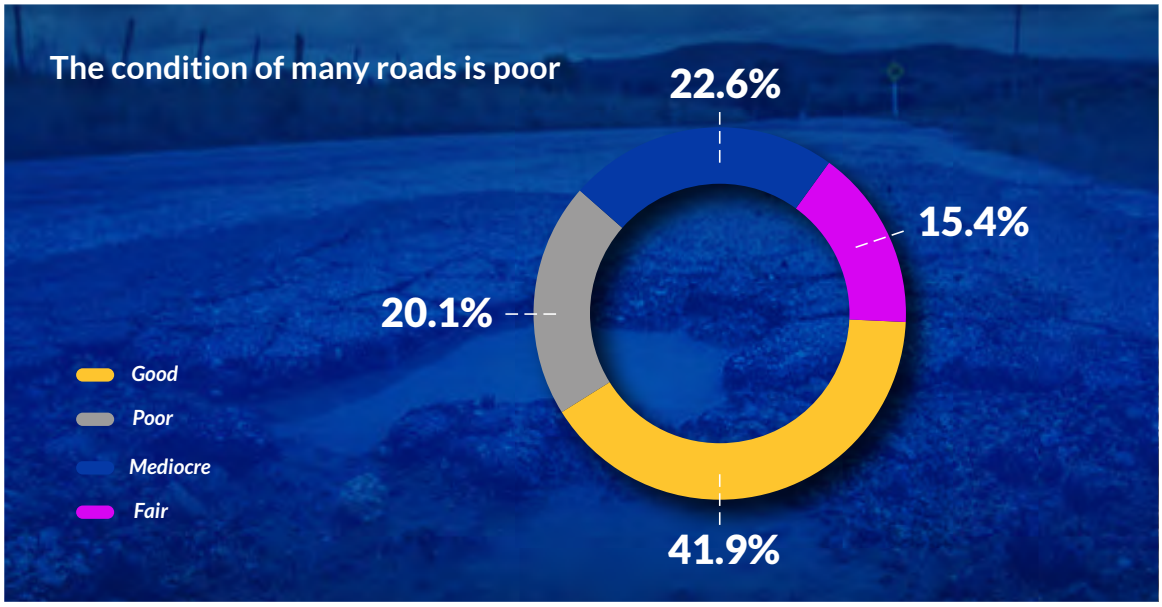


Fig 5: US roadway condition

- **There is a massive repairs backlog:** Building and maintaining roads is expensive and there is a years-long backlog of repairs, estimated to cost more than $700B.[10]
- **Increasing traffic volumes are making our roads less efficient:** It is estimated that a 60-minute trip today will take 106 minutes by 2039.[11]
- **Climate change is affecting infrastructure:** Rising temperatures are estimated to add approximately $19B to pavement costs each year by 2040.[12]
- **Safety is a concern:** While improvements to the safety of cars means that motor vehicle fatalities *as a percentage of the population* have been falling in recent years, the *absolute number* is still high: Almost 43,000 Americans die in road traffic crashes each year.[13] In 1954, the number was 33,000, which was deemed unacceptably high.

There is a years-long backlog of road repairs in the US alone, estimated to cost more than $700B.

These long-term trends point to increasing challenges for our roads systems, for those who use them, and for those responsible for building them, policing them, maintaining them and collecting revenues from them.

Projecting forward, it is no exaggeration to suggest that if that same time traveler from the 1950s were to travel to 2050 or beyond, they might find a roadway system that is no longer fully operational without major change.

Is there a case for more roads?

It is tempting to suggest that the answer is for governments to bite the bullet and commit to fully funding not just the necessary repairs, but the expansion to our roads infrastructure's capacity that the increasing demands placed upon it appear to suggest are required.

But 'more of the same' is not necessarily the solution. When the Eisenhower administration proposed the federal investment in roads infrastructure that would include the Interstate Highway System, it highlighted the following imperatives:

- **Safety -** too many people were dying on roads
- **Congestion -** bottlenecks dramatically increased the time to travel
- **Courts -** civil suits related to traffic clogging up the courts
- **Economy -** bad roads nullifying economic efficiency
- **Defense -** "the appalling inadequacies to meet the demands of catastrophe or defense, should an atomic war come" [14]

While the threat of nuclear war may have receded, every other issue outlined then is as relevant today as it was 70 years ago.

The theory of induced demand asserts that as roadways become wider and able to accommodate higher volumes of traffic, additional vehicles will materialize, as drivers feel incentivized to use the expanded road due to the belief that added lanes have reduced congestion.

Expanding the capacity of our roads will not solve congestion issues.

Seventy years of evidence suggest that expanding the capacity of our roads will not solve congestion issues, and will be insufficient to keep pace with the increasing demands placed on them.[15]

The climate crisis hangs over everything

Every industry is wrestling with the effects of climate change, with rising temperatures and extreme weather events accelerating the deterioration of roads. The issue of Greenhouse Gas (GHG) emissions is a pressing one for the transportation sector, which accounts for 29% of all GHG emissions in the US.[16]

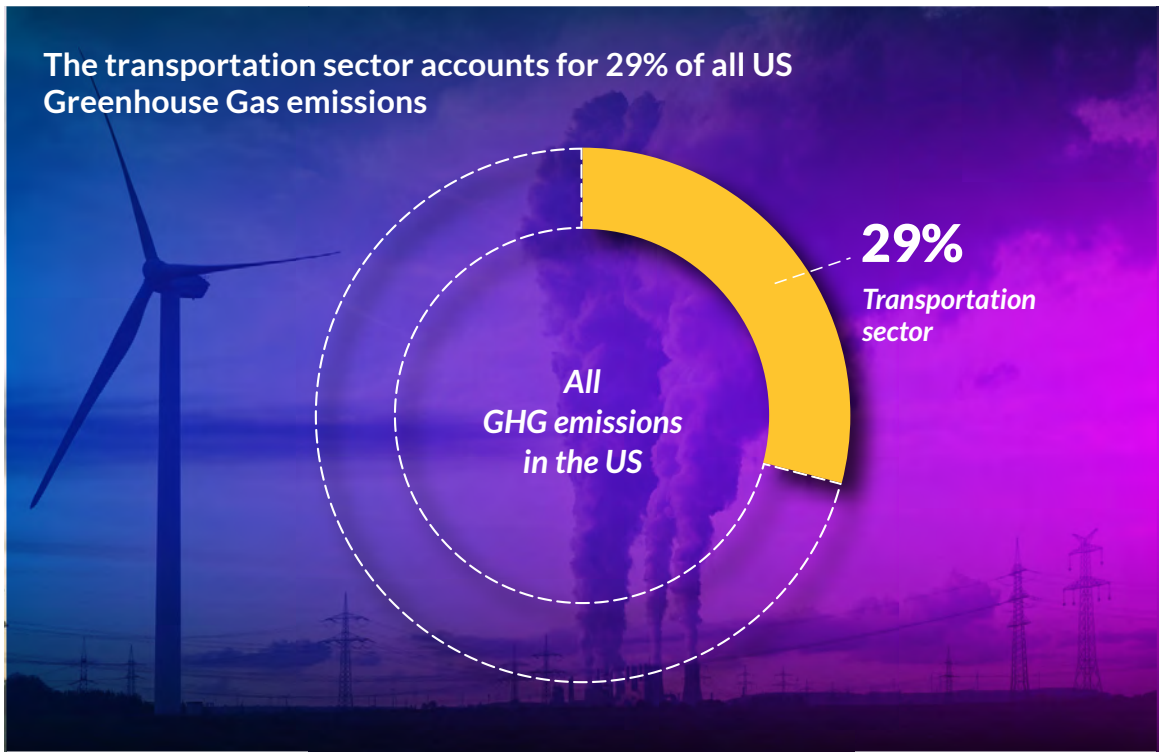


Fig. 6: Contribution of Transport sector to U.S. Greenhouse Gas emissions

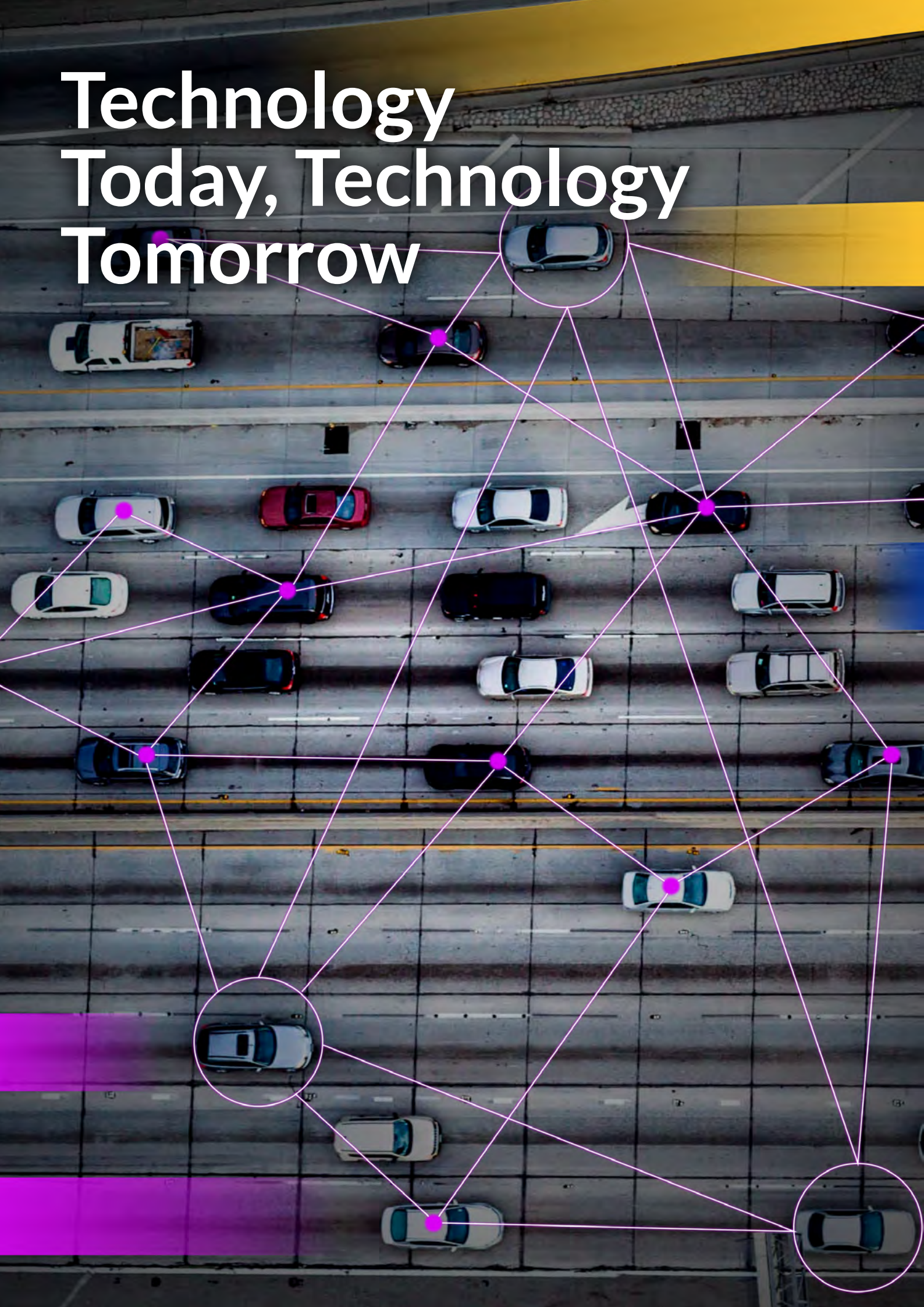
Technological advancements open up new opportunities

There has been enormous innovation in motor vehicles over the past 20 years or so. Many of these technological advancements have environmental benefits, with electric vehicles able to mitigate the negative impact of Internal Combustion Engine (ICE) vehicles on the environment, while autonomous vehicles offer the tantalizing prospect of a world with fewer collisions and less congestion.

These advances rightly attract a lot of attention, but they are not the only areas of innovation that have the potential to transform our roads systems.

The next section of this report considers some exciting innovations that have a potential role in solving the roadway infrastructure crisis.

Technology Today, Technology Tomorrow



Technology Today, Technology Tomorrow

Throughout the world, there is a wealth of innovation taking place that addresses many of the issues identified - safety; capacity and congestion; sustainability; efficiency.

There are exciting technologies emerging from multinational companies and entrepreneurial startups alike. There are government-funded pilot programs, VC-backed prototypes and bootstrapped blue sky thinkers whose ingenuity has the potential to transform roads systems over the coming decades.

The road technology ecosystem

Innovation is happening in every aspect of the roads ecosystem and we have organized our analysis of the technology accordingly:

- **On the road:** Electrification, autonomy and so much more. Vehicles are being planned and built not only to be more sustainable, but to improve issues of safety and congestion.
- **In the road:** What of the roads themselves? The materials used to build and repair roads in the future could look very different from those used today.
- **Under the road:** There is enormous potential to build all manner of technologies into our roads, to make them smarter, safer and more sustainable.
- **Beyond the road:** From traffic flow planning tools to smart drones for maintenance, there are many other technologies that can contribute to a better, smarter roads infrastructure.

Here we examine some of those technologies, which we have categorized based on which key issue(s) they have the potential to impact:

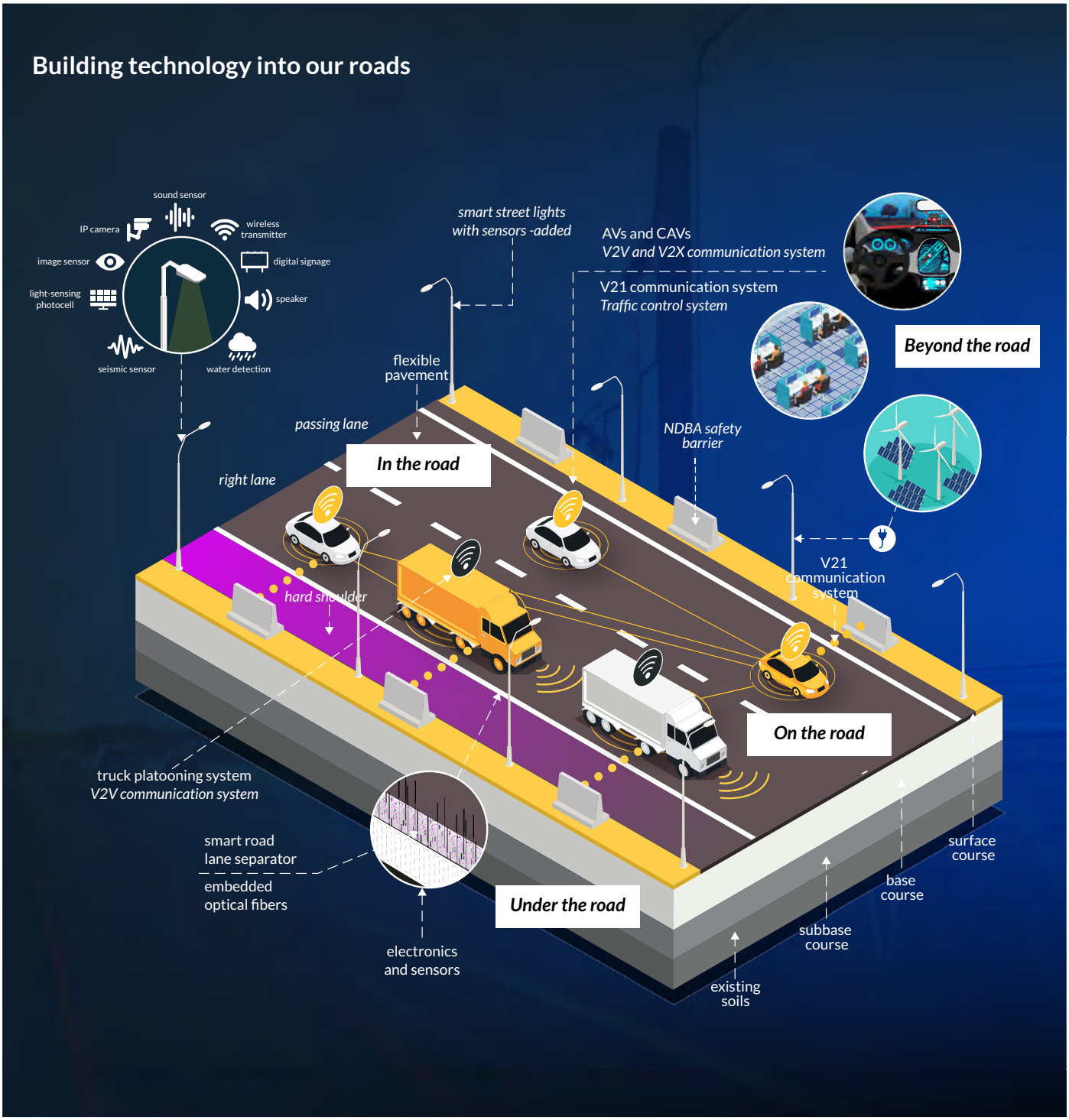


Fig. 7: The road technology ecosystem

Sustainability: Roads are not going away, and neither are motor vehicles, although both need to evolve. Which technologies can minimize the environmental impact of our roads and the traffic on them? How do we maximize the robustness of our roads infrastructure under the weight of increasing traffic volumes, while minimizing the cost of maintaining them?

Safety: Our roads will continue to be a vital means of transporting people and goods, over distances large and small. But the number of fatalities and injuries only increases with the volume of vehicles on the road, and since the number of vehicles and the number of vehicle miles traveled (VMT) are only likely to increase, what role can technology play in making our roads safer for those who use them?

Congestion: Building more roads and expanding existing ones has not solved the issue of congestion. This is particularly acute in cities, which are becoming both larger and more numerous. Can technology help to keep traffic moving, both in urban areas and other choke points?

Efficiency: Economies are only successful if physical goods produced can be efficiently transported from one place to another. With the volume of commercial goods transported by roads projected to continue increasing, what role does technology have in ensuring freight gets from A to B, quickly and efficiently?

For each of the technologies we highlight in the following pages, we have used the above icons to highlight which issues they contribute to mitigating.

On The Road

Vehicles are being planned and built not only to be more sustainable, but to improve issues of safety and congestion.

While today's roads may be indistinguishable from those built in the 1950s or even before, the same could not be said of the vehicles that drive on them, which are now as much about computing power as they are horsepower.

Today's vehicles are as much about computing power as they are horsepower.

And we sit at the cusp of two simultaneous revolutions that are transforming vehicles almost beyond recognition: Electrification and Autonomy.

Electrification: Throughout the world, governments have set targets to reduce the number of Internal Combustion Engine powered vehicles on the road. This, combined with the improving efficiency and range of electric vehicles (EVs), is resulting in successive year-over-year increase in sales. According to the International Energy Agency, sales of EVs are expected to surge by 35% this year, following a record-breaking 2022.[17]One in every three cars sold worldwide is now electric, and more than half of those are in China[18], a country which has truly embraced EVs. Commercial vehicles stocks are also going electric. Electric light commercial vehicle (LCV) sales worldwide increased by more than 90% in 2022, to more than 310,000 vehicles, even as overall LCV sales declined by nearly 15%.[19] Data from Boston Consulting Group suggest that the tipping point, when sales of battery-only electric vehicles outnumber those of gas vehicles, is less than a decade away.[20]

The main implication of this change for our roadway network is the need for a robust and comprehensive charging network, and much has already been written about this, including the conversion of gas stations into 'energy stations'.

While EV charging stations are now a common sight, there are questions about the aesthetic impact on the urban environment if similar stations were to line every street. Companies like Urban Electric[21] are addressing this with retractable charge points that reduce the risk of vandalism or other damage, as well as the impact on the urban streetscape.

Advances in wireless charging may soon supersede the need for EV charging networks.

Urban Electric

Will we even need these charging stations? Advances are being made in wireless charging for EVs that may soon supersede the need for such networks.

Wireless charging for EVs works in much the same way as it does for mobile phones, but with higher power levels and larger batteries. The technology for stationary wireless EV charging is not new, and although it has yet to take hold in the US in the same way it has in Europe and Asia (where automaker Genesis is installing wireless charging pads for its Genesis GV60 model in parts of Korea[22]), the market is expected to grow as EV adoption increases.

WiTricity

The US company responsible for those Genesis charging pads, WiTricity does not have this field to itself. Other players include HEVO; Plugless Power; Wave, which specializes in charging solutions for mass transit and other commercial vehicles; and established global giants such as Toshiba, Continental, DAIHEN Corporation, and Lumen, all of which are developing charging pads.

While static EV charging is likely to change where, when and how we 'fuel' our vehicles in the future, perhaps of even greater significance for the future of our roads, and the way they are constructed and maintained, is the possibility offered by dynamic wireless charging, which we cover below (see 'Under The Road').

Autonomy: While electrification is undoubtedly going to bring about behavior changes on the part of the vehicle user, and will have environmental benefits, it is unlikely to have the same impact on our roads as autonomous vehicles.

Autonomous vehicles (AVs) have been 'five years away' for at least a decade, but there is evidence to suggest this technology really is about to become more commonplace.

On the streets of San Francisco, driverless cars operated by Alphabet's Waymo[23] and GM's Cruise[24] are now regular sights, while Zoox robotaxis (an Amazon subsidiary) are being piloted in nearby Foster City.[25]

The use of autonomy in commercial fleets is already well advanced, with companies like TuSimple[26] already piloting its self-driving technology for heavy duty trucks in Arizona, and in China and Japan.

Companies are already piloting self-driving technology for heavy duty trucks.

TuSimple

There are many legislative and regulatory hurdles to be overcome, and safety concerns to be addressed, before AVs take hold in the same way as EVs. But with companies like May Mobility[27] and others entirely focused on maximizing safety, any residual concerns are likely to be overcome, making AVs a part of our landscape going forward.

What does this mean for our roads and for the road user? The Alliance for Automotive Innovation highlights a number of societal benefits of AVs, including[28]:

- **Greater safety:** US government data identifies driver behavior or error as a factor in 94% of crashes.
- **Reduced congestion:** Researchers at the University of Texas predict that tightly spaced 'platoons' of AVs could reduce congestion-related delays by 60% on highways.
- **Environmental gains:** Fewer traffic jams save fuel and reduce greenhouse gasses from needless idling, and it is believed that automation will further increase demand for EVs.

'Platooning' by AVs will make more efficient use of existing road capacity and reduce or eliminate the need to build more.

Other projected benefits include: Greater productivity, with AV users able to focus on things other than driving, such as working, reading, or even sleeping; greater independence, for people with disabilities, for example; and better land use. The ability of AVs to drive safely in close proximity with each other will make more efficient use of existing road capacity and reduce or eliminate the need to build more.

Vehicle-to-Vehicle and Vehicle-to-Infrastructure Communication: As significant as electrification and autonomy will be in transforming our road use, they are not the only technologies being developed that will do so.

Vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and vehicle-to-everywhere (V2X) technologies use wireless communication to enable vehicles to communicate and interact with each other and with surrounding infrastructure, such as traffic signals. Sharing real time data about location, speed and intentions can optimize traffic patterns for improved efficiency, prevent collisions and provide information on road conditions.

On-board computers in modern vehicles already collect massive amounts of data, and as big data analytics improve, this data will become more valuable in optimizing road conditions. Instead of the driver needing to check and respond to what Google Maps is telling them, their vehicle will receive the information from road infrastructure, and alert them, or even react automatically. In the future, in-vehicle sensors could even monitor a driver's heart rate, eye movements and brain activity to detect issues ranging from drowsiness to a heart attack, and the vehicle could alert the driver to take a particular action or even drive itself to a hospital.

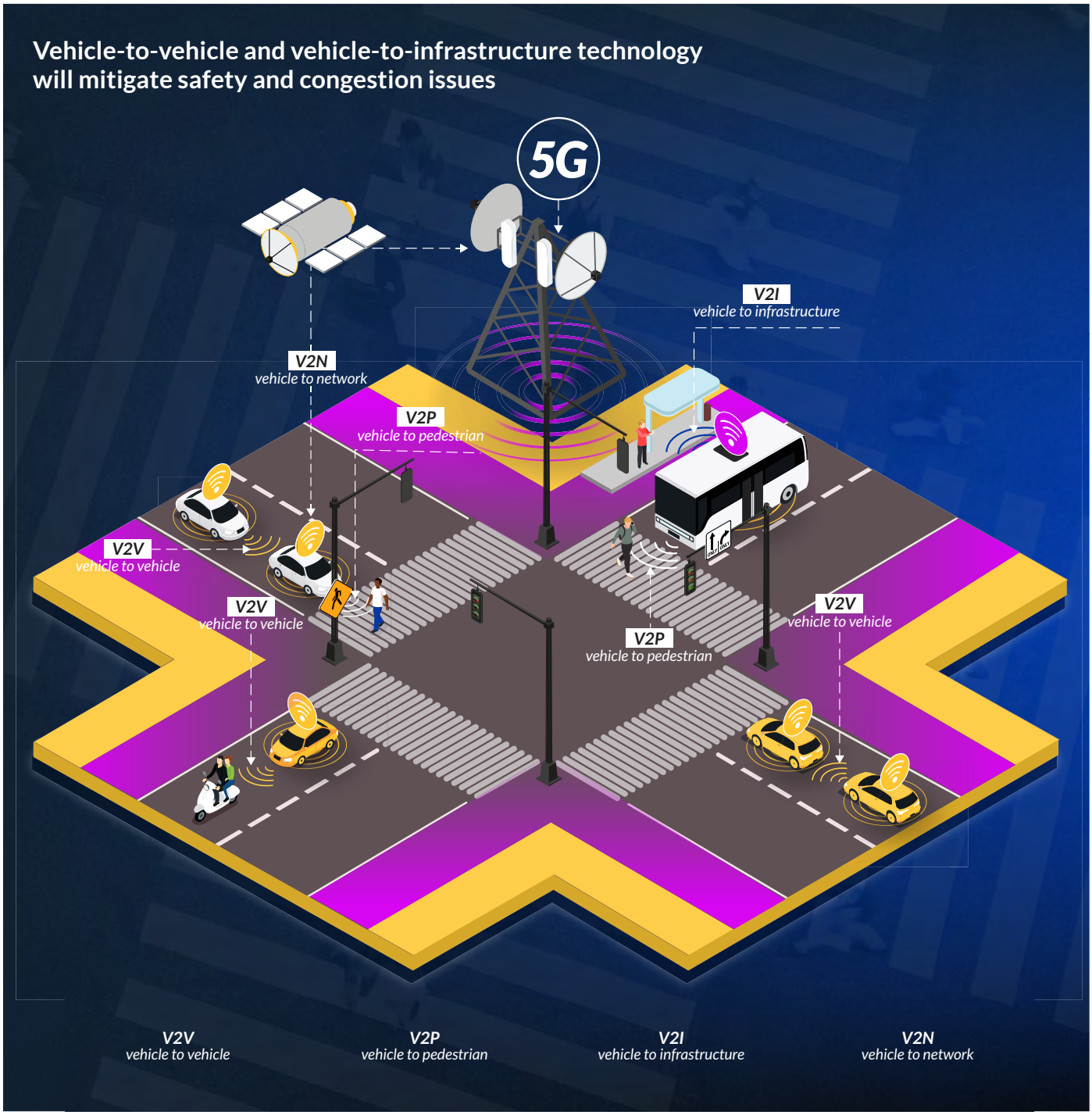


Fig.8: Vehicle-to-vehicle and vehicle-to-infrastructure communication

Unsurprisingly, the major automotive OEMs and their tier 1 suppliers are leading the charge here, looking at ways to build this technology into their vehicles on the production line, though there are plenty of startups innovating in this space, too. Chicago-based HAAS Alert[29], for example, has a vehicle-to-vehicle software that provides notifications to road users designed to increase safety, such as "slow down" through work zones. Other players in this space include Visteon[30], based in Detroit; Hungary's Commsignia[31]; and Israeli firm, Valerann.[32]

Valerann

Valerann is a UK-based smart transportation start-up that is redefining modern mobility through improving roadway operations efficiency and safety.

The company's Data Fusion platform, Lanternn by Valerann™ detects over 95% of road incidents in under five minutes, provides 100% road monitoring coverage and delivers real-time road traffic insights and accidents risk predictions.

By using information from a broad range of available disparate data sources and leveraging proprietary AI and computer vision algorithms, Valerann extracts value from Big Data to deliver a real-time, comprehensive and holistic road situation overview for the entire road.

Road traffic authorities in the US, Europe and Latin America use Lanternn by Valerann™ to improve their real-time situational awareness and to increase their roads' safety through proactive and timely road traffic management.

HG Ventures led Valerann's Series A funding, in early 2022, based on the technology's potential to transform the safety and efficiency of our roads.

Another company, Hayden AI[33] is utilizing AI to power "Smarter, safer and more sustainable cities" with a 'mobile perception platform'. Cameras and sensors installed on buses, streetcars and other municipal vehicles collect real time data that enable cities to monitor traffic flow to aid with road planning, enforce bus and cycle lane violations, and improve the safety and efficiency of their public transit systems.

Energy recovery and storage: Technologies like regenerative braking convert the kinetic energy produced during braking into electrical energy, which can be stored and reused to power vehicle systems. This approach increases energy efficiency and reduces fuel consumption.

Advancements in battery technology, meanwhile, are enabling the development of more efficient energy storage systems. These innovations will support longer electric vehicle ranges and faster charging times, accelerating the widespread adoption of electric transportation, including in commercial fleets.

Advanced Driver Assistance Systems: OEMs have for some time been incorporating other technologies into their vehicles that are designed to improve safety and fuel efficiency, such as Advanced Driver Assistance Systems (ADAS) whose features include lane departure warnings, adaptive cruise control, and automatic emergency braking.

Vehicle Lightweighting sees the use of lightweight materials, such as carbon fiber composites and high-strength steel alloys, to help reduce the weight of vehicles and to improve fuel efficiency and reduce GHG emissions.

The Role of Public Transport

With increasing pressure on our roads, the role of public transport in reducing the number of vehicles should not be ignored.

Priority bus lanes are one example of a policy that may be shown to induce the use of public transit by people who might otherwise drive themselves. This 'carrot' may be counterbalanced with 'stick' policies, such as 'user fees' like congestion charging.

The advent of electrification and autonomy are unlikely to change the trajectory of such policies; if anything, autonomous electric vehicles may make the use of public transport even more attractive.

Some analysis suggests that the widespread introduction of autonomous vehicles may reduce demand for car ownership, in favor of an on-demand model.

The future of our roads is likely to be something of a 'mosaic', with public transport options alongside on-demand robotaxis, privately owned and commercial autonomous vehicles, and driver-operated vehicles.

Sustainable Fuel Alternatives: Research is ongoing to explore alternative fuels like hydrogen, biofuels, and synthetic fuels. These options offer potential for reduced Greenhouse Gas (GHG) emissions and increased sustainability in transportation.[34]

As truck fleets are one of the main contributors to GHG emissions, they are often targeted by companies seeking a sustainable and carbon-free option. Canada-based Hydra[35] offers a "dual fuel" solution for commercial truck fleets; a plug-and-play Hydrogen Injection System (HIS) modifies the traditional diesel engine.

The US-based startup, Manta Biofuel[36] produces carbon-neutral crude oil biofuel. The company grows algae in open ponds, uses a patented magnetic harvesting technology to collect concentrated biomass, and converts this into biofuel using hydrothermal liquefaction reactors.

Meanwhile, the Bertone GB110 sports car[37] uses 'Select Fuel', a patented method of converting waste polycarbonate materials, such as plastic bottles, into liquid fuel.

Bertone GB110

As well as sustainable fuel alternatives, non-petroleum alternatives to lubricants are also being developed. One such company involved in this field, is Biosynthetic Technologies[38], in which HG Ventures has invested, and which is producing bio-based biodegradable, and carbon negative lubricants.

In The Road

The materials used to build and repair roads in the future could look very different from those used today.

While there is plenty of public discourse about the technologies being incorporated into vehicles, relatively little attention is paid to the roads on which those vehicles travel, and how innovations in their construction, maintenance and operation can make our infrastructure safer, more reliable, and more sustainable.

Innovations in the construction, maintenance and operation of roads can make our infrastructure safer, more reliable, and more sustainable.

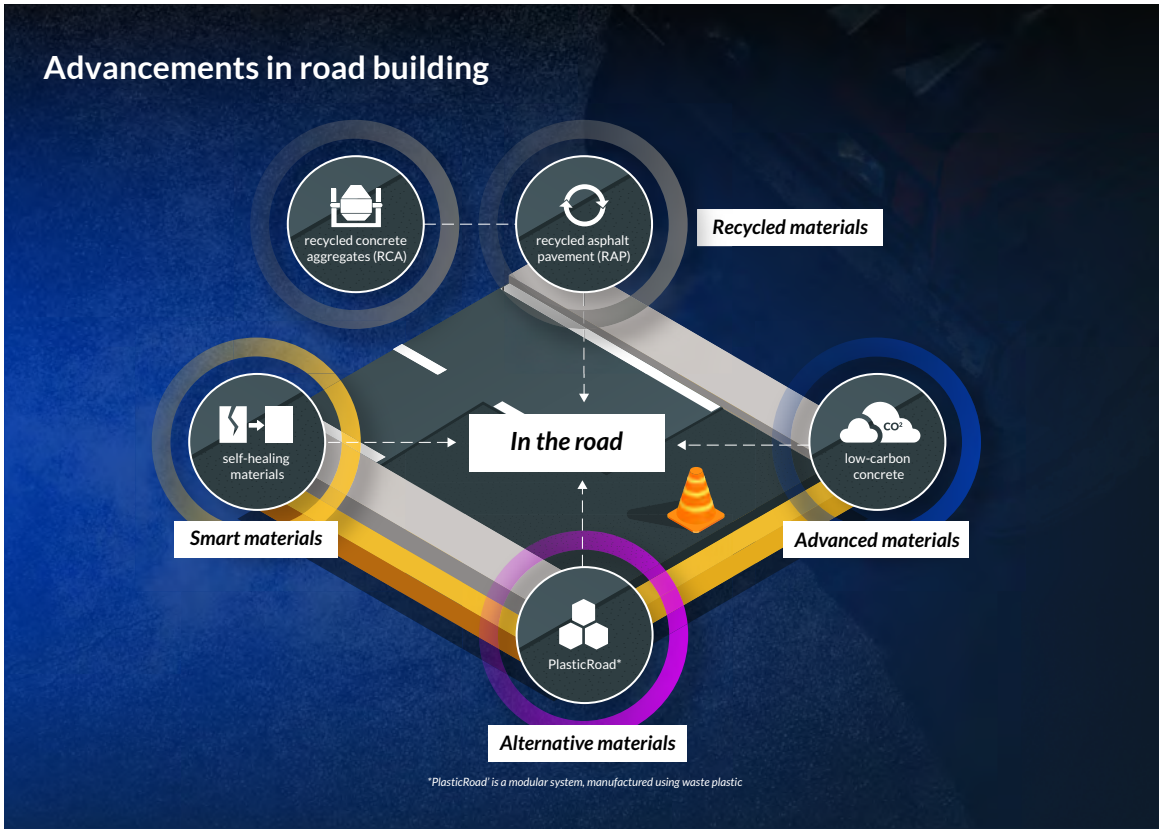


Fig. 9: In the road technologies

Recycled materials: Using recycled materials in road construction helps reduce waste and environmental impact. Recycled asphalt pavement (RAP) and recycled concrete aggregates (RCA) are commonly used to create sustainable road surfaces. Asphalt is already one of the world's most recycled materials (82.2M tons in the US in 2021, versus 58.5M tons of paper, plastic, aluminum/ steel cans and glass, combined),[39] although regulations often limit the amount of recycled materials that are permissible. Advances in materials science could see the amount of recycled materials increase over time, further reducing the environmental impact of road construction , and the National Asphalt Pavement Association has set an industry goal of net zero carbon emissions during asphalt production and construction, by 2050.[40]

Asphalt is already one of the world's most recycled materials... Advances in materials science could see the amount of recycled materials increase over time.

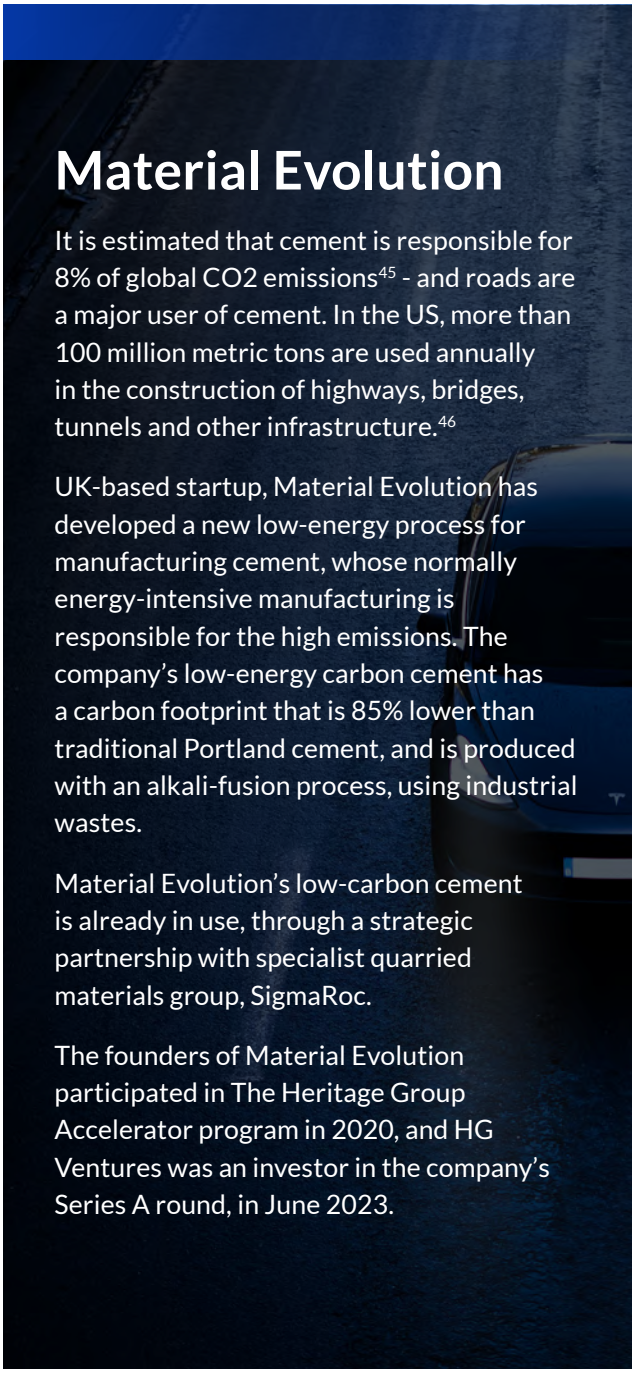
Advanced materials: A number of companies are developing ways of improving the longevity and sustainability of the materials used to construct roads, which is especially relevant as the road construction industry focuses more on life-cycle assessments (LCAs), and Environmental Product Declarations (EPDs) become the norm. Material Evolution[41] has developed a method for producing low-carbon concrete, while US startup Allium Engineering[42] is manufacturing longer-lasting stainless steel-coated rebar, which can be used in concrete roads and bridges.

Alternative materials: KWS, a subsidiary of Dutch-owned international construction company VolkerWessels, is just one firm exploring the possibilities of alternatives to traditional road building materials. Its 'PlasticRoad' is a modular system, which fits together like children's LEGO bricks. The modular units are manufactured using waste plastic and are being trialed on cycle paths in the Dutch towns of Zwolle and Giethoorn.[43]

A May 2023 report by the World Bank reviewed the incorporation of plastic waste into road construction as an asphalt modifier, and suggested there may be potential for this technology.[44]

Clearly, non-petroleum based materials are preferable, and considerable research is happening in this field for road construction, too. Bio-based materials are derived from renewable sources such as plant fibers, agricultural waste, and bio-based resins. Such materials are environmentally sustainable, durable, and reduce our reliance on fossil fuels.

Bio-based materials derived from plant fibers, agricultural waste and bio-based resins are environmentally sustainable, durable, and reduce our reliance on fossil fuels.



Material Evolution

It is estimated that cement is responsible for 8% of global CO2 emissions[45] - and roads are a major user of cement. In the US, more than 100 million metric tons are used annually in the construction of highways, bridges, tunnels and other infrastructure.[46]

UK-based startup, Material Evolution has developed a new low-energy process for manufacturing cement, whose normally energy-intensive manufacturing is responsible for the high emissions. The company's low-energy carbon cement has a carbon footprint that is 85% lower than traditional Portland cement, and is produced with an alkali-fusion process, using industrial wastes.

Material Evolution's low-carbon cement is already in use, through a strategic partnership with specialist quarried materials group, SigmaRoc.

The founders of Material Evolution participated in The Heritage Group Accelerator program in 2020, and HG Ventures was an investor in the company's Series A round, in June 2023.

Smart materials: Researchers are developing smart materials that can sense and respond to changing conditions. For instance, self-healing materials can repair cracks and potholes automatically, increasing road longevity and reducing maintenance needs. Researchers at the University of Bath in England are exploring self-healing concrete with bacteria.[47] When the concrete cracks, the bacteria are exposed to oxygen and water, allowing them to feed on the feedstock within the concrete to fill in voids. Magnetite iron ore is also emerging as a viable solution for improving the repair of cracks and potholes[48], thereby minimizing the disruption from repairs.

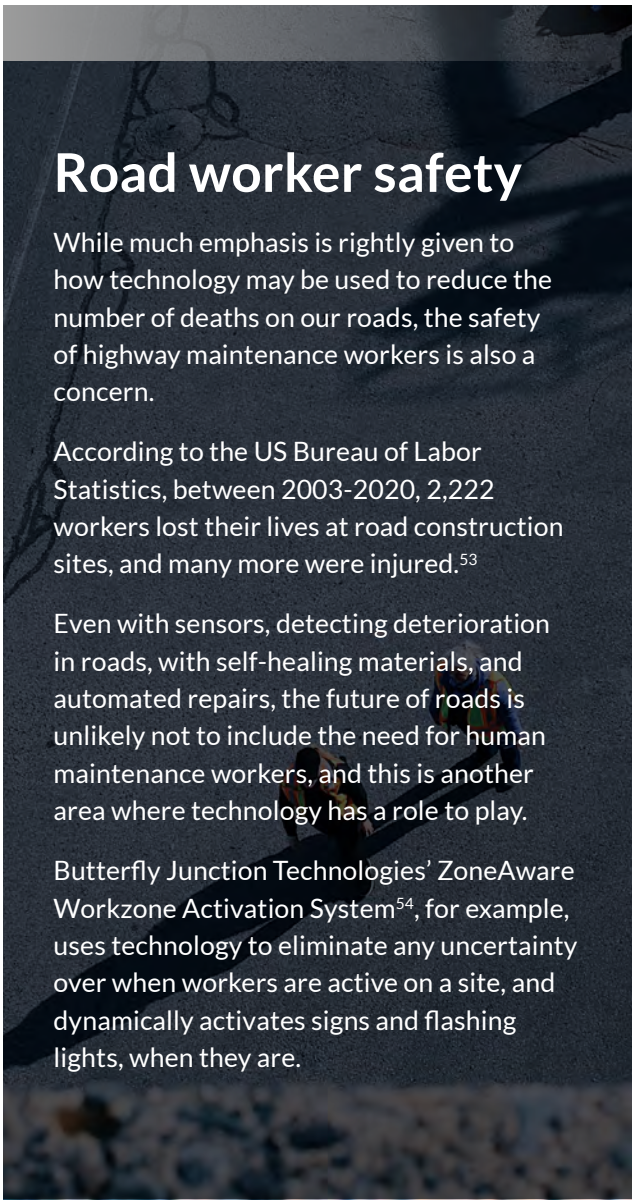
Self-healing materials can repair cracks and potholes automatically.

In Europe, trials have taken place with **solar paint** on roadways.[49] This paint collects energy during the day and glows at night, with the aim of improving visibility and safety.

AI-powered construction and maintenance:

There are a number of startups leveraging AI or machine learning in road construction to optimize processes and improve efficiency. One such company is XBE[50], which has developed a comprehensive software solution for optimizing horizontal construction. XBE's software uses advanced algorithms and machine learning to optimize various aspects of road construction projects.

Another area in which AI is being applied, beyond construction, is maintenance. Companies like GoodRoads[51] in North Carolina, and RoadBotics[52], a startup that was acquired by Michelin in 2022, use AI technology to enable cities and transport authorities to map the state of their roads and prioritize repairs. Not only does this obviate the need for time-consuming and labor-intensive manual assessments, it enables necessary maintenance to be carried out before conditions become chronic, thereby minimizing the disruption of road closures and diversions, keeping traffic flowing.



Road worker safety

While much emphasis is rightly given to how technology may be used to reduce the number of deaths on our roads, the safety of highway maintenance workers is also a concern.

According to the US Bureau of Labor Statistics, between 2003-2020, 2,222 workers lost their lives at road construction sites, and many more were injured.[53]

Even with sensors, detecting deterioration in roads, with self-healing materials, and automated repairs, the future of roads is unlikely not to include the need for human maintenance workers, and this is another area where technology has a role to play.

Butterfly Junction Technologies' ZoneAware Workzone Activation System[54], for example, uses technology to eliminate any uncertainty over when workers are active on a site, and dynamically activates signs and flashing lights, when they are.

Under The Road

Building technologies into (and under) our roads, to make them smarter, safer and more sustainable.

As well as innovations in the construction materials used and the maintenance methods deployed, the roads of the future are likely to incorporate new technologies buried within or under them.

Smart pavements are embedded with technology that enables them to communicate with vehicles, pedestrians, and other devices in real-time.

Smart pavements: Smart pavements are embedded with technology that enables them to sense and respond to changes in the environment, allowing them to communicate with vehicles, pedestrians, and other devices in real-time. Sensors and communication devices built into the pavement can gather information about traffic volume, speed, weather conditions, and other factors that affect road safety, enabling the optimization of traffic flow, alerting drivers to potential hazards, and improving overall safety on the roads. Smart pavements or standalone sensors are required for the vehicle-to-infrastructure and vehicle-to-everything communication described earlier.

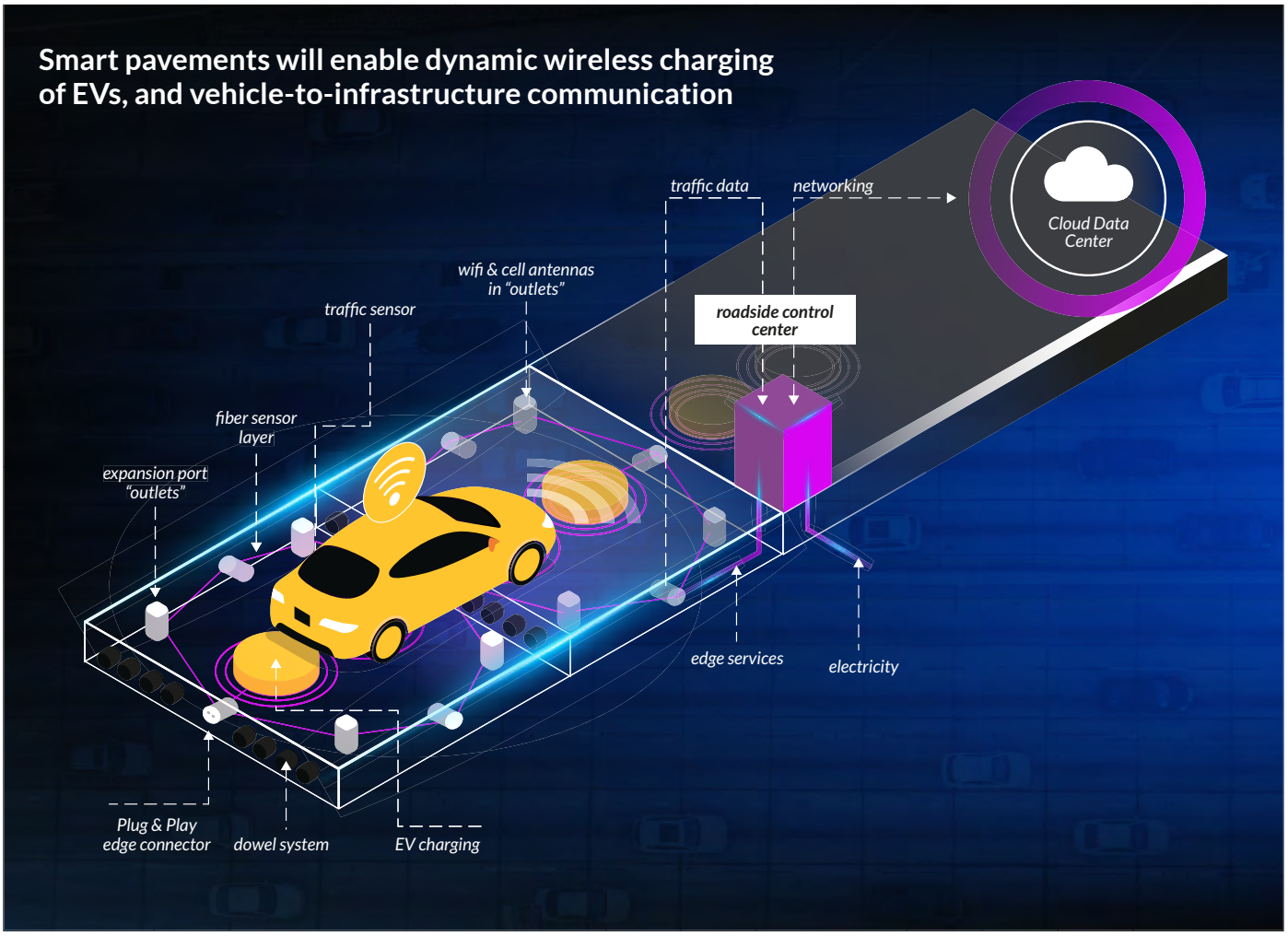


Fig. 10: Smart pavements

As self-driving cars become more common, they will need reliable and accurate data about their surroundings in order to navigate safely. Smart pavements can provide this information by communicating with these vehicles in real-time, allowing them to make informed decisions about speed, route, and other factors.

Smart pavements are already being trialed in the United States. Integrated Roadways' modular Smart Pavement System[55] is being used in a section of Denver, Colorado, with another project to follow in Lenexa, Kansas.

The 'sensorization' of roads is more costly and time-intensive than laying a traditional road surface, but new technology is being brought to bear here, too: Virginia startup, TRAXyL[56] has developed a 'minimally disruptive alternative' that involves 'painting' optical fiber on to the road surface, a process that is 25 time faster than embedding it.

Electrified roads: The idea behind electrified roads is to enable EVs to charge while moving. There are three different technologies for achieving this, all of which are being experimented with in different parts of the world - the catenary, conductive and inductive systems.

Electrified roads enable EVs to charge while moving.

The catenary system uses overhead wires to provide electricity to buses or trams and therefore can only be used for heavy-duty vehicles. With conductive charging, the charge is carried in a track built into the road, which transfers to the vehicle via a detachable lead. This system was used in the world's first electrified road, a 2km stretch in Sweden, which opened in 2022.[57] The Swedish Transport Administration, Trafikverket, used this as a pilot, and has already committed to transforming one of its major highways into an electric road, although has yet to settle on which technology to use.

The inductive system uses Dynamic Wireless Power Transfer (DWPT) technology buried under the asphalt to send electricity wirelessly to a coil in the vehicle. Stellantis, the OEM behind brands including Chrysler, Citroen, Fiat and Peugeot has trialed the use of this technology in some of its vehicles[58], and DWPT is being piloted in different parts of the world, notably by German firm, Magment.[59] The company manufactures patented magnetic concrete, and is a previous participant in The Heritage Group Accelerator program. In the US, DWPT developed by Israeli firm Electreon[60] is to be tested on a stretch of road in Detroit.[61]

Electric roads have the potential to further increase the adoption of EVs by reducing 'range anxiety' among consumers and overcoming commercial vehicle operators' concerns about any need for multiple recharging stops over long distances.

Beyond The Road

Other technologies that can contribute to a better, smarter roads infrastructure.

Beyond modifications to roads themselves and to the vehicles that travel on them, there are a myriad of technological innovations that may be applied to improve the sustainability, safety and efficiency of our road networks.

Internet of Things (IoT): In particular, the advent of the Internet of Things (IoT) technology has opened up new possibilities.

IoT enables the seamless integration of physical objects with digital systems. By connecting various devices and sensors through a network, IoT offers unprecedented opportunities to enhance road safety, improve traffic efficiency, and promote sustainable transportation solutions, through multiple applications:

IoT offers unprecedented opportunities to enhance road safety, improve traffic efficiency, and promote sustainable transportation solutions.

Traffic speed sensors, acoustic sensors that detect abnormal noises like crashes or tire screeches, Internet Protocol (IP) cameras and similar technologies can all be deployed to collect information that may be used to reduce accidents, improve dispatch times of emergency services, and minimize disruption.

Digital signage can display real-time traffic information, alternative route suggestions, and emergency alerts, providing drivers with valuable information, improving their decision-making and contributing to safer and more efficient travel. 'Smart traffic signs' can even guide drivers on how to use the road for optimal safety and efficiency, for example by relaying a voice message telling the driver of a smart car what to do, or even communicate directly with the vehicle in order for it to take action independently.

Intersections are particularly prone to crashes and have become a focus for the testing of IoT technology. The idea of the 'smart intersection' is that traffic signals, digital signs and other pieces of infrastructure collect real time data and communicate with each other and with vehicles to control traffic flow and speed, increase safety and reduce congestion. Trials with smart intersections are underway in different parts of the world including China, many parts of Europe and in the US, Ann Arbor, Michigan[62], and Chattanooga, Tennessee.[63]

IoT-enabled weather monitoring systems gather real-time weather data, such as temperature, precipitation, and wind speed, and can alert drivers about adverse weather conditions, or dispatch road maintenance crews for necessary actions.

IoT technology can provide a convenience factor to drivers as well, and companies like Libelium[64] are using IoT technology to help drivers find parking spaces.

Technology giants including Cisco, Ericsson, IBM, Intel, Siemens and Qualcomm are heavily invested in this area, although there are plenty of VC-backed businesses making waves too. Canadian firm, Miovision,[65] has developed a range of solutions to help cities become smart cities by optimizing traffic flow; and Israeli company, NoTraffic[66] has developed an AI-powered traffic signal platform that connects road users to the city grid. German firm, SmartMicro,[67] produces highly sensitive traffic sensors and radars, while companies such as StreetLight[68] and INRIX[69] provide platforms for analyzing the big data generated. Silicon Valley startup, Cavnue is also developing infrastructure technology to power 'connected roads'. The company is working in partnership with the Michigan Department of Transport to develop a 'connected and automated vehicle (CAV) corridor' on Interstate 94,[70] and the mini weather stations produced by Frost Solutions[71], a Notre Dame spin out, enable snow and ice management professionals to monitor and respond to conditions in real time.

Pretred

Concrete, a highly carbon-intensive material, is not just used in the construction of roads, but in the barriers that line millions of miles of highway.

Colorado startup, Pretred, did not have to look far for an alternative; the company manufactures sustainable barriers by recycling waste tires.

Pretred is GreenCircle certified for recycled content, which guarantees that each of its barriers is made from at least 95% recycled materials. A six-foot barrier repurposes at least 70 waste tires, and one mile of Pretred barriers diverts more than 1.4 million pounds of waste tires from landfills or incineration.

Pretred barriers are already used on construction sites and parking lots, as well as for erosion control and other uses. The company expects to receive roadway certification by the end of 2023.

China is already implementing IoT technology, with stretches of many highways embedded with sensors that collect valuable data about stress and strain on the roadways and bridges. Roadside cameras monitor the history of the vehicles using the highways, prompting rest stop suggestions to drivers where relevant, or even producing fatigue-reducing light shows.

In June 2023, the Chairman of the China Highway and Transportation Society said smart roads are “an inevitable trend and choice for future road construction in China”.[72]

Drones: Innovation is taking place above the road, too. Research has been carried out into the use of Unmanned Aircraft Systems (UAS, or drones) for monitoring critical infrastructure, including roads, to identify maintenance needs in an efficient manner.[73]

Technology Map

Here, the technologies highlighted in this report are mapped against the twin axes of their stage of development, from Blue Sky to Fully Deployed, and the key issues they have a role in solving or mitigating.

	Blue Sky →	Testing →	Piloted →	Fully Deployed
	Technologies that are still largely theoretical and have yet to be developed	*Technologies that are being or have been tested*	*Technologies that are being or have been piloted in real world situations*	*Technologies that have been deployed in the real world, and have the potential to be replicated elsewhere*
Sustainability *Technologies that minimize the environmental impact of our roads and the traffic on them.*	Net zero road materials Plastic roadways Asphalt/cement manufacturing without fossil fuels Clean energy paving fleet	Kinetic energy recovery Bio-based road materials Bidding process for total cost of ownership vs lowest cost	Electric pavements Advanced materials Autonomous vehicles Onboard AI	Electric vehicles Sustainable fuel alternatives Recycled asphalt materials Lightweighting
Safety *Technologies that make our roads safer for all those who use them.*	Road surfaces that repel water or ice Color changing road surfaces Smart road barriers Tech to disable phones near accident hot spots	Solar paint IoT Worker safety tech Smart pavements	Autonomous vehicles Onboard AI V2X	ADAS
Congestion *Technologies that help to keep traffic moving, both in urban areas and other choke points.*	Traffic signals talking to vehicles Incentive pricing to stay off certain roads	AI-powered maintenance Smart pavements IoT	Autonomous vehicles Onboard AI V2X Platooning	Dynamic tolling Smart Parking Congestion charging
Efficiency *Technologies that help ensure freight gets from A to B, quickly and efficiently.*	Drone repairs Robotic road repair Ultra long-range EVs	AI-powered maintenance Smart pavements IoT Drone detection	Autonomous vehicles Onboard AI V2X	Digital fleet management Optimized routing

Market Map

The startup ecosystem is a hotbed of innovation, with hundreds of companies around the world engaged in developing technologies that will enable the necessary reimagining of our roads infrastructure.

Roadmap To The Future

Roadmap To The Future

With growing populations, expanding cities, increasing traffic volumes, and the environmental impacts of the climate crisis, it is clear that radical new thinking is required if our roadway infrastructure is to continue to serve us as it has done in the past.

Advancements in technology are out-pacing the way we think of our roads. Autonomous vehicles, electrification, vehicle-to-vehicle communication and vehicle-to-infrastructure communication, are already a reality, and being trialed, piloted or rolled out in different parts of the world. Meanwhile, our roads remain similar to how they have for 70 years or more, in terms of their construction and maintenance.

Advancements in technology are out-pacing the way we think of our roads. The future of roads will need to look very different, if our vital infrastructure is to keep the global economy moving.

The future of roads will need to look very different, if our vital infrastructure is to keep the global economy moving, and finally address the longstanding issues of safety and the environment:

- **Increased use of lower-carbon construction materials,** to minimize the environmental impact of roadbuilding
- **Efficient 'sensorization' of major roads,** to enable the real-time sharing of data around the usage and state of repair of roads and other pieces of infrastructure, to enable efficient planning of repair or replacement
- **Embedding sensors and other technology beneath roads' surfaces,** in order to enable the capture of and transmission of vital data
- **Use of modular roadways with embedded technology,** in places, to improve the efficiency of building, maintenance and repair
- **Incorporation of electrification technologies** into and under our roads, to service the needs of commercial electric vehicles, and any private EVs traveling long distances
- **Use of self-healing materials in road surfacing,** to minimize disruptions caused by road closures for maintenance
- **Adoption of 'autonomous-only' lanes on highways,** to allow for the safe 'platooning' of AVs, and make the most efficient use of available space
- **Transformation of major roads into 'smart roads',** through the incorporation of smart cameras, smart signs, sensors and other IoT-enabled infrastructure, to enable road operators to improve both safety and efficiency
- **Installation of IoT technology at busy intersections,** to improve safety for road users and pedestrians, and improve traffic flow
- **Use of intelligent traffic planning and management systems by cities,** to facilitate improved traffic flows and safety

Building and maintaining roads is an expensive business. In the US, government spending on highways and roads is more than $100B a year.[74] That expenditure is a mix of State and Local (around 75%) and Federal (25%). While around 40% of the total expenditure on highways and roads goes on operational costs such as maintenance and snow and ice removal, almost 60% goes towards capital spending on the construction of new roads. While for other areas of government expenditure capital spending is typically 10% of the budget, capital spending on roads and highways has been between 50-60% since the 1970.[75] As we have observed, despite the building of more and more new roads, road deaths and injuries continue to increase, congestion remains a challenge, impeding the wheels of our economy, and legitimate environmental concerns make the continued building of more roads hard to justify.

Road deaths and injuries continue to increase, congestion remains a challenge, and environmental concerns make the continued building of more roads hard to justify.

If the answer is not more roads, it must be better, smarter roads.

However, this too comes with challenges:

- **Cost:** The transformation of roads into smart roads has a price tag attached. Laying roads with embedded sensors or means of wireless electrification is inevitably more costly than the construction methods and materials currently used.
- **Unproven technologies:** Smart roads technology is still in its infancy. While there are many examples of pilots in different parts of the world, widespread adoption would be a leap of faith for those charged with the responsibility of investing public money into roads.
- **Lagging benefits:** While there is a consensus that the incorporation of the technologies we have outlined will result in fewer deaths and injuries, ease congestion, and improve the efficiency of our roads infrastructure, as well as reduce environmental impact, these benefits may not be evident for some time.
- **Uneven benefits:** The technologies outlined are arguably not appropriate or even necessary on all roads. For example, a rural road with little traffic may still be a vital link between different communities, but would the benefits of installing IoT sensors justify the cost of doing so? Further, would the absence of that technology (and the data it collects) create or exacerbate a divide between the most and least traveled roads?

Who pays the price?

While HG Ventures has no position on policies around the funding of smart roads infrastructure, this report would be incomplete without at least enumerating some of the options open to policy makers:

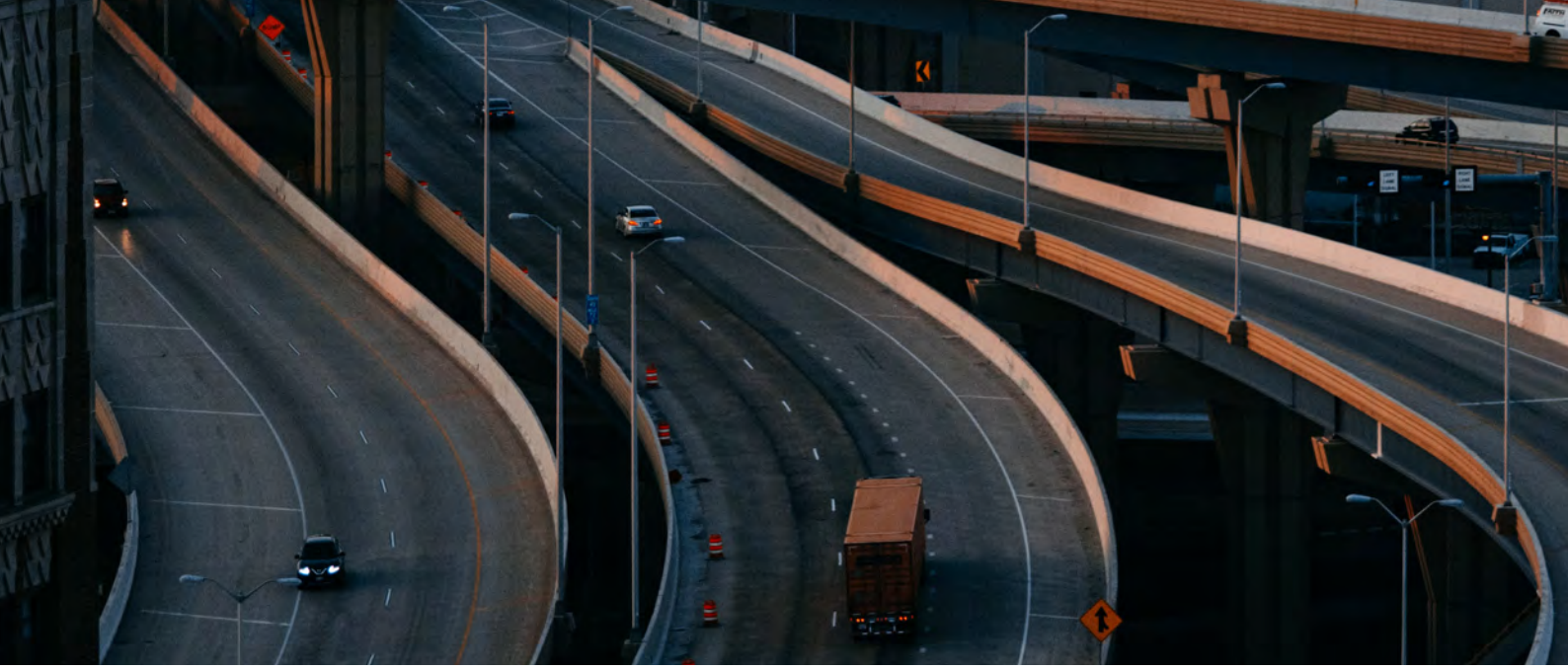
- **Toll roads and user fees:** Road-building has continued unabated for so long because it is considered to be 'free' by road users, paid for through general taxation. 'User fees' of different types, such as toll charges or congestion charges, have been introduced in different parts of the world to introduce more of a 'cost per use' dimension to road usage. It has also been suggested that user fee structures could vary by vehicle type since, for example, heavier vehicles such as trucks are a greater determinant of road deterioration.[76] And experiments with 'dynamic tolling' see charges vary depending on the time of day.

  Another policy option is that of a Vehicle Miles Traveled (VMT) tax.[77] As the name suggests, fees are levied on vehicle users for the use of a roadway. This system is being piloted in various US states, notably Oregon and California,[78] and is deemed attractive to many as an alternative to the gasoline tax, whose returns will continue to diminish with the increased adoption of EVs, compounding the effect of inflation on taxation levels set in 1993.

- **Public-private partnerships:** Public-private partnerships (PPPs) have long been a feature of highway development in the US around the world. PPPs enable governments to leverage the financial, managerial and technical expertise and resources of private companies, and draw funds from the public over time. PPPs are typically involved in design, construction and maintenance of projects, and share the risk associated with major infrastructure projects. While controversial, there is potential for PPPs to include the incorporation of smart technologies into our roads networks. The smart intersections project in Chattanooga, Tennessee is an example PPP that involves the Chattanooga Department of Innovation Delivery and Performance, the Center of Urban Informatics and Progress and Seoul Robotics.[79]

- **Business model innovation:** Innovations in the area of roads is not limited to technology; much thought is being put into different and better ways to plan and manage the enormous capital expenditure involved in road building and maintenance. Avenew, for example, a company in which HG Ventures has invested, works with those with responsibility for roads, applying their expertise to increase capital efficiency, through 'Build-Operate-Transfer' models.[80]

- **New funding streams:** Transforming roads into smart roads is effectively a change from analog to digital. Through IoT and V2X technology, road operators will have access to a wealth of data that will be of value to them in ensuring the smooth-running of the roads, but will also be of value to others. Road operators in the future will be able to monetize this data by selling it to commercial partners, in much the same way that some phone carriers sell customer data to companies wanting to target advertising more effectively. Commercial fleet operators could use the data gathered to plan more efficient routes, for example.



The way forward

How might these challenges be overcome in a way that gives policy makers and other stakeholders the confidence to green-light adopting the technological innovations necessary for the future sustainability of our roads?

- **Achieve a consensus:** The need to transform our roads infrastructure should not be controversial. The need is clear enough, as are the potential societal, economic and environmental benefits. But there are many stakeholders involved in the planning, construction and funding of roads, and there will need to be broad consensus on the need to approach things differently–and the opportunities this presents.
- **Adopt a long term perspective:** Nobody is suggesting that the transformation of our road networks is or even should be a short-term project. It should be seen as a 25-year endeavor, with the benefits accruing and compounding over time. In the US, the 2022 Inflation Reduction Act earmarked billions of dollars for infrastructure investment over the next decade, which presents an historically rare opportunity to take a long term perspective.
- **Embrace innovative funding models:** The cost of upgrading road networks to incorporate new technologies cannot be ignored, and will need to be addressed by policy makers. A range of options are available that require some rethinking of the prevailing model of the past century or more (see panel).
- **Take a flexible approach:** As we have noted, not all roads are created equal. America's Interstate Highway System accounts for 2.6% of all roadway lane miles in the US, but carries 26% of the nation's vehicle travel.[81] Conversely, about 71% of the country's 4.1 million miles of roads are considered rural.[82] Clearly, one size does not fit all, and just as the roads network does not need to be transformed overnight, neither does every road need to be treated in the same way. A mix of solutions, with different technologies applied in situationally appropriate locations, at appropriate times, would appear to be the pragmatic way forward.
- **Pursue a 'mosaic' solution:** Just as we are likely to see different technologies applied in different ways and in different locations, so too are we likely to see a 'mosaic' of different modes of transport. Some car owners will never give up their love of driving themselves, while others will be happy to let the technology do the driving. Public transport will remain a key part of managing capacity and minimizing congestion, as will on-demand solutions such as autonomous robotaxis.

- **Embrace the role of the Private Sector:** Much of the innovation that has the potential to improve our roads is taking place in the Private Sector and the transformation of our roads will require governments to partner with high tech companies, and forge different types of long term partnerships with them. Simply put, the transformation of our roads, and the realization of the benefits of that, will not be possible without the involvement of Private Sector technology firms, with their access to skills, resources, technology and finance.
- **Look to startups for transformational innovation:** While many of the world's largest technology companies are involved in developing solutions that may be applied to upgrade and transform our roads, much of the innovation in this field is coming from new businesses. This is a type of firm with which governments and road operators are unaccustomed to partnering, yet doing so presents the opportunity to develop, pilot and implement truly innovative technologies, and so deliver benefits to taxpayers and road users.

As with any roadmap, we have choices to make. But the desired destination is a world in which roads continue to be a vital part of the infrastructure that keeps global, national and local economies moving.

And reaching that destination is not possible on the road we are on.

The technology required to secure our path to that destination is already here. We just need to embrace it.

We are excited to share the road with our partners on this journey.

Postscript by Geoff Dillon, CEO, Heritage Construction & Materials

Roads are something I think about every day - their composition and construction, the stresses and strains we place on them, their maintenance, the safety of the teams building them, and how to maximize their effectiveness while making the most judicious use of the resources available.

I recognize that I am unusual in that regard and most people take roads for granted, unless or until something goes wrong. I am very happy we remain unnoticed, as this means we are doing our jobs well. I am grateful for the daily hard work of my colleagues, building or repairing the roads themselves, mining and formulating road products, and developing new materials and techniques in Heritage Research Group.

However, as this report highlights, we all have a lot of work ahead to build the next generation of roads that drive our economy for future generations.

For more than 65 years, Heritage Construction & Materials companies have been engaged in building and maintaining the roads and bridges that transformed the American economy into an economic powerhouse. I am proud to say that during that time our business has been at the forefront of innovation, making enhancements to construction techniques, developing new materials, and increasing the sustainability of both over time. This work continues, with more improvements being made constantly.

More than ever, we see that more radical solutions are on the horizon, with new opportunities coming from innovative materials, autonomy, electrification and more.

Every day, my colleagues and I see the hard choices that those responsible for the stewardship of our road infrastructure must make; the choices of which roads' repairs will be prioritized, and which communities will have to wait for their turn.

Even just thinking about road surfacing, we can see that while there are many exciting alternative materials being developed and trialed, asphalt is reliable, durable, cost-effective and, with so much of it recyclable, sustainable. Asphalt will also be part of the make-up of our roads, but it will be joined by other materials, where they are more appropriate solutions. The same goes for construction techniques, materials used for repair, funding models, and every other area.

I endorse my HG Ventures colleagues' view that the future of roads will look different - and it may be a surprise to some that this is something that excites me. Thinking differently about our roads, and how technology can play a bigger part in their future, does not mean scrapping what we currently have, but it means we have new opportunities to serve the public with impactful solutions that benefit all.

The Heritage Group has survived for nearly a century because it has always evolved. More than that, our company has often led the way, and I see the future of our roads as our greatest opportunity yet to continue that tradition of innovation and evolution, so that we all may continue to rely on our roads to keep the world moving.

Geoff Dillon
November 2023

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Joe McGuinness, Avenew

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Justin Patterson, Milestone Contractors LP

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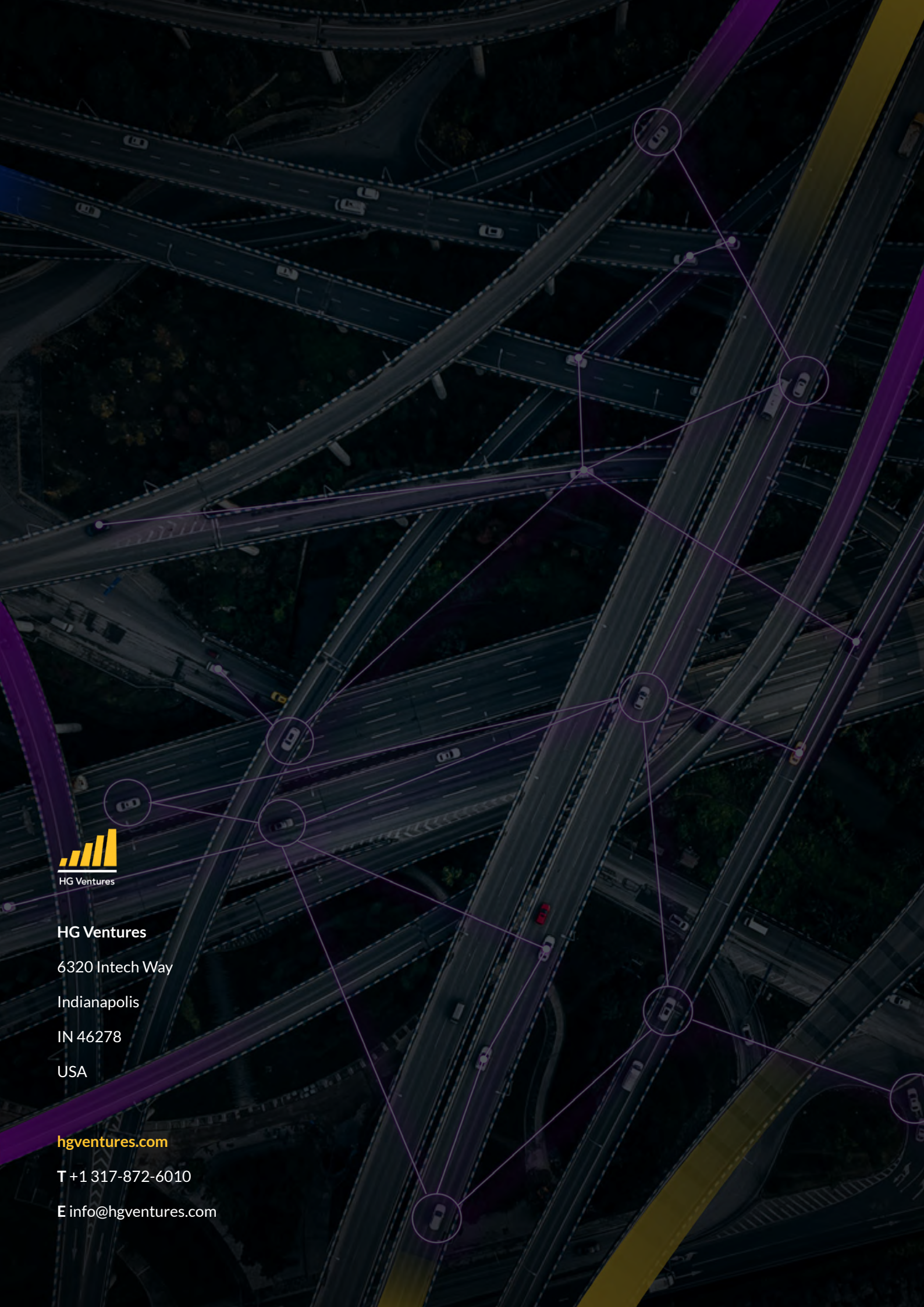
About HG Ventures

HG Ventures is the corporate venture arm of The Heritage Group, headquartered in Indianapolis, Ind. HG Ventures supports innovation and growth across The Heritage Group by investing and partnering with innovative, high-growth companies to support a sustainable future. We leverage the world-class expertise of The Heritage Group operating companies and research center to offer a unique value proposition to our portfolio company partners. **hgventures.com.**



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