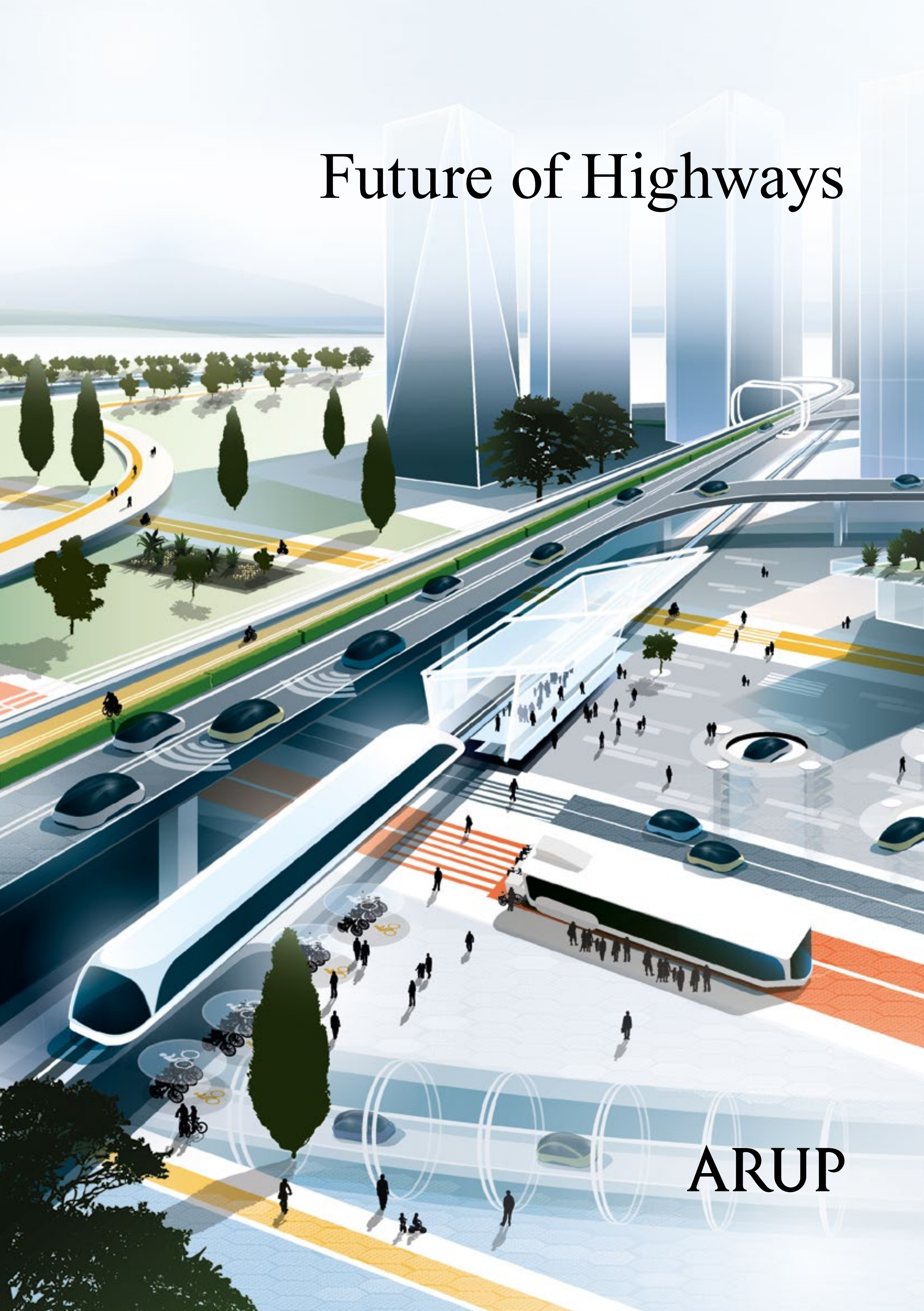
Future of Highways



ARUP

Arup Foresight + Research + Innovation

Foresight + Research + Innovation is Arup's internal think-tank and consultancy which deals with the future of the built environment and society at large. We serve Arup's global business as well as external clients from a broad range of regions and sectors. We help our organisations understand trends, explore new ideas, and radically rethink the future of their businesses. We developed the concept of 'foresight by design', which uses innovative design tools and techniques to bring new ideas to life and engage clients and stakeholders in meaningful conversations about change.

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Foreword

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In the future, highways and transport infrastructure will face increasing pressures and impacts from a range of issues including changing weather patterns, population growth, capacity constraints, shortages of land and capital, and rapidly changing technologies that outstrip the pace of new infrastructure development.

Thinking about these trends and issues, as well as new concepts and emerging solutions, will help us better understand the long-term challenges and will hopefully also inspire innovation across the sector.

For developed cities, transport infrastructure may be repurposed and adapted to accommodate greener modes of travel. Motorised travel in cities will be required to fit into, rather than be at the centre of, planning decisions. In developing countries, rapid population growth and the rise in demand for mobility will require policies and measures to avoid repeating the mistakes of the developed world. This will take foresight as well as strong leadership.

Advanced technologies such as autonomous vehicles, lighter materials and intelligent transport solutions will all play a part in managing the increase in passenger and freight mobility. Changing travel behaviours will also have a significant impact on the transport solutions of the future. As more effective use is made of the big data associated with our transport networks, there will be increasing acceptability of new ownership models, rapid gains in the quality of travel planning, and increasingly sophisticated customer decision-making tools and capabilities.

The long-term goal will be to create an integrated transport network with seamless connections to multiple modes, including cars, buses, rail, and non-motorised transport. By thinking across modes, we can move towards a connected, low-carbon future.

The aim of this report is to look beyond day-to-day challenges and think about the forces driving change, and how these might shape the roads and highways of the future. By pushing the boundaries in thinking about what is possible in highways design, the hope is that the roads of the future will continue to provide benefits for economic growth, productivity and connectivity while minimising any negative impacts associated with highway construction and operation.

Left: Route 8, Tsing Yi to Cheung Sha Wan Highway, Hong Kong

Introduction

“The future is already here — it’s just not evenly distributed”
—William Gibson

Good quality highways infrastructure, including roads, tunnels, bridges, buildings and utilities, brings about a wide range of economic and lifestyle benefits. Highways attract business and promote social wellbeing by providing access to jobs, services, leisure activities and connectivity to other transport modes. However, the limitations of road infrastructure, particularly in cities, is evident where overcrowding and congestion can cause costly delays, pollution and other negative externalities.

Although vehicles and technology have advanced dramatically over the past 40 years, roadways have arguably failed to evolve at the same rapid pace, especially from the user perspective. This is changing, as new technologies have the potential to make radical changes to the construction, management and efficiency of road infrastructure. Consequently, the roads of the future may look and perform very differently to today.

What will highways look like in the future? How will they cope in a world experiencing a rising demand for mobility and freight capacity? In an age of rapid economic, political, social, environmental and technological change, the future is far from certain. But we can explore possible futures based on current trends and trajectories as well as emerging ideas and solutions.

This thought-piece moves beyond the day-to-day focus on current challenges and opportunities and explores the forces that Arup believes may shape highways and the use of transport infrastructure in the future.

Firstly, this report looks at the macro-forces that will drive changes in highway design. Megatrends such as climate change will impel environmental improvements in construction materials, construction techniques and infrastructure resilience. Technological changes such as connected infrastructure, vehicle- to-vehicle communication, smart logistics, new materials and new powertrains are also likely to impact the design and construction of roads. Changing user behaviours and preferences, as well as new ways to finance infrastructure, will all have an impact on how roads are utilised and paid for in the future.

Secondly, this report focuses on the user experience of transportation and highways infrastructure. The user journeys imagined here are intended to set out a forward-looking, inspiring vision for highways and to challenge our thinking about the future.

Finally, the case studies that are included throughout the user journeys indicate emerging trends taking place in highways design. They are early signs of possible future change, and reveal directions in which we could be heading.

Left: View from a pedestrian bridge, Singapore

Megatrends

Megatrends are the game-changing forces that will shape the world in the years ahead. As drivers of change, these are far-reaching, sustained and relatively certain. These macro forces will present both challenges and opportunities as they transform the way society and markets function. The megatrends described below will have global implications for transport infrastructure and transport services.

An urban world

Today, over half the world's population lives in cities. It is estimated that the global urban population is growing at a rate of two people per second, adding 172,800 new city-dwellers each day.[1] This rapid urbanisation means that by 2050 around 70-75% of the global population will be urban dwellers.

Within this overall growth, the pace of urbanisation will vary across the world. Megacities (cities with populations of over 10 million people) are increasing in number and size and most of these are located in emerging markets. China and India will lead the wave of urbanisation and between 2011 and 2030 these countries will account for 40% of the world's urban growth. Of the world's 24 megacities, four are in China; by 2025 there will be three more. This is some of the fastest urban expansion in history.[2] By 2030, there will be six Indian megacities with populations of 10 million or more, and it is estimated that more than 30 million people will live in Mumbai and 26 million people will live in Delhi.[3]

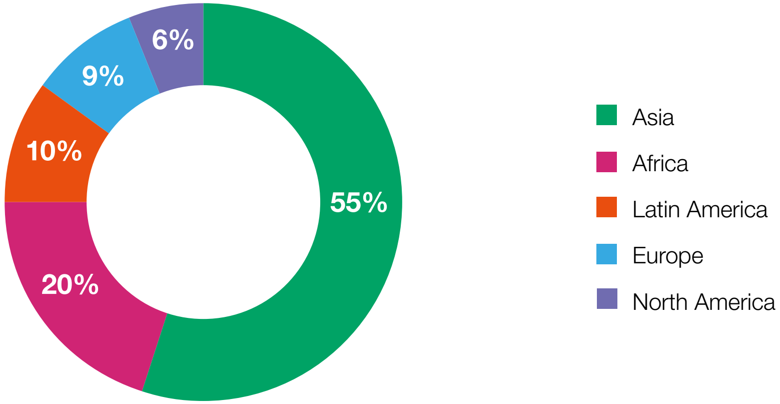
The increasing pace of urbanisation will place added stress on already strained city systems and infrastructure. As cities expand and people become more prosperous, the desire for individual mobility will grow, potentially leading to gridlocked streets.

Of the world's 24 megacities, four are in China and by 2025 there will be three more. This is some of the fastest urban expansion in history.

Left: Times Square Pedestrian Plaza, New York

Distribution of the world's urban population in 2050

Source: World Urbanisation Report (2011)



The number of motorised vehicles worldwide is expected to increase by 3% annually until 2030. Rates of growth in Europe and the U.S. are likely to be slow (1% and 2% respectively), but in India growth rates could be as high as 7 or 8%.[4] China is also seeing the number of vehicles on its roads expand exponentially. According to the China Ministry of Public Security, the vehicle population in China reached 240 million in 2012, of which 120 million were passenger cars. The 15.1 million new cars added in 2012 totalled more than the entire car count at the end of 1999, which shows the challenges posed to the government in controlling emissions and traffic congestion in China's cities.[5]

The growth of megacities may also lead to unprecedented urban sprawl, new slums and a growing gap between the rich and poor. This is a global trend with the richest 1% of people now owning nearly half of all of the wealth on the planet.[6] Currently about 1 billion people live in slums, and over 90% of these slums are located in cities of developing countries.[7] By 2050 the slum population could be as large as 3 billion.[8]

The number of motorised vehicles worldwide is expected to increase by 3% annually until 2030.

Technology and connectivity

The growing pace of technological change will be one of the major drivers for the transport sector. The history of technological progress provides powerful evidence that change is not linear but exponential, and cycles of innovation and technological improvements are very likely to accelerate further.

New developments in areas such as nanotechnology, information and communication technologies, and robotics are providing new opportunities for innovation and growth. Advances in nanotechnology in particular may lead to new materials that are lighter, stronger, smarter and greener. Materials like graphene, which has revolutionary properties in terms of strength, flexibility and conductivity, could have numerous applications and support completely new structures, while self-healing materials may lead to lower maintenance costs by extending the lifetime of structures and decreasing the need for repairs.

It is expected that lighter materials (aluminium, carbon-fibre composites, high-strength steel) combined with better aerodynamics could potentially double vehicles' fuel efficiency.[9] Developments in material science are also dramatically improving the performance of batteries, changing the potential for electricity storage.[10]

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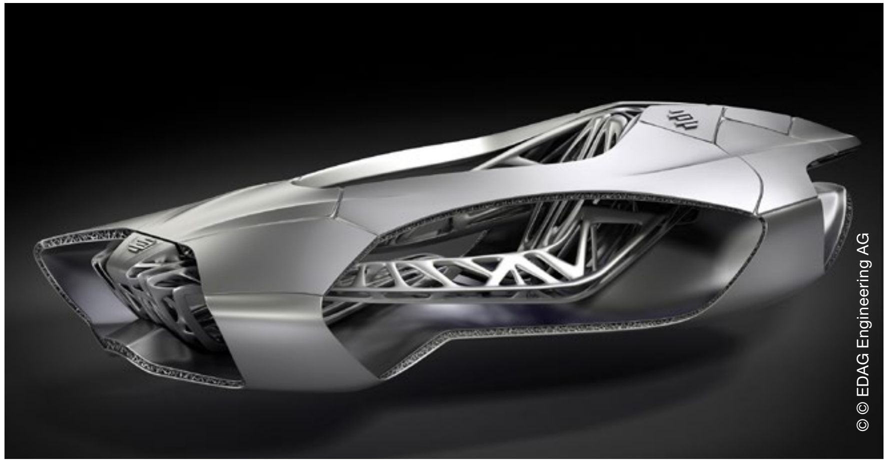


EDAG, a German engineering firm, has designed a fully 3D printed car body known as Genesis. It is also an example of biomimicry, based on a turtle's shell, to provide protection and cushioning.

3D printing, or additive manufacturing, is being hailed as a breakthrough technology which could lead to a new industrial revolution. The technology could have a dramatic effect on the vehicle manufacturing industry. Entire vehicles could be produced by additive manufacturing, allowing shape and form to be much more flexible and the vehicle body to be lighter and stronger. Additive manufacturing could also make vehicle maintenance cheaper as parts could be printed on-demand closer to the consumer, thereby reducing the cost of shipping and storing spares.

The rise of the Internet of Things — the connection of a huge range of devices, sensors, and machines to the Web — will enable new technologies, platforms and services to multiply and scale up. Today, there are about 1.84 connected devices per person on the planet. By 2020, this will rise to around 6.6 devices per person. Currently, 99% of physical objects that may one day be part of this network are still unconnected.[11] The Internet of Things will enable the rise of technologies such as intelligent vehicles that can self-monitor and self-diagnose, communicate with other vehicles and the wider environment, and measure the latest traffic, road and weather conditions.[12] Vehicle-to-vehicle communication will enable cars to broadcast their speed and direction and warn other vehicles about potential safety hazards. Wireless sensor networks combined with ultra-low power sensors will make it possible to monitor a wide range of structures like bridges or tunnels.[13]

Fully automated navigation systems will enable driverless vehicle technology and open up new markets for automotive companies to sell to the elderly, or those with physical or mental impairments. Driverless vehicles will also have implications for the infrastructure that supports them. Roads could be made narrower, for example, and roadside signage could be reduced. Driverless cars could also increase the peak capacity of the existing infrastructure because they can safely travel in closer proximity to other vehicles.

Intelligent robots may play a greater role in the inspection of infrastructure such as tunnels and bridges, and in the efficient maintenance of ageing structures. For example, smart robots are already being built to repair and retrofit ageing water pipes, while crawling robots can test load-bearing cables and tethers of bridges, elevators and cable cars. Swarm robotics is another area for future transport and infrastructure projects. A theory based on behaviour seen in ant and bee colonies, swarm robotics involves small individual robots working collectively towards a larger goal by distributing the work. Large-scale construction, as well as infrastructure repair, could benefit from swarms of cheap robots in the future.[14]

Smart robots are being deployed to inspect and repair ageing water infrastructure as well as to examine and evaluate the condition of load-bearing cables.

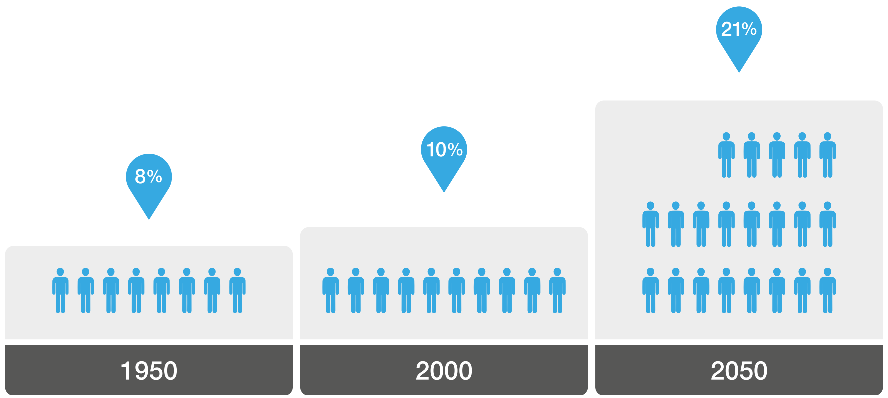
A growing and ageing population

The global population is expected to reach around 9.5 billion in 2050, by which stage the population will still be growing but the rate of growth will have slowed. Not all regions will grow equally, with some parts of the world experiencing explosive growth while others will continue to experience population decline. By 2050, the populations of Russia, Japan and Germany are expected to decrease by more than 10%. This means that Russia would lose 23 million people, Japan would lose 19 million; and Germany would lose 10 million.[15] An estimated 90% of future population growth is expected to occur in the cities of the developing world,[16] with India replacing China as the world's most populous country.

With more than 20% of the world population 60 years old or over in 2050 — an estimated 2 billion people — ageing populations will have an impact on the design and choice of mobility solutions as older generations could have markedly different needs, preferences and concerns to previous

Proportion of the world population aged 60 years or more

Source: World Urbanisation Report (2011)



generations. Within this overall trend, some societies will age rapidly, which means that the supply of working-age people will decline as a proportion of the total population and working age people will have to support more dependents. This could have implications for the cost and affordability of transport options. In other regions there will be more young people, providing a larger work-force and growing consumer markets, but also placing strain on existing systems.

By 2050 it is expected that 50% of the world's population will have moved into the middle class, which will have important implications for how people choose to travel. Emerging economies are predicted to contribute the most to this trend, especially Asia, and by 2030, nearly two thirds of the global population — 5 billion people — could be classified as middle class.[17]

Demographic and economic shifts will result in a new global order. Much of the economic growth will be concentrated in China, and South and Southeast Asia. China will likely overtake the United States at some unspecified point in the next 50 years to become the world's largest economy with a population growth of 1.43 billion. India's economy will grow rapidly from US$960 billion to more than US$8 trillion by 2050, adding 400 million people to its population.[18]

> By 2050 it is expected that 50% of the world's population will have moved into the middle class, which will have important implications for how people choose to travel.

Changing behaviour and the sharing economy

In some parts of the world, increased awareness of environmental concerns and greater global regulation is causing individuals and corporations to engage in more sustainable patterns of behaviour, while increased public focus on health and wellness is shifting mobility choices towards more active modes such as walking and cycling. High density and integrated transport planning are crucial ingredients to raise the modal share of non-motorised transport (NMT) in cities. Walking, cycling and other modes of transport running on human energy help promote healthier citizens as well as remove the adverse impacts of emissions and other pollutants.[19] NMT also increases affordable access to vital services and employment.

Transport systems in the future will focus on multi-modal solutions, with seamless transfer between different modes. Smart ticketing systems, dynamic and real-time travel planners, and convenient and reliable car and bike sharing services can contribute to this goal.

Traditional models of ownership are also changing, especially within younger generations. For example, the trend towards a shared economy of service provision rather than product ownership means that consumers are increasingly likely to purchase access to a car rather than buy their own

car. Both car ownership and vehicle-kilometres in cities in developed countries may be reaching saturation, or even be decreasing. Vehicle ownership is not necessarily the best model for urban residents who prefer access to as many transport modes and routes as possible.[20]

The trend towards the sharing economy is more likely to take hold in the developed world, while in developing countries car ownership is likely to remain a trend and aspiration for some time.

Changing weather patterns

The effects of climate change are complex and wide ranging, but there is an ever-growing body of evidence to suggest that there will be an increase in the frequency and intensity of extreme weather events. With growing populations living in closer proximity and expanding to areas more vulnerable to flooding or sea level rise, this also means that more and more people will be affected by climate change.

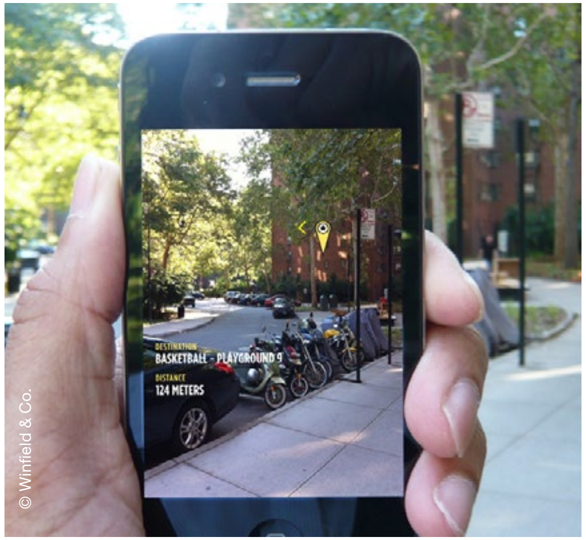
Changes in temperature, more intense storm activity and sea level rises may have important implications for transport infrastructure design, operation and maintenance. This could increase the risk of disruptions, damage and failure of transport systems.

Climate change is projected to concentrate rainfall into more intense storms. Heavy rainfall and flooding could affect infrastructure repair and construction, disrupt traffic flow and weaken the infrastructure that supports roads, tunnels, and bridges. Roads in areas along the coast are particularly vulnerable to more frequent flooding or submergence from sea level rise and storm surges.[21] Paved roads are sensitive to extreme heat, as well. At certain high temperatures, roads can weaken and degrade even under normal or light traffic loads.

The road network in developing countries is particularly vulnerable due to more unpaved roads, poor infrastructure condition and limited resources. Developing countries will need to spend about US$200-300 billion per year by 2020 to ensure that public infrastructure — like bridges, power supplies and roads — is more resilient to the effects of climate change.[22]

Heavy rainfall and flooding could affect infrastructure repair and construction, disrupt traffic flow and weaken the infrastructure that supports roads, tunnels, and bridges.

Left: Arup Assists Taiwan in Post-Typhoon Reconstruction



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Roads are also one of the greatest contributors to greenhouse gas emissions, both directly through mining, transporting, and road construction, and indirectly through the emissions of the vehicles that utilise them. To limit the increase in average global temperature to within 2°C by 2100, emissions of greenhouse gases worldwide will have to be cut by 40 – 70% by 2050 from their 2010 levels.[23] This will require subjecting carbon emissions to much tighter regulations and stronger price mechanisms than today. More stringent regulations on emissions may affect the planning and operation of transportation systems, with a preference for greener materials and modes of travel. Vehicles will have to adapt to these regulations and road infrastructure will have to accommodate new vehicle and fuel technologies.

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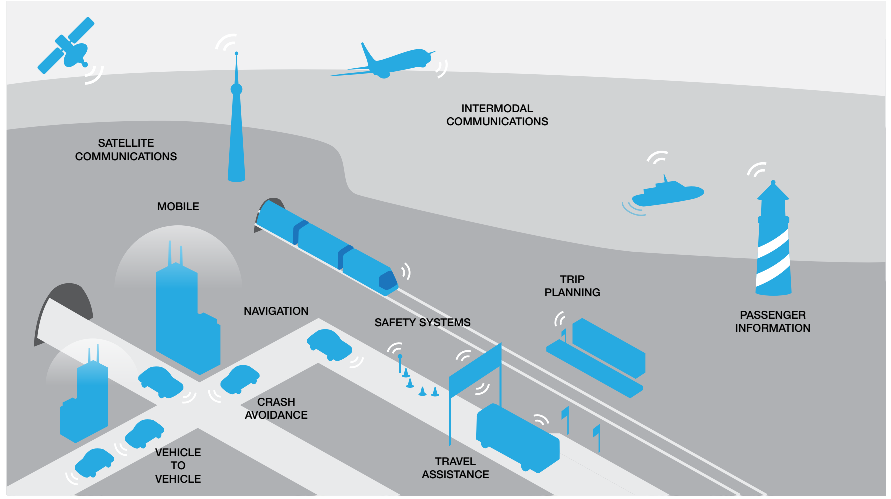
Smart and integrated mobility

According to the International Transport Forum, by 2050 there will be around three to four times as much global passenger mobility (compared to 2000) and 2.5 to 3.5 times as much freight activity.[24] This means that smart solutions will need to be implemented to provide adequate transport capacity for growing volumes of goods and people.



Intelligent Transport Systems include communications in vehicles, between vehicles, and between vehicles and fixed locations. Source: European Telecommunications Standards Institute

The incredible pace of technological change in transportation makes it difficult to know exactly what changes will occur or how they will play out. However, trends point to an intelligent, more integrated system for moving passengers and freight.

For transport, advances in Information Communications Technology will have far-reaching impacts, making it more integrated, efficient, comfortable and eco-friendly. Machine-to-machine (M2M) technology will increase efficiency by automating tasks and providing real-time analysis through the use of sensors inserted into objects and systems.[25]

Increases in computer power and the ability to handle the processing of large amounts of data in real time, will lead to more effective use of big data. Big data and the Internet of Things will allow transportation modes to communicate with each other and with the environment, paving the way for truly integrated and inter-modal transport solutions that maximise efficiency gains.

Cloud-based services will become more widespread driven by the uptake of smarter mobile devices and faster connectivity. Smart communications technology will be one of the key infrastructures of future cities, helping to limit

Advances in ICT will have far-reaching impacts, making transport more integrated, efficient, comfortable and eco-friendly.

the use of resources and improve liveability.[26] Intelligent Transport Systems will enable better traffic flows, more accurate road pricing, and enhanced capacity and safety.

The advent of Web 3.0 will provide users with richer and more relevant experiences. Users will increasingly be able to access data from anywhere through smart devices and cloud applications. Web 3.0 will be driven by the meaning of data, personalisation, intelligent search and behavioural advertising.[27]

Smart communications technology will be one of the key infrastructures of future cities, helping to limit resource use and improve liveability.

Energy and resources

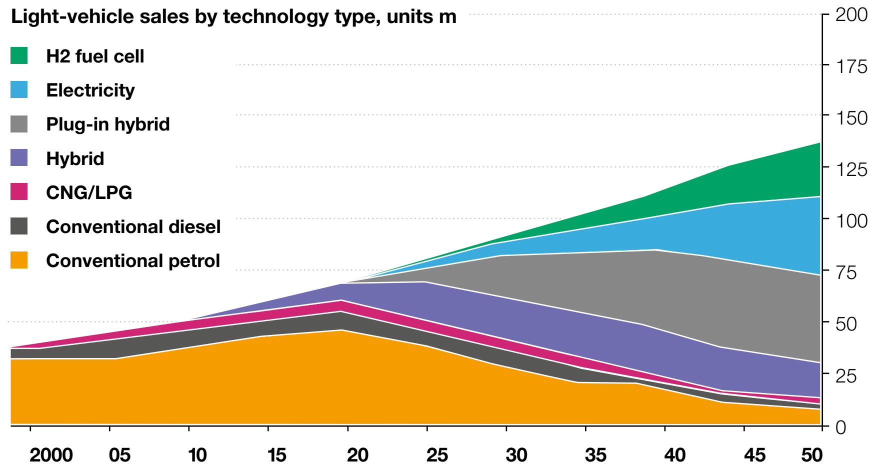
A larger global population with expanding consumption needs will place growing demands on energy and resources. Global consumption of resources will nearly triple to 140 billion tons per year by 2050, if economic progression and consumption continue on their trajectories.[28] This surging demand will occur at a time when finding new sources of supply and methods of extraction is becoming increasingly difficult and expensive.

The resources required to sustain current levels of economic growth may not be available over the next decades. Constraints on available resources, and high and volatile prices, may limit economic growth. However, by 2050 there could be better application of a circular economy — where used materials are recycled back into the production stream, thereby reducing waste.

Global consumption of resources will reach 140 billion tons per year by 2050, nearly triple the current rate.

The political instability in many oil-rich regions will create uncertainty about oil supplies and prices, and is likely to underpin the shift towards alternative forms of fuel. New fuel technologies, such as LNG (liquefied natural gas), hydrogen and algae will also cause a shift away from fossil fuels.

These new fuel technologies will also drive advances in combustion engines or replace them with new drivetrains altogether. Performance across drivetrain technologies is rapidly improving, including plug-in electric, battery electric, internal combustion, hydrogen fuel cells and natural gas. This mix will play a crucial role in improving fuel efficiency and reducing operating costs. It is unlikely that there will be just one drivetrain solution for the future, and there will be



By 2050 the world's car fleet is likely to be propelled by a broad mix of powertrains.
Source: International Energy Agency.

a large role for dedicated hybrids. Due to the fact that most drivetrains in the future will be electrified to some extent, it will be vital that there are well-developed networks of chargers to support battery electric vehicles.[29]

In the future, wireless charging infrastructure could also be embedded in the road, providing induction charging for electric vehicles on the go. The availability of alternative fuels could lower transportation costs significantly and transform global economics. There will be a marked shift in transport fuel demand from developed countries to developing ones, most notably China and India.

These new fuel technologies will also drive advances in combustion engines or replace them with new drivetrains altogether.


1 Cloud-based information management
2 Monitoring drone for predictive maintenance
3 Freight shuttle system for high-volume freight containers
4 Bioluminescent trees for natural street lighting
5 Dedicated cycle and pedestrian lanes
6 Urban greenway to encourage walking and cycling
7 Congestion Charging Zone to encourage use of public transport
8 Self-healing road surface
9 Cycle superhighway separated from traffic
10 Vehicle-to-vehicle communication
11 Recycled material roadway
12 Photo-luminising road markings that glow in the dark
13 Space-saving underground car parks
14 Fully synchronised traffic signals
15 Wireless induction charging for electric vehicles
16 Solar roadways for power generation
17 Integrated bike racks on all buses
18 Transparent LCD information displays on buses
19 Smart fare collection for ticketless travel
20 Intelligent pedestrian crossing
21 Driverless vehicle to increase safety and relieve congestion
22 Underground roadway for non-autonomous vehicles
© Rob House

User Journeys

The following journeys reflect visionary experiences of future road users and set out a forward-looking and inspiring vision for the highways of the future.

The case studies highlight emerging trends and indicate directions in which the future could be heading. They include technical elements to support the vision of future user journeys.

Thandi Ndebele, 35 — Financial Analyst

Thandi lives alone in a gated community town-house in the city's leafy suburbs. Although she has a car of her own, it is far more efficient and relaxing to take the bus to work. She wouldn't be able to drive her car all the way to work in any case, due to private vehicle restrictions in the city centre as well as limitations on non-automated vehicles. She tends to only use her electric vehicle on weekends in the suburbs and, every now and then, to travel to see her family on a farm a few hours away.

Thandi is heading for the number 49 bus to work, which according to her mobility app, will arrive in 3 minutes' time. As she waits, she notices a visually impaired commuter using a robotic smart cane to monitor his surrounding environment and direct him accordingly. The man's smart bracelet also provides him with real-time travel information via an ear-piece so he knows when his bus is nearing the stop.

Thandi turns to see the driverless electric bus approaching. It glides to a stop on the inductive power transfer pad and the sliding doors open. As the bus waits, the battery is given enough of a boost to power it until the bus reaches the end of its scheduled route. The transparent LCD displays covering the bus flash information about the bus route, the weather and news headlines along with advertisements.

Thandi allows the visually impaired man to board in front of her, and notices a light above the doorway flash green, indicating that his authorisation to travel is valid. Thandi sees a lady slotting her bike onto the rack on the front of the bus and the LCD display acknowledges that there are now two bike racks in use. As she settles into her seat, Thandi connects to the bus Wi-Fi and watches an episode of a documentary series as she heads towards the city.

Soon, the bus enters an urban greenway which has dedicated lanes for electric buses, as well as bicycles and pedestrians, separated from each other by trees and landscaping. Besides public transport electric vehicles, the greenway is a car free zone. It was developed on the site of the old, car-congested highway and provides a faster and far more pleasant commute into the city. The bus travels quietly along the recycled material roadway and stops at a signal which has detected that a number of pedestrians are waiting to cross. The signal dynamically adjusts its timing according to vehicle and pedestrian flows.

As she watches her screen, Thandi notices a swarm of robots out of the corner of her eye. She glances up to see that the robots are repairing the surface of the cycle pathway about five metres away.

An alert pops up to remind Thandi that her stop is approaching and she steps towards the doors to disembark. From the bus stop to her office, Thandi follows a pedestrian-only route. Energy-recovering flooring on a section of the route generates electricity from footfall to power the streetlights and convenience kiosks that line the pedestrian zone.

Case Study: Wireless Inductive Charging for Buses

In January 2014 a fleet of eight electric buses began operation in Milton Keynes, UK. The buses receive a wireless booster charge from plates set into the road at the start and end of the busy bus route. The technology allows for an energy-transfer efficiency of 90% or higher. The 10-minute top-ups allow the bus to complete its entire 17-hour working day on battery power alone. The buses are being trialled in a collaboration programme being led by eFleet Integrated Service ("eFIS"), an enabling company set up by Mitsui & Co Europe and Arup.

Case Study: LCD Panelled Bus

The Willie Bus designed by Tad Orlowski is a concept that uses transparent LCD screens on the exterior to transform the bus into a giant, moving LCD screen. It can project information such as adverts, route plans, tourist information or weather reports.

Case Study: Intelligent Pedestrian Crossings

In the summer of 2014, Transport for London (TfL) began trialling a new technology called “Pedestrian SCOOT” (Split Cycle Offset Optimisation Technique), the first system of its kind in the world for pedestrian signals. The system uses high-tech video cameras to detect pedestrian numbers at crossings, and extends the green man light when large numbers of people are waiting to cross the road. TfL is also developing a call cancel technology which can detect when a pedestrian who has pushed the crossing button has either crossed before the signal goes green or walks away, thereby eliminating needless traffic delays.

Case Study: Smart Fare Collection

HopOn is a smart mobile payment and ticketing platform for public transport. It uses ultrasonic sound for fare validation enabling many passengers to board a bus at the same time. The validation occurs via the passenger’s smartphone and the cloud. The ultrasonic transmitter usually operates within two to three metres of the entrance of the vehicle, but can be easily calibrated to varying distances, which means no standing in line.

Case Study: Hamburg Urban Greenway

The city of Hamburg is planning to create an extensive 27 square-mile network of bike and pedestrian greenways to provide easy access to the entire city, without requiring users to interact with motor vehicle traffic. It will link green areas on the outskirts of the city with parks, recreational areas, gardens and other green spaces within the city. The result will be easier access to nature for every resident, and a city that is more resilient to flooding and less reliant on motorised transport. The green network will cover 40% of the city’s land area. There is also a plan to cap a two-mile stretch of a major highway with woods, parks, trails, and garden plots for city residents.

Case Study: Energy from Footfall

A trial is underway in St Omer, France, to harness energy from the footfall of pedestrians. Fourteen of Pavegen’s energy tiles have been installed on part of a pavement outside a busy train station. These tiles harness and convert kinetic energy from pedestrians into electricity that then powers parts of the station. More than 5,000 people walk over the tiles each day, and it is estimated that the installation will result in a 30% energy saving for the train station over an 18-month period.

Jake, Zoe and Diego, 21 — Students

Jake, Zoe and Diego attend university in the same city, although they all originate from other parts of the world. The three friends met while studying Entrepreneurship and share a love for seeing different areas of their new country. They work hard on their course as they know how much competition there is for jobs: all three believe that working for themselves will be the most rewarding career path.

Diego confirms their destination by speaking to the in-car navigation system and chooses the most direct route to their destination. It looks as though most of their trip will be made on dedicated automated highways.

Jake, Zoe and Diego throw their bags into the back of an autonomous shared car and chatter excitedly as they bundle in from the cold. The three friends have a two week break from studying and have decided to take a road trip to Niagara Falls for a few days. According to news reports, the falls have almost frozen over in the extreme cold weather. By notifying the highway management system in advance of their trip, they have saved some of the cost of road usage charges.

Diego confirms their destination by speaking to the in-car navigation system and chooses the most direct route to their destination. It looks as though most of their trip will be made on dedicated automated highways, so they plan to make full use of the included entertainment-on-demand service on their journey. They also select to receive historical and cultural information about passing landmarks. As the car makes its way out of the city, they tear open cardboard drinks and activate the entertainment system. The lightweight, carbon fibre car travels at a steady distance from the vehicle ahead, constantly communicating its position via a system of sensors. The billboards that once blighted this part of the inner-city highway are long gone; without a driver, the focus of car passengers is internal to the vehicle. Where billboards once loomed, green buildings now stand. Buildings in the city are covered with algae facades and vertical gardens, and there are urban greenways in areas where heavy traffic once used to clog the streets. There are also dedicated cycle and pedestrian lanes alongside the highway, which has separate lanes for automated passenger vehicles and public transport.

Once the car reaches the city outskirts, it detects a change in speed limit and accelerates to merge with the fast flowing traffic. As this highway is high volume and dedicated to autonomous vehicles, any human-controlled vehicles are prohibited. A few hours later, engrossed in an interactive 3D game, the three friends don't notice the car moving onto the inductive priority changing lane, which tops up the car battery on the go. At the end of the lane the vehicle passes over a payment strip which deducts the cost of the charging automatically.

About an hour from Niagara Falls the vehicle navigation system voices an alert about the icy road conditions, to explain the slight drop in vehicle speed. Jake looks out of the car window and sees temperature-activated snowflake symbols on the road surface. These symbols are a holdover from a decade ago; when the road was open to self-drive vehicles they served to warn drivers of icy conditions. The car automatically slows down and the tyres deploy retractable studs for a better grip on the slippery road surface. Jake instructs the vehicle to continue on its course, as there is no indication of any significant delays due to ice on the road ahead.

Just before dark, the group arrives at their lodging. They unpack the vehicle, then accept the command to end the journey. Once the doors slide closed, the vehicle moves off to its next pick-up point.

Case Study: Smart and Dynamic Highways

The Smart Highway, by Studio Roosegaarde and civil engineering firm Heijmans, is a concept to develop more dynamic highways. The aim is to make roads that are safer and more sustainable by using interactive lights, smart energy and road signs that adapt to specific traffic conditions.

One idea is to use a photo-luminising powder for road markings that charges during the day to slowly emit a green glow at night. A trial of the glow-in-the-dark road markings has been launched in 2014 on 500m of highway N329 near the town of Oss in the Netherlands.

The use of small wind turbines along the roadside could also provide an emission-free source of illumination. LED lights would be attached to small turbines placed at certain intervals to take advantage of wind generated by passing vehicles.

Another idea in development is to use temperature-sensitive paint to create giant snow flake-shaped warning signs on the roads to indicate icy conditions.

Case Study: Retractable Tyre Studs

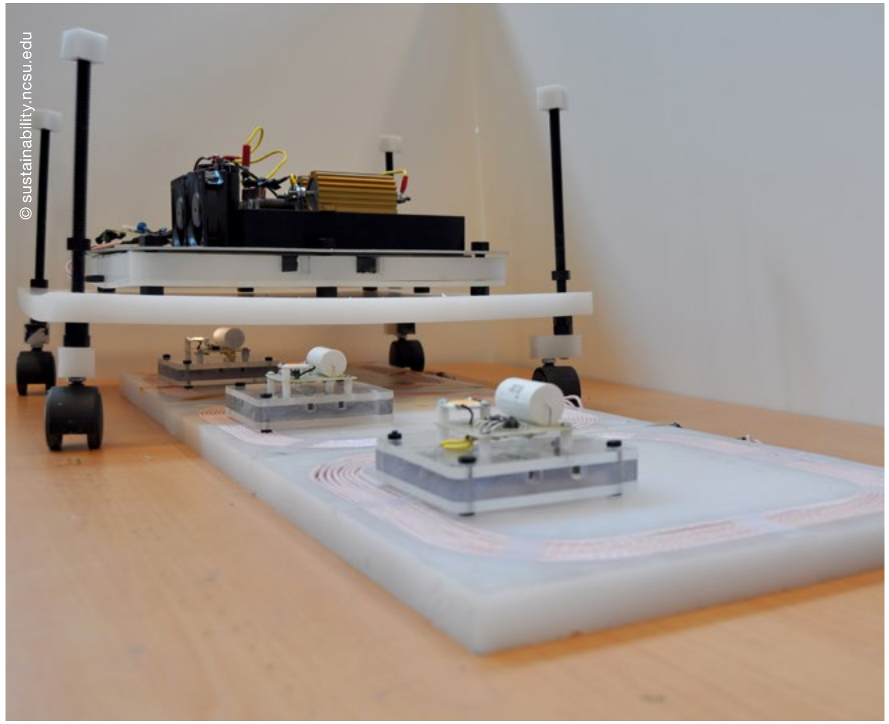
Nordic tyre manufacturer, Nokian, has created a snow tyre with retractable studs. These studs make it easier and safer to drive on ice, but can be retracted when used on dry tarmac to stop them being worn down. A driver could activate and withdraw the studs on all four wheels by the press of a button. The project is in demonstration stage.

Case Study: Driverless Vehicles

Technology giant Google, has been working on driverless vehicle technology for a number of years and Google's automated cars have now driven 700,000 miles (1.1 million km) around Mountain View in California.

Google's self-driving vehicles have shown that they can recognise and respond to roadworks, level crossings, complex intersections and a variety of communications with cyclists. For example, using laser imaging, the car can recognise a cyclist waving his hand, will expect the cyclist to move over and will not pass until it is safe to do so.

In 2014, Google launched their first scratch-built driverless car; the vehicle has no steering wheel or pedals, and a top speed of 25mph (40km/h). The company aims to build 100 of the electric vehicles for testing. The cars will be equipped with two buttons — one to start the vehicle and one for panic stop.



Case Study: Dynamic Electric Vehicle Charging

The ability to charge electric vehicles while driving could one day be a reality. Researchers at North Carolina State University have developed new technology and techniques to enable the wireless transmission of power from a stationary source to a mobile receiver. The system uses a specialised receiver that generates a burst of power only when a vehicle passes over a wireless transmitter. Early models suggest that installing charging coils in 10% of a roadway would extend the driving range of an electric vehicle from about 96 km to 480 km.

Aarav Pilay, 45 — Freight Controller

Aarav works for the Port Authority, helping to control the flow of shipping traffic in and out of the bustling port. He is also responsible for tracking shipments to their destinations. The automated tracking and monitoring makes his job much easier. Although he is trained to deal with incidents, there haven't been many occasions where he has needed to take corrective action. He lives a couple of kilometres from the port with his family and walks to and from work every day.

Aarav glances out of his office window overlooking the port as shipping containers are lowered onto a convoy of waiting freight trucks. He turns back to his screen and notices that the containers are destined for a number of cities in the west and north of the country. An alert tells him the convoy of autonomous trucks is loaded up and ready to go, and he watches as it makes its way out of the port.

The convoy will travel on a dedicated lane on a plastic roadway until it reaches the other side of the city. From there, the trucks will disperse to different locations. Aarav sees that the majority of the trucks will connect with the freight shuttle system on National Highway No. 3. This system carries cargo on an elevated, dedicated track above a 600km stretch of highway. The unmanned shuttles are propelled by electric, linear induction motors and can travel without inferences from other transport systems. The system makes it easier to implement pay-per-mile charging for container freight as it weighs and tracks each shuttle. It is also much safer in terms of accident prevention and security.

Robotic arms unload the containers from the specified trucks and slot them onto the shuttles. They are then whisked northwards.

Five hours later, as Aarav prepares to head home for the day, the tracking system informs him that the freight containers on Highway No.3 have reached the freight consolidation centre outside of Jaidur. Here, the shipping containers will be unloaded and the contents scanned and sorted for distribution. The goods destined for certain parts of the city will be consolidated and loaded onto electric vehicles.

Heavier vehicles are only allowed to deliver in off-peak traffic hours, but light goods electric vehicles operate throughout the day to deliver priority goods. The consolidation centre in Jaidur also provides a base station for services to areas where the road infrastructure is not adequate or reliable. For these hard-to-reach rural areas, a fleet of drones carries small deliveries and necessary medical supplies. These drones provide vital connectivity to remote areas and are often a lifeline for the rural poor.

Case Study: India's Plastic Roadways

Rajagopalan Vasudevan, a professor of chemistry at Thiagarajar College of Engineering near Madurai, has devised an innovative way of dealing with the 15,000 tons of plastic waste generated daily in India: creating roads.

Vasudevan's method transforms common plastic waste into a partial substitute for the bitumen in roadways. This has a number of advantages as it uses a largely non-recyclable waste product to build stronger roads, which also cost less to construct. This simple technique requires little specialist knowledge, and doesn't require large investments or changes to road-laying methods.

The method can use a variety of plastic types, including multi-layered wrappings, which are shredded, heated and used to cover granite pebbles. More than 5,000 km of plastic roads have been laid in 11 states in India.

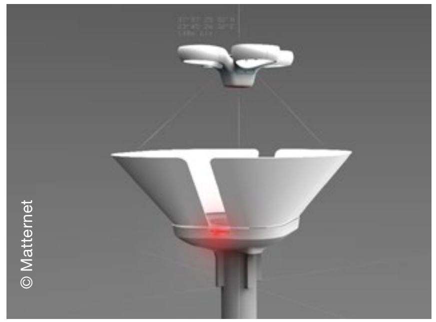
Case Study: Freight Consolidation Centres

FREVUE (Freight Electric Vehicles in Urban Europe), an EU funded project, is looking into the electrification of supply chains in eight cities to demonstrate the benefits of electric vehicles operating last mile freight movement in city centres. FREVUE will see demonstrator projects running in eight countries, drawing on the expertise of over 30 partners. Arup is leading one of two London projects which will aim to deliver significant traffic reduction and improved air quality. Arup, working with The Crown Estate and Land Securities, is looking to establish new consolidation centres for end-users with significant logistics delivery demands.

Case Study: Volvo Self-Drive Convoy

Over the past few years, Volvo has been testing self-driven vehicle convoys, where cars are wirelessly linked to each other and follow a lead vehicle controlled by a driver. In 2012, in the first public test of such vehicles, a convoy of self-driven cars comprising three cars and a truck, completed a 200km (125-mile) journey on a Spanish motorway. Using wireless communication, the vehicles in the platoon "mimicked" the lead vehicle using autonomous control. Vehicle convoys can reduce congestion through more efficient use of road space and cut fuel consumption by up to 20%.

Case Study: Drone Delivery System



US company Matternet is designing a drone delivery network for regions, particularly in low-income countries, where a road network doesn't exist or is unreliable. In such areas, lightweight, autonomous drones could be the fastest and most cost-effective method for delivering food, medicine, and other necessities to isolated communities. Matternet proposes a system of base stations where drones could rapidly switch batteries or payloads with other drones and then continue through the network of base stations to their drop-off or collection point. According to Matternet, this cheaper and more environmentally friendly transport system could be a substitute for expensive investments in road infrastructure.

Gabriela Viegas, 51 — Corporate Executive

Gabriela is Chief Operating Officer of a large aerogels firm and enjoys the corporate perks. She lives in a clean, quiet residential neighbourhood in the outskirts of the city. Her husband teaches at the local secondary school. When he's not biking in to work he usually takes a bus, which stops locally on demand. Gabriela prefers to use an autonomous car service to get in to the city, although she sometimes takes the train as she likes the walk to the station.

Gabriela is preparing for a meeting with a supplier of insulated eco-windows and hopes to close an important contract. As she kisses her two sons goodbye and heads towards the front door, an alert informs her that the car service has arrived and is waiting outside. She climbs into the car's spacious passenger area, noting that the vehicle's interior has been adjusted according to her saved preferences. The polished side table is in position, the arm rests have been stowed and the smart glazing has been given additional tint. A console slides towards her and she confirms her destination. She agrees to the vehicle's proposed route and, at her voice command, the car pulls away into the light morning traffic.

Within ten minutes she joins a three-lane carriageway and begins to cruise towards the city's commercial district.

In the few years since the city authorities mandated that only autonomous vehicles can use the city's roads, congestion has eased significantly. There are no accidents these days, and the dynamic speed limits have relaxed as a result. Most of the cars Gabriela sees around her are electric or hybrid. She recalls the air and noise pollution caused by petrol and diesel cars and buses when she was a girl, and she is grateful that her sons don't have to endure such conditions.

The highway is paved with solar panels which help power some of the city's neighbourhoods and also provide power to electric vehicles. The panels contain LED lighting to display traffic markings and information and also have a section to store, treat, and move stormwater.

As Gabriela arranges her paperwork she is asked by the vehicle if she would like to join a train of cars travelling at a higher speed towards her destination. Users can gain points, and offset their company's carbon travel allowance, by joining these trains as they greatly increase efficiency. Gabriella accepts in accordance with her company policy, reclines her seat and calls her personal assistant, David.

The highway is paved with solar panels which help power some of the city's neighbourhoods and also provide power to electric vehicles.

With a flick of her finger she moves David's image from her device to the 40-inch anti-glare screen towards the front of the car. Gabriela notices a pop-up message confirming that a road use charge for single occupancy vehicles will be billed directly to the company. The dashboard display also informs her of the charge per mile and displays the running total, including information on carbon emissions and the real cost of her journey. As she is travelling at peak time, she will be paying the highest applicable rate per mile.

Thanks to a system of fully synchronised traffic signals for autonomous vehicles, traffic flow in the city has improved and there is less waiting at intersections.

While Gabriela and David discuss a scheduling issue, an alert warns Gabriela that there is a 90% chance of rain. She looks up through the wide transparent roof, notices the heavy clouds and checks to see that there is a supply of umbrellas, emblazoned with her company logo, in a side compartment. Luckily she opted for a rain-safe commuting mode today!

Case Study: Driverless Car Interiors

Driverless vehicle technology means that passengers could spend their time in a more meaningful way whilst travelling. As the focus will be internal to the vehicle, there will be more emphasis on the passenger experience. Swiss company Rinspeed has proposed one vision of this driverless future with its Xchange concept car. Rinspeed transformed the interior of an electric Tesla Model S with seats that swivel, tilt and slide into 20 positions, a wide-screen television in the rear and an Italian espresso maker in the centre console.

Case Study: Uber On-Demand Car Service

Uber uses GPS and algorithms to match drivers with passengers faster and more efficiently than would occur through minicab dispatchers. Cars are reserved through text message or via a mobile app, and journeys are automatically charged to a credit card on file. Uber has launched in over 70 cities and is expanding rapidly. Mobility as a service is likely to be more widespread in the future.

Case Study: Solar Roadways

The Solar Roadways project, the brainchild of Scott and Julie Brusaw, aims to replace standard asphalt roads, parking spaces, pavements and bike paths with advanced solar panels that generate clean and renewable power. The panels also contain LED lighting, heating elements to melt snow, inductive charging capability for electric vehicles while driving, and even some storm water management abilities. The project more than doubled its original crowdfunding goal of US$1 million through site Indiegogo, raising US$2,200,886 to take it to the next phase of development.

Case Study: Synchronised Traffic Signals

Los Angeles, USA, is the first major city in the world to fully synchronise all its traffic signals. The Automated Traffic Surveillance and Control system is one of the world's most comprehensive traffic systems for alleviating traffic. The city has synchronised all 4,400 of its traffic signals by using magnetic sensors in the road to measure the flow of traffic. The system also uses cameras and a centralised computer system which receives information from the sensor network and automatically makes adjustments to traffic flow.

Stefan Treuhaft, 23 — Software Programmer

Stefan is a software programmer who regularly commutes by bike to his office. He likes the exercise as well as the convenience, independence and ability to be spontaneous that a bicycle offers. He also enjoys having a more direct interaction with the city around him. On his bike he feels closer to the sights, sounds and smells of a vibrant metropolis.

Stefan loves Route 52, the highway he uses to commute to work, as a flyover section means that he avoids a congested area that is full of traffic lights, roundabouts and zebra crossings.

Stefan hears a familiar click as his smartphone slides into its cradle and his bike's LED lights blink on. During the morning rush hour, he uses a laser light which projects an image of a bike onto the roadway several metres in front of him. This tells those motorists wanting to turn left that he may be in their blind spot. Most cars now have sensors that automatically detect the presence of cyclists, but there are still old cars on the road and Stefan doesn't like to take any chances. He also wears an InvisiHelmet™, which can inflate rapidly to protect him if he falls off his bike.

After two kilometres Stefan turns off his laser light and joins the cycle superhighway, a dual carriageway for bicycles only. He still gets a surge of adrenalin as he joins the throng of pedalling commuters. As cycling has become so much more popular now, the superhighway network has been scaled up. The familiar blue lanes are now found in most neighbourhoods across the city, and it is estimated that over 80% of these have barriers offering cyclists greater protection from road vehicles.

Stefan loves Route 52, the highway he uses to commute to work, as a flyover section means that he avoids a congested area that is full of traffic lights, roundabouts and zebra crossings. He remembers the days of potholes, marvelling at the advances in materials science that have made them a thing of the past. He also likes the slight flexibility and give of the self-healing road surface, as falls from a bike are no longer quite so painful.

As he starts the slow descent back to ground level, Stefan notices the plant growth emerging through the noise barrier's green wall substrate. Turning left on to the canal, he spots a new pop-up bike repair station. The early morning light bounces off the water's mottled surface. He soon arrives at his office and follows other cyclists into the basement where the AutoBay, an automated cycle storage system, whisks his bike away for secure storage.

After a busy day of client meetings via holographic software, Stefan decides to join some friends at a table tennis hall. He collects his bike from the AutoBay and cycles a kilometre or so towards the centre of town. He enjoys riding downtown as he can take one of several avenues lined with bioluminescent trees that glow in the dark. He feels safe riding under their soft green light. His device reminds him that there is indoor parking for bikes at a shopping centre across the road from the hall. The parking also has cameras trained on the rows of racks, which send live video feeds and notifications to registered mobile devices in the event of a security incident.

Stefan stays out for longer than planned and, feeling tired, he decides he decides to take a night bus home. His device tells him which night buses offer bike storage, and shows the nearest one to be just a few streets away. He loads the sleek titanium frame onto the rack and boards the bus. He's relieved to see the sign showing that there are six empty seats upstairs as he has had a long day.

Case Study: Laser Bicycle Light


© Blaze

The BLAZE Bike Light is a front bicycle light with super-bright LEDs that projects a fluorescent green image of the bike onto the road five metres ahead of the cyclist. The bright symbol helps to alert road users of the cyclist's presence, helping prevent accidents by making cyclists more visible especially where they may be in a vehicle's blind spot.

Case Study: Automated Bicycle Storage


© Al&Koko, Flickr

In Tokyo, where space is at a premium, Japanese construction company Giken has developed an underground bicycle park for secure storage and to relieve street clutter. Members place their bike on a runway and use a membership card to access the parking. The automated system then conveys the bike to a slot underground in 15 seconds. Bikes are retrieved and returned to users in a similar amount of time.

Case Study: Bicycle Racks on Buses


© CBC

The entire TransLink bus fleet in Vancouver, Canada, is equipped with bike racks, making multi-modal journeys possible at no additional cost. Translink also allows bikes on to their trains and ferries and has installed safe bicycle parking facilities at a number of bus and rail stations. The aim is to increase the number of people who move around the city via greener modes of transportation.

Case Study: Self-Healing Concrete Surfaces


© University of Bath

Researchers at the University of Bath, Cardiff University and the University of Cambridge are working on a self-healing concrete that uses bacteria to seal cracks that can lead to decay and collapse. The aim is to create a concrete blend containing bacteria in microcapsules that will germinate if water seeps through a crack. The bacteria will produce limestone as they multiply, sealing the crack before the water can cause structural damage. Self-healing concrete could vastly increase the life of concrete structures, remove the need for repairs, and reduce the lifetime cost of a structure by up to 50%. As over 7% of the world's CO_2 emissions are due to cement production, extending the lifetime of structures and removing the need for repairs could have a significant environmental impact.

Samuel Cheng, 34 — Client Account Manager

Samuel is an account manager for an advertising and brand design agency. He and his colleague Yan-Song sometimes share their commute to work, as they both live in District 57. Samuel's hybrid car is the new love of his life. Among its more exciting features is a fully web-enabled dashboard monitor that feeds him selected information in real-time. Advanced sensors also monitor his vital signs such as heart rate, eye movements and brain activity. The car also features superior aerodynamics and an invisible bonnet.

It is 9.45am and Sam is on his way to pick up his colleague Yan-Song before driving to a nearby commuter zone to pick up other passengers. The two men work the same hours, from 10.30am to 7.30pm, as it suits them both for different reasons. They often pick up two or three passengers, usually strangers, in order to qualify for use of high occupancy vehicle lanes that allow them to travel toll-free if there are three or more people in the vehicle. Sam is excited because this evening he will put his car on the train and head down the coast for a week's holiday at a friend's beach house.

Yan-Song sees Sam's car appear on the street outside his apartment. Sam adjusts his mobility settings to enable tailored real-time traffic and weather updates silently via his screen, so that they can listen to the radio and chat uninterrupted. Yan-Song jumps in and they pull away into the bright morning sun. Sam checks his app and notices that there are a few passengers going in his direction who have requested a lift. They swing by the local commuter lot and pick up two people standing at the front of the queue, and then join a free car-pooling lane on the intra-city highway. Sam reflects that the car-pooling lanes have helped ease the extreme congestion that used to plague the city's motorists. The traffic on this lane is fairly light and they notice the Estimated Time of Arrival adjust to just 33 minutes.

Yan-Song is impressed by the new model of car and they chat about the innovative hydrogen drivetrain and the sensing technology that is embedded throughout the chassis. Before they get to the underground car park near his office, Sam receives a message to say that he is to leave his car in Area B. He drops the two passengers off and proceeds to the parking lot. Yan-Song watches as the car self-drives onto a platform. He and Sam turn to leave as it is lowered down through the basement floor.

While he waits, Sam adjusts his mobility settings to enable tailored real-time traffic and weather updates silently via his screen, so that they can listen to the radio and chat uninterrupted.

As his computer goes into power-saving mode at the end of a frenetic day, Sam uses a mobility app to request that his car is made ready, and checks that he has sufficient credit to drive across town via the express lane. Reaching the basement, Sam sees his car rise up from the rotating storage area below. He gets in and heads to the rail station, taking one of the suggested routes shown on his dashboard screen.

He is relieved to reach South Station in good time, and is directed through to a side approach where an overhead display tells him that the train will be leaving on time in eight minutes. The message is repeated on his in-car screen. He slides his car door up into its open position and alights before watching his car board a ramp to the back of the train. His new car may be fast, but it can't match the speed of the maglev. By his estimation he and his car will be nearly 1,000 km away in just over two hours. He boards the train excitedly, as an alert tells him that his car is securely parked in slot A22. He's looking forward to waking up to the smell of the sea.

Case Study: Ridesharing Platforms

Pogoride is a community ridesharing marketplace, connecting drivers with those who need rides across major cities and destinations in Washington State and British Columbia. It aims to bring reliability and trust to ridesharing for both drivers and passengers. Similar initiatives include Zimride, Lyft and BlaBlaCar. In some parts of the world, the sharing economy is becoming much more prevalent, especially in cities.

Case Study: Hydrogen Fuel Cell Powered Automobiles

Hydrogen fuel cells offer some key benefits over technologies such as all-electric lithium-ion batteries and the traditional internal-combustion engine. Hydrogen fuel cells are capable of long-range journeys of up to 640km and can be refuelled in minutes. Unlike gasoline or diesel engines, fuel cells are environmentally friendly, with water being the only waste output. Toyota, GM, Honda and Hyundai are all planning to roll out models of fuel cell vehicles. Toyota, for example, has announced that it will begin selling its first hydrogen-powered car in the US in 2015 at a price of around US$70,000. Current barriers to mass uptake of these vehicles include cost and the lack of fuelling infrastructure.

Case Study: Smart Cars and Vehicle-to-Vehicle Communication

Cars of the future will be smarter and safer. They will be able to monitor the alertness of the driver and communicate with each other to avoid collisions. On-board computers are already creating a huge amount of data and as big data analytics improve, further trends and inefficiencies will be identified. Vehicles will also be able to communicate with each other about traffic, weather and road conditions and warn the driver about potential safety hazards. In the future, systems could automatically take over braking or steering if they sense an imminent accident. Advanced sensors within the vehicle could also monitor a driver's heart rate, eye movements and brain activity to detect issues ranging from drowsiness to a heart attack.

Case Study: Automated, Space Saving Car Parks

Volkswagen's car towers at Autostadt in Wolfsburg, Germany, are 60m tall parking towers of glass and galvanised steel. They house 800 cars and are connected to the Volkswagen factory by a 700m underground tunnel. In the vertical carparks, cars are lifted into position via mechanical arms that move vehicles in and out of their bays at a speed of two metres per second. Eito & Global Inc is a Japanese company that makes circular automated Robot-Park™ parking systems which can accommodate the same number of cars in less than half the space of surface parking. The company also makes cylinder-shaped automated underground parking facilities that are earthquake resistant and cheaper to build than conventional garages.

Conclusion

As populations grow and cities expand, providing safe, convenient and affordable mobility will become one of the greatest challenges for transport planners, policy makers and strategists worldwide. Transport infrastructure will also need to cope with rising freight volumes and the increasing demand for fast, reliable and environmentally friendly mobility solutions. Rapidly evolving technology, especially in relation to electric and autonomous vehicles, will also impact the future of highways design, leading to innovative business models and new service offerings.

Shifting mobility needs and customer expectations will require mobility systems to evolve and adapt. Transport users will expect reliable and accurate travel information in order to make informed choices about routes and modal options. Travellers across the spectrum, from tourists to seasoned commuters, will soon come to expect seamless, end-to-end journey experiences. This will require us to plan for people and outcomes, not just transport systems.

Travellers across the spectrum, from tourists to seasoned commuters, will soon come to expect seamless, end-to-end journey experiences. This will require us to plan for people and outcomes, not just transport systems.

How we design and build highway infrastructure today will have a lasting effect on urban and rural environments alike. Thinking creatively across disciplines and areas of expertise, while leveraging opportunities brought about by advances in technology, will be key to uncovering an innovation pathway towards more sustainable and resilient transport infrastructure.

Our vision is that tomorrow's roads and highways will feed into an interconnected and seamless mobility network that is safe, accessible and energy efficient, and that reduces congestion, greenhouse gas emissions and other forms of pollution. In order to achieve this desired future, we must start laying the foundations of this vision today.

Left: Aerial view of Brisbane, Australia

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About Arup

Arup is the creative force at the heart of many of the world's most prominent projects in the built environment and across industry. We offer a broad range of professional services that combine to make a real difference to our clients and the communities in which we work.

We are truly global. From 100 offices in 38 countries our 11,000 planners, designers, engineers and consultants deliver innovative projects across the world with creativity and passion.

Founded in 1946 with an enduring set of values, our unique trust ownership fosters a distinctive culture and an intellectual independence that encourages collaborative working. This is reflected in everything we do, allowing us to develop meaningful ideas, help shape agendas and deliver results that frequently surpass the expectations of our clients.

The people at Arup are driven to find a better way and to deliver better solutions for our clients.

We shape a better world.

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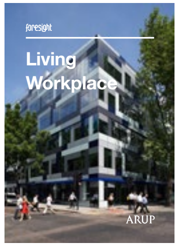
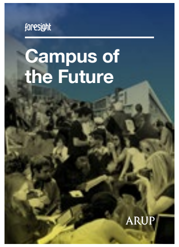
Publications

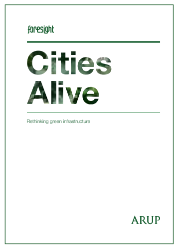


Living Workplace focuses on the future of the workplace. It investigates the impact of growing cultural and generational diversity, the role of new technologies and working patterns and the importance of creativity and collaboration for organisational success.



Campus of the Future highlights Arup Foresight + Research + Innovation group's opinion on the future of the campus. It summarises some of the key Drivers of Change and gives examples of innovative campus environments, both physical and digital, that are leading the way around the world.

Moving beyond static objects in glass cases, *Museums in the Digital Age* outlines how future museums will see personalised content, new levels of sustainability and a visitor experience extended beyond present expectations of time and space.



The ideas being developed in *Cities Alive* seek to capture not only the beauty of nature but also the sustainability of balanced ecosystems. These are challenges for landscape designers creating new cities that meet our increased expectations for access to clean water, cheap and plentiful supply of food, and fast and effective transport systems, with the need to reduce the impact on natural resources.

Future of Rail 2050 focuses on the passenger experience and sets out a forward-looking, inspiring vision for rail. The user journeys imagined here are intended to generate a conversation about the future and provide the big-picture context for future planning and decision making by governments and the rail industry.

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In the future, highways and transport infrastructure will face increasing pressures and impacts from a range of issues including changing weather patterns, population growth, capacity constraints, shortages of land and capital, and rapidly changing technologies that outstrip the pace of new infrastructure development. Changing travel behaviours will also have a significant impact on transport solutions in the decades to come.

So what will highways look like in the future? And how will they cope in a world experiencing a rising demand for mobility and freight capacity? The long-term goal will be to create an integrated transport network with seamless connections to multiple modes, including automobiles, buses, rail, and non-motorised transport. By thinking across modes, we can move towards a connected, low-carbon future.

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