Future of Rail 2050

ARUP

Arup Rail

Arup Rail provides a comprehensive consultancy service for all aspects of the rail industry, from feasibility and planning through to design, implementation and asset management. An in-depth knowledge of the market, combined with a reputation for working at its cutting edge, enables us to deliver appropriate solutions to help our clients, addressing whole-life issues and including safety, reliability, operability and maintenance.

Our work at the forefront of the industry has seen us involved in the creation of rail projects that have transformed cities and communities across the world and it is this ethos that has led us to commission this report.

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

TC Chew
Global Rail Leader, Arup

Across the world, rail is undergoing something of a renaissance, with demand propelled by a number of converging trends. Digital evolution, climate change, increasing demand, rapid urbanisation… these mega-trends all have major implications for the future shape of our railways, pulling it in new directions. We believe there are ways to navigate through these trends to develop a rail industry that is ready to meet tomorrow's expectations.

New questions, exciting answers

Digital technologies are appearing at a rapid rate, promising innovation across the industry's operations, with improved passenger experience a key priority. We can already see how smartphones have transformed the way passengers plan their commutes and leisure travel. Passengers will choose rail only if it offers convenience, comfort, speed, safety, reliability and an increasingly personalised experience. How do railway operators, designers and planners design a rail system that works for digital natives?

To achieve continued growth, rail services will need to expand their customer focus to encompass the passenger's entire journey, understanding the passenger experience from home to destination. Passengers are already demanding live-updated information and seamless connections to other transport modes, expecting a new, more joined-up travel experience where they are in control. Achieving this requires new thinking and new levels of technical integration.

The planet's rapidly changing climate is recalibrating the risk equation for everyone and travellers are increasingly aware of their carbon footprint. For those operating rail networks, extreme weather events and rising sea levels are making routes and infrastructure prone to more common flooding. How should the rail industry adapt and build resilience into such vital and expensive public infrastructure?

With each new rail line connecting people and communities, rail's popularity grows. This has led to unprecedented growth in demand for passenger and freight rail worldwide, but how will existing infrastructure and systems cope?

Physical network, digital world

The staggering increase in service demand means we will grow ever more reliant on the precision and automation new technologies bring. Dealing with this will require new competencies, knowledge and experience within the industry. Are we doing enough

Beijing South Railway Station

to empower our existing and future generation workforce to embrace the digital evolution and innovate in this changing landscape? This report looks at the challenges.

Global growth

All over the world, regions that haven't traditionally had a culture of rail travel are investing with enthusiasm – while others are looking at how their existing networks can be enhanced to meet growing challenges. This report looks beyond the status quo, examines the likely effects of major world trends, and draws valuable conclusions for existing rail businesses and new entrants alike.

Rail services will focus on the total journey… Integrated journey information and seamless connections to other transport modes will create a hassle-free, holistic travel experience.

New Delhi Railway Station Redevelopment

Introduction

"The best way to predict the future is to invent it."

—Alan Kay

If we look backwards as far as we're looking forwards, to the late 1970s, most of the advances we now enjoy in railways (not to mention in information communications technology) would have been unthinkable. In an age of rapid economic, political, social, environmental and technological changes, exercises in strategic foresight are not intended to predict the future with complete accuracy. Rather, the idea is to explore possible futures based on current trends and trajectories as well as weak signals.

Looking ahead to 2050 requires us to think in conceptual terms in the hope of pushing the boundaries of creative thinking. The rail industry is often thought of as conservative; however there is a need to proceed with foresight, to embrace creative thinking beyond projecting the present into the future.

This thought-piece focuses on the passenger and user experience. The 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 the rail industry and by governments. They are also intended to set out a forward-looking and inspiring vision for rail. With the increasing pace of technological change, perhaps the more imaginative scenarios will come to fruition. The case studies indicate trends taking place in rail. They are early signs of possible directional change, and reveal directions in which the future could be heading. Whether these become more widely implemented remains to be seen.

While the specifics may be difficult to forecast, a number of macro-drivers will shape the world in which rail operates. These megatrends will have far-reaching implications for transport in general and rail in particular, and provide the context in which the railways of the future will operate. They will present challenges, but are also likely to spur innovation to meet these challenges.

Advances in technology, for instance, will have wide-ranging and unknown impacts. But we can reasonably expect some major advances in how railways operate: more driverless trains, real-time monitoring of rolling stock and infrastructure, improved accuracy of passenger information, predictive maintenance planning, and most importantly, seamless journeys integrating with other modes of transport.

To move forward with innovation, it is vital that decisions are made, not solely on past experiences, but also on future possibilities and preferred outcomes. The future of rail is something that will be created, not entered into. So to achieve the desired vision for rail, those in the rail industry and government should be asking themselves: if this is the role we want rail to play, how do we ensure things are in place for this to happen?

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Megatrends

Megatrends are the game-changing forces that will shape the world in the future. 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 impacts in terms of mobility and transport infrastructure.

Megacities

By 2050, around 75% of the world's population will live in cities. It is estimated that the global urban population is growing at two people per second, adding 172,800 new city-dwellers each day.[1] A megacity may be a single metropolitan area or two or more metropolitan areas that converge to form mega-regions. These mega-regions may stretch hundreds of kilometres and be home to more than 100 million people.[2] Examples include the Boston-New York-Washington corridor, the São Paulo-Rio de Janeiro region, or the Hong Kong-Shenhzen-Guangzhou area of China which is home to more than 120 million people.

Megacities are increasing in number and size and most of these are located in emerging markets. Four of the world's existing 24 megacities (cities with populations of over 10 million people) are in China — by 2025 there will be three more, some of the fastest urban expansion in history. Chinese planners hope to merge nine cities in the Pearl River Delta — from Guangzhou to Shenzhen — to create a 26,000 square kilometre urban area that will be 26 times larger than Greater London. Over the next six years, £190bn will be spent integrating transport, energy, water and telecommunications networks.[3]

Megacities are increasing in number and size and most of these are located in emerging markets.

Shanghai 1990

Shanghai 2010

Urbanisation

Source: http://catalystreview.net/

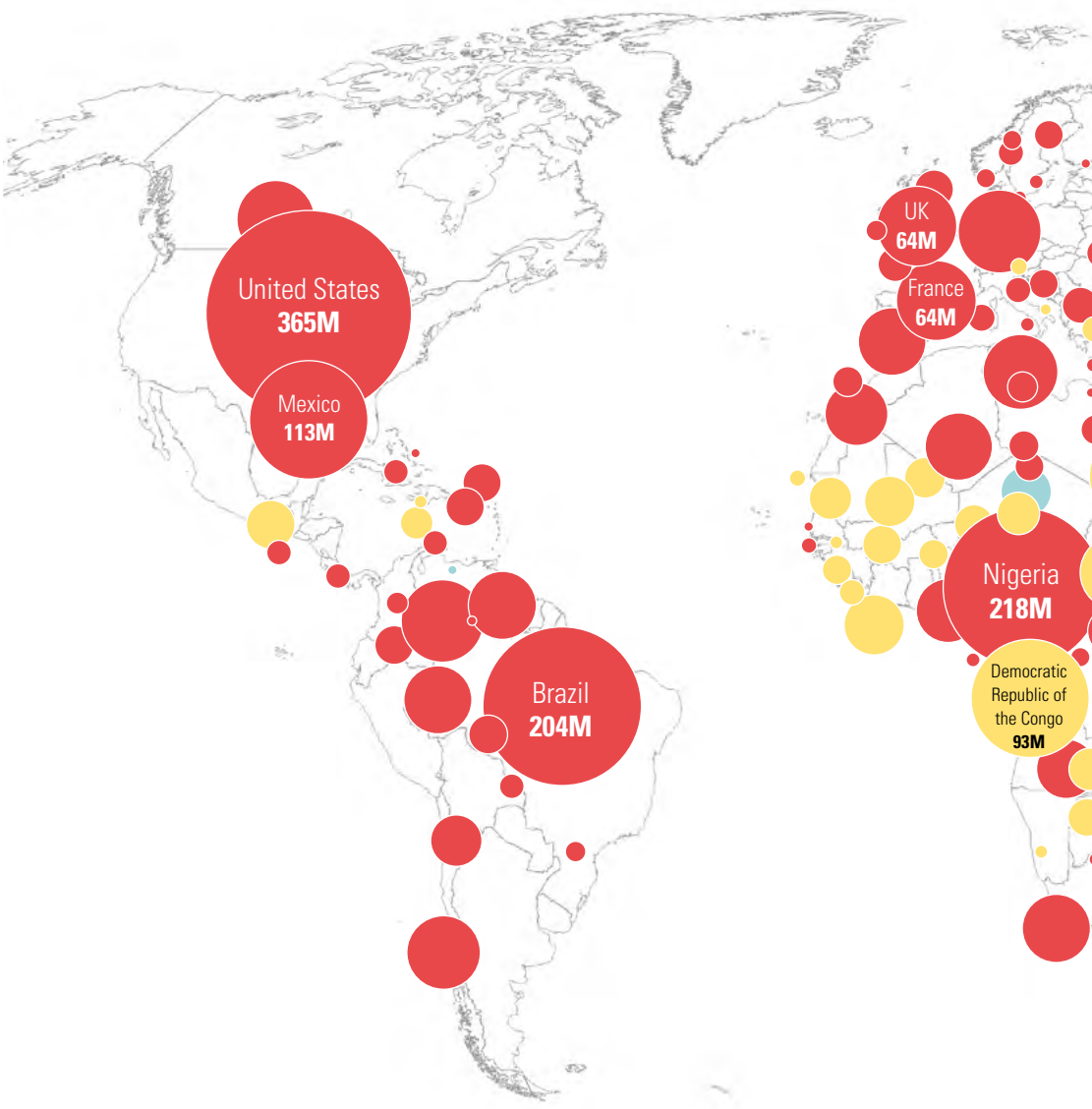
The increasing pace of urbanisation will place added stress on already straining city systems and infrastructure, requiring urban areas to be far more efficient. But denser urban areas could also provide opportunities for forms of transport, such as rail, that rely on density to function efficiently.

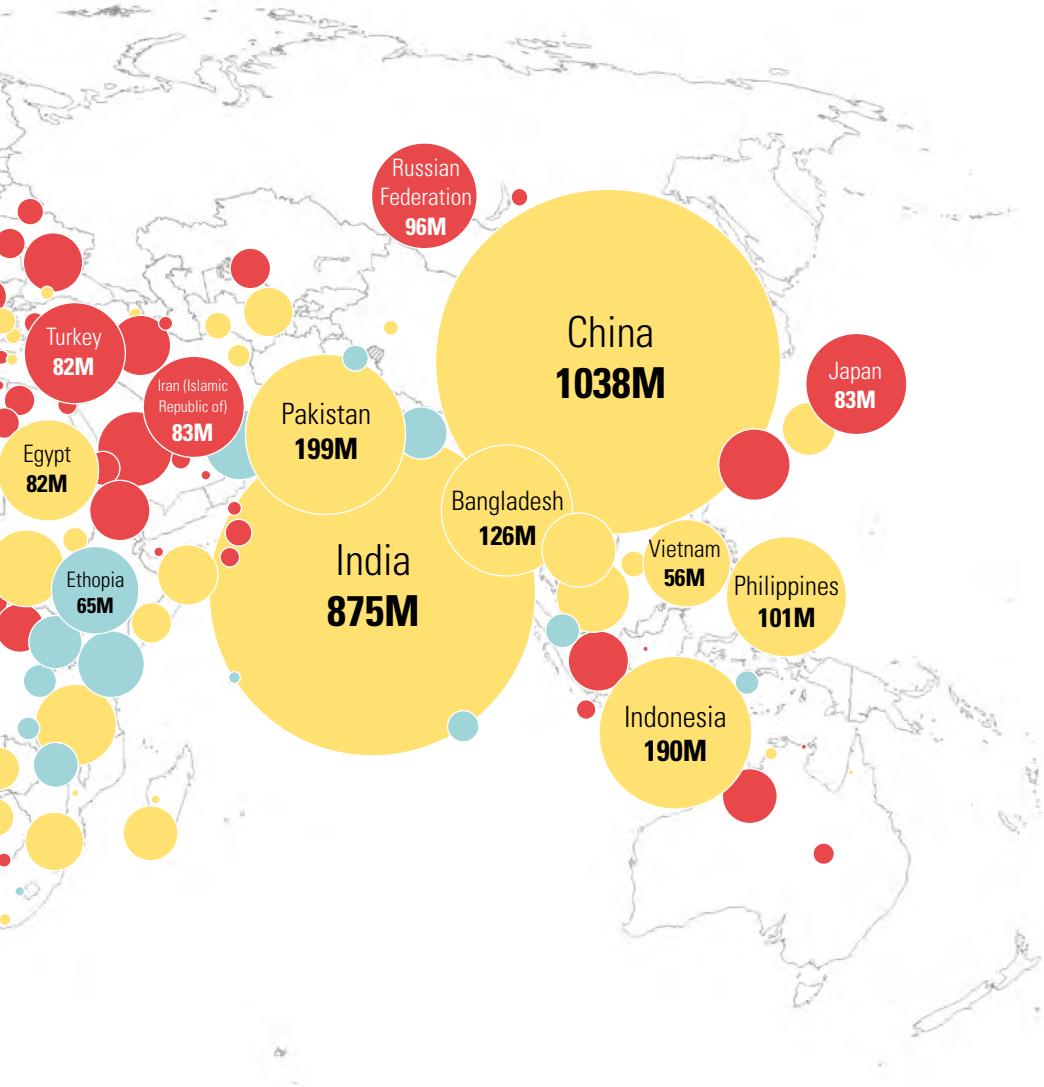
The growth of these megacities will also lead to unprecedented urban sprawl, new slums and a growing gap between the rich and poor. This is a global trend with the richest 1% of people now owning nearly half of all of the wealth on the planet.[4] Currently about 1 billion people live in slums, and the vast majority of these slums — more than 90% — are located in cities of developing countries.[5] By 2050 the slum population could multiply to 3 billion.[6]

The growth of these megacities will also lead to unprecedented urban sprawl, new slums and a growing gap between the rich and poor.

Urban Populations 2050

This graphic depicts countries and territories with 2050 urban populations exceeding 100,000. Circles are scaled in proportion to urban population size.
Source: UNICEF (2012).




Russian Federation
96M
China
1038M
Japan
83M
Turkey
82M
Iran (Islamic Republic of)
83M
Pakistan
199M
Egypt
82M
Bangladesh
126M
Vietnam
56M
Philippines
101M
India
875M
Ethopia
65M
Indonesia
190M
Urban Population (% of total population)
Greater Than 75%
51 – 75%
25 – 50%

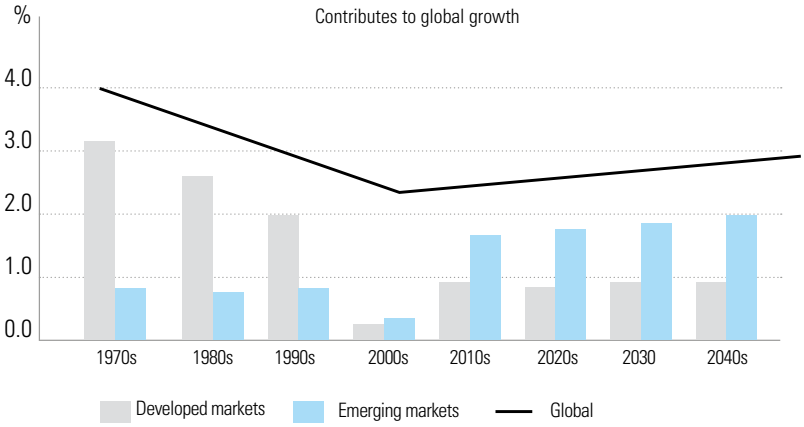


Figure 1. Emerging markets will power global growth Source: CEIC, HSBC

Demographic change

The global population is expected to reach around 9.5 billion in 2050, by which stage the rate of growth will have slowed. Not all regions will grow equally, with some parts of the world, such as parts of Europe and Japan, continuing to experience population decline. An estimated 90% of population growth is expected to occur in the cities of the developing world.[7]

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With more than 20% of the world's population predicted to be 60 years old or over in 2050, compared to around 11% today, ageing populations will have an impact on the design and choice of mobility solutions. In more developed regions, 32% of the population will be 60 years old or over by 2050, and the number of older persons will be nearly twice the number of children. Developing countries will also see an increase in the proportion of older people

By 2050 it is expected that 50% of the world's population will have moved into the middle class, which will have big implications for the volume of travellers and how people choose to move around. Emerging economies are predicted to contribute the most to this trend – growing at 5% per year, while developed economies will average only 2% growth.

Demographic and socio-economic shifts will result in a new global order. Much of the economic growth will be concentrated in China, and South and Southeast Asia. But it is not just the likes of China and India that will be powering global growth over the next four decades. Countries as varied as Nigeria, Peru and the Philippines will also play a significant part. In 2050 there will be almost as many people in Nigeria as in the United States, and the population of many African countries will have doubled. Pakistan will have the sixth-largest population in the world. Even if some of these countries remain relatively poor on a per-capita basis, they could see a dramatic increase in the size of their economies thanks to population growth. In contrast, the Japanese working population looks set to contract by 37% and Russia's by 31%. The Eurozone faces similar problems with working population declines of 29% in Germany, 24% in Portugal, 23% in Italy and 11% in Spain.[9]

Demographic and economic shifts will result in a new global order.

© Kenneth Lu (Flickr)

Climate Change

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, this also means that more and more people could 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.

Like roadways, coastal railways and subways are subject to inundation from sea level rise and storm surges. This is particularly true in underground pathways and tunnels, which are often already below sea level. Increased flooding from heavy precipitation and storm surges could disrupt passenger rail as well as freight operations. Damages from flooding may require rail lines and subway infrastructure to be rebuilt or raised in future expansion projects.[10] Transport infrastructure will therefore need to be built with resilience in mind.

Changes in temperature, more intense storm activity and sea level rises may transport infrastructure design, operation and maintenance.

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 50% by 2050. 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 modes of travel. Increased urbanisation and road congestion, and a focus on the environment and energy consumption make railways a strong alternative to road transport for the movement of people and goods.

Increased flooding from heavy precipitation and storm surges could disrupt rail travel as well as freight operations.

Smart and integrated mobility

According to the International Transport Forum, by 2050 passenger mobility will increase by a staggering 200-300% and freight activity by as much as 150-250%.[11] This means that smart solutions will need to be implemented to provide adequate transport capacity for growing volumes of goods and people.

The incredible pace of technological change in transportation makes it difficult to forecast the future with accuracy. However, trends point to intelligent, more integrated systems for moving passengers and freight.

For transport, advances in Information Communications Technology will have far-reaching impacts, making it seamless, and more efficient, comfortable and eco-friendly. Machine-to-machine (M2M) technology will increase efficiency by using sensors embedded in a wide array of objects and systems to automate tasks and deliver real-time analysis and monitoring.[12]

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 wider environment, paving the way for truly integrated and inter-modal transport solutions.

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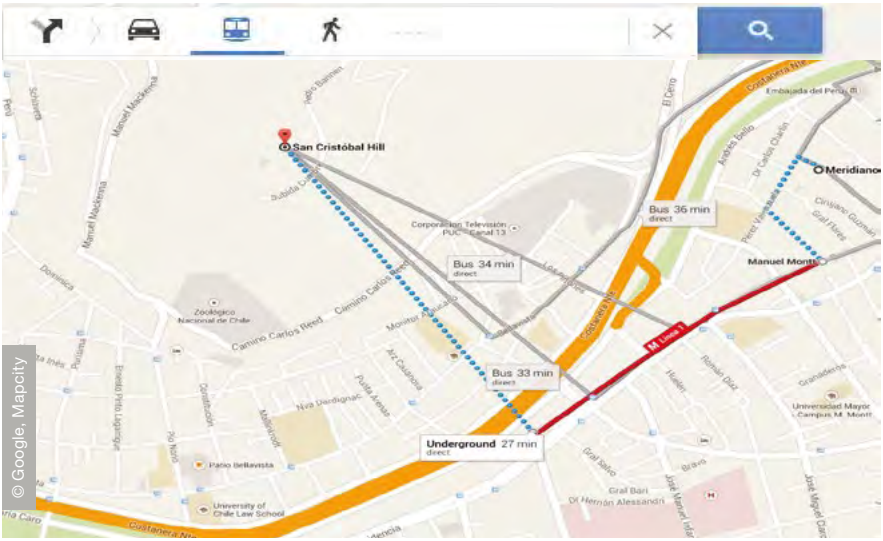

Cloud-based services will become more pervasive, fuelled both by smarter mobile devices and superfast connectivity. Smart communications technology will be one of the key infrastructure pillars of future megacities, helping to improve quality of life and conserve resources.[13] Smart technology will provide travellers with useful information and more comprehensive services, as well as a sense of control and participation. Interoperable tickets, valid for trains, buses, car-sharing schemes and bicycles, could encourage intermodal travel by providing seamless connections to other modes.

Web 3.0 will be about the semantic web (or the meaning of data), personalisation, intelligent search and behavioural advertising.[14] As it develops, it 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.

Speed and access to data will influence passengers' relationship to transportation, as well as their decision-making processes. Passengers will expect certainty in terms of time, so reliable and accurate real-time information will be key, and they will assume optimal pricing. Customer-centric products and services will be based on a wealth of information about the individual passenger and their needs.

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Technology

The growing pace of technological change will be one of the major drivers of change 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. Change is occurring especially rapidly in the cluster of converging sciences and technologies in nanotechnology, biotechnology, information technology, and cognitive sciences (the so-called NBIC cluster). The NBIC cluster is likely to be a major driver of innovation and growth, changing the ways in which we work, live and communicate.[15]

Advances in nanotechnology in particular may lead to new materials that are lighter, stronger, smarter and greener. Materials like graphene, which is revolutionary in its strength, flexibility and conductivity, could have numerous applications and support completely new structures. Developments in material science are also dramatically improving the performance of batteries, changing the potential for electricity storage.[16]

3D printing is expected to revolutionise the supply chain, reducing the need for mass-produced manufacturing, transportation and storage. Certain industry sectors will see a shift from central to decentralised production, and from intercontinental shipping to more regional and domestic distribution.

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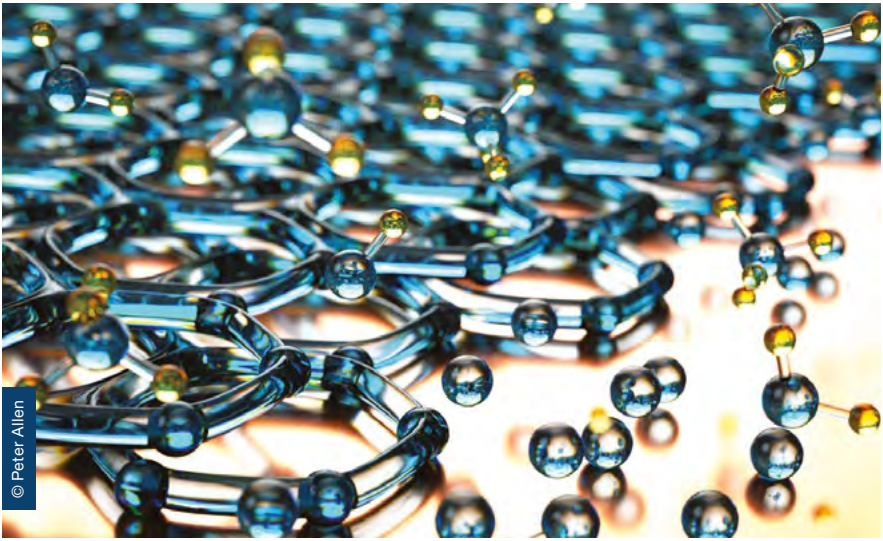


Intelligent robots will play a greater role in the inspection of infrastructure such as tunnels and bridges, and in the efficient maintenance of ageing structures. For example, smart robots are already being built to repair and retrofit ageing water pipes, while crawling robots can test load-bearing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

New forms of transport could also emerge. For example, NASA is developing a new generation of airships, which it believes will replace trucks, trains and ships as a means of carrying freight. New materials and aerodynamics knowledge means that the airships would be capable of safely carrying loads that could not be managed in the past. Space travel, or low-Earth orbit, is a potential means of transport in the future. Ambitious ideas such as Elon Musk's Hyperloop may also lead to incredibly fast methods of travel.

Swarm robotics is another area for future transport and infrastructure projects.

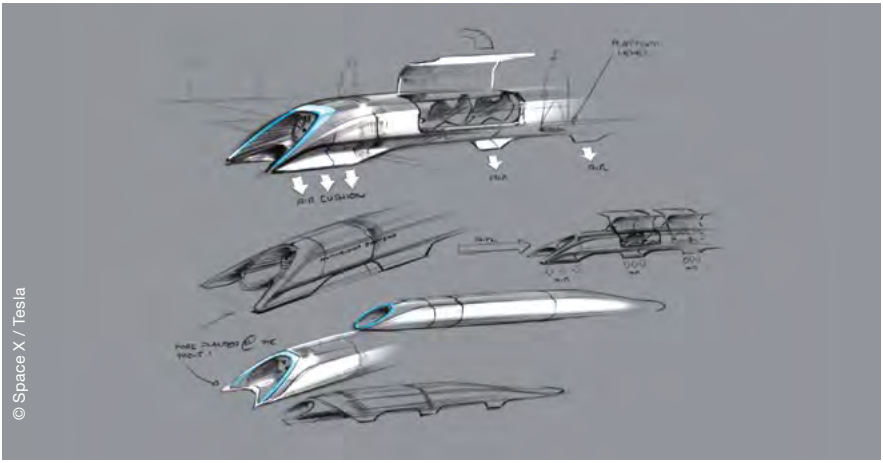
Energy and resources

A larger and more affluent 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.[17] 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 therefore 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, reducing waste and increasing efficiency.

Constraints on available resources, and high and volatile prices, may limit economic growth.

The political instability in many oil-rich regions could 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 could also cause a shift away from fossil fuels and require new methods of transportation (for example rail transportation of liquid hydrogen). Air propulsion, such as the differential air pressure used in an atmospheric railway, could also be an emission-free method of moving trains.



© Space X / Tesla

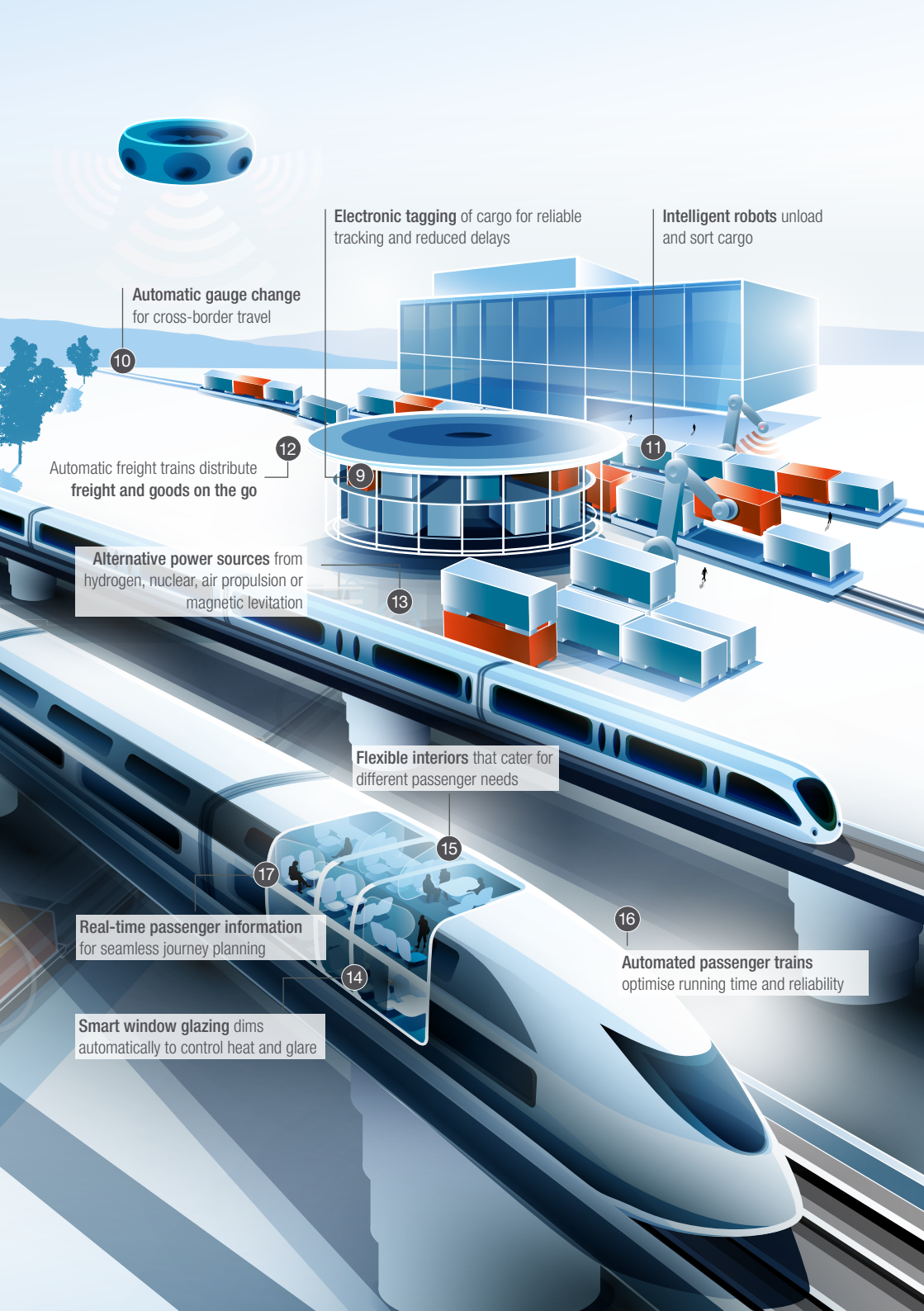
The Hyperloop is Elon Musk's concept of a 'fifth mode' of transport. In theory, people and cars would be transported between cities inside aluminium pods travelling at speeds of up to 1,300km per hour inside elevated tubes.

By 2050 it is thought that hydrogen, or hydrail, could be a primary means of powering trains. Hydrogen for locomotive power might come through nuclear, wind, solar, solar concentrate, hydro-electric, or other emerging ways of making hydrogen. It would harness sustainable and renewable non-carbon energy sources to power rail and transit lines electrically but without the high cost and visual pollution of overhead wires. Hydrail concepts fit in with the industry's trend towards hybrid rail vehicles. Hydrogen fuel cells could replace the diesel engines and generators used in modern diesel-electric trains, using energy generated by the fuel cells as well as the electricity stored in batteries from regenerative braking. Hydrail technology could be particularly useful for remote rural lines which are unlikely to have been electrified.[18]

The availability of alternative fuels could lower transportation costs significantly and transform the global economy.

Global consumption of resources will nearly triple to 140 billion tons per year by 2050.


Mobility and lifestyle hub for business, leisure and connectivity
1
Monitoring drone for predictive maintenance and improved security
2
3
Ticketless and security technology eliminates gate-lines in stations
Virtual shopping wall that offers convenience and ease
4
Intelligent robots to repair and maintain infrastructure
5
Energy flooring that generates electricity from footfall
6
Driverless pods powered by clean energy
7
8
Underground freight pipelines for moving goods in cities
© Rob House


Electronic tagging of cargo for reliable tracking and reduced delays
Intelligent robots unload and sort cargo
Automatic gauge change for cross-border travel
10
12
Automatic freight trains distribute **freight and goods on the go**
9
11
Alternative power sources from hydrogen, nuclear, air propulsion or magnetic levitation
13
Flexible interiors that cater for different passenger needs
15
17
Real-time passenger information for seamless journey planning
16
Automated passenger trains optimise running time and reliability
14
Smart window glazing dims automatically to control heat and glare

User Journeys

The following journeys reflect visionary experiences of future passengers and set out a forward-looking and inspiring vision for rail.

Hugo Dupont, 31
Smart City Engineer

Hugo lives alone in an apartment in a large European megacity. Having studied abroad, he has returned to his home city and works as a Smart City Engineer for the City Authority, maintaining a network of sensors tracking electricity, traffic and people flows to create efficiencies across city systems. He likes gadgets and his wearable computers perform a variety of functions from wayfinding, to holographic communication, to the real-time monitoring of his health.

Hugo is rushing to catch the Metro train to work. Earlier, as he reached Rue Daval, he remembered that he had left a parcel on his kitchen counter and had to turn back to get it. Now, running a little late but parcel in hand, he pauses as a fleet of driverless pods pass by and then crosses the road at the signal, disappearing into the Metro station.

He needs the package to be delivered that evening, as today is his friend Nuno's birthday. At the entrance to the Metro, he drops the parcel into the International Express box next to the interactive tourist information wall. As he selects to receive freight alerts to track the progress of his package and pays for the shipping with a tap of a button, a message notifies him that his meeting with colleagues in Hong Kong via holographic software will start in 15 minutes. He hurries to the platform to catch his train.

The platform screen doors slide shut just before Hugo can board the Metro. However, he isn't too worried as he knows the next train will arrive in under a minute. The driverless metro trains can travel in close succession as they constantly communicate with each other and with rail infrastructure and automatically respond to the movements of the other trains on the track, making the metro extremely safe and efficient.

As he waits, Hugo notices other commuters buying groceries from the virtual shopping wall. As his fridge hasn't sent him any alerts, he thinks he is stocked up well enough at home for the time being. He also glances at some of the artwork on platform screen doors — he enjoys seeing the changing digital exhibitions every day.

Meanwhile, at 08:46, Hugo's parcel drops onto a conveyor belt and is transported to a pod on the underground freight pipeline. The routing code is scanned as it is loaded onto the pod, and the package is whisked away to Gare Centrale. The electric pod travels uninhibited at a steady pace, independent of traffic and weather conditions, and at 09:16 the package is loaded onto the mail carriage at the back of the waiting high-speed EuroTrain that carries both passengers and small express freight. At 10:35, the train leaves the station and runs directly to Berlin.

In his office, Hugo is testing a new system for analysing how much electricity from braking trains is fed back into the grid, when he receives a notification informing him that his package is on the train and is running on schedule.

CASE STUDY: AUTOMATED PASSENGER TRAINS

Examples of driverless passenger trains include the automated systems in operation in Copenhagen, Paris, Singapore, Dubai and São Paulo. Automated systems optimise the running time of trains and increase the average speed of the system, allowing more trains to operate closer together, reducing the time it takes a train to slow down at stations, and increasing reliability. The Dubai Metro is the longest driverless metro network in the world, spanning 75km. The Copenhagen Metro was one of the first to feature a fully automated system, including depot operation and launching, and operates 24 hours a day. Arup is the designer for an expansion of the metro, the Cityringen, which is under construction and scheduled to open in 2018. São Paulo's Metro Line 4 is South America's only fully automated, driverless subway line. It carries around 700,000 passengers a day on an 8km stretch, and by 2015 the fully built-out system will be 13km long with 11 stations, carrying an estimated 1 million passengers per day.

Dubai's driverless metro (top) and Copenhagen's fully automated metro (inset)

CASE STUDY: VIRTUAL SHOPPING WALL IN METRO STATION

Virtual supermarkets could become more common especially in metro stations. In 2011 in Seoul, South Korea, Homeplus (which is 95% owned by Tesco) set up the first virtual shop along the platform of the Seonreung subway station, displaying over 500 of its most popular supermarket products. Smartphone users scan the QR code of a product to order it. If the order is placed before 13:00, Homeplus will deliver the shopping the same day. After a trial in the Shanghai metro, China's biggest online retailer Yihaodian plans to open 1,000 virtual supermarkets in the country. As Smartphones or other smart devices become ubiquitous in the future, the opportunities for e- and m-commerce will continue to grow. There may even be virtual shopping walls inside the carriages themselves.

CASE STUDY: FREIGHT PIPELINES

CargoCap is a German company with an innovative idea: transporting freight within and between urban areas using underground pipelines. The system relies on intelligent, individual pods or caps, and is independent of above-ground traffic congestion and weather conditions. The caps are aerodynamic and powered by electricity.

The benefits include low energy consumption, low initial costs, a long lifespan, and low maintenance needs.

Another freight pipeline concept as part of the GRID (Green Rail/Intelligent Development) project in Southern California, envisages freight containers being loaded onto trains in underground pipelines (using massive pipes originally designed for long-distance water transmission). The electric and automated trains would shuttle containers to and from the twin ports of Los Angeles and Long Beach. The increase in container transport capacity this would provide means that several very expensive, environmentally and socially damaging freeway expansions could be cancelled.

CASE STUDY: MOBILE STORES

In addition to virtual shopping walls, retailers such as Starbucks are seeing other opportunities to engage a captive audience. This extends retail from the domain of the station and could give rise to new financing opportunities. Starbucks has launched its first ever store on a train that travels from Geneva Airport to St. Gallen, Switzerland. The company has completely redesigned a two-level carriage to accommodate up to 50 passengers, who can order from their seats or from the counter. Starbucks had to take into account stringent safety regulations as well as factors like the constant movement of the train and space limitations.

Marina Aliyev, 41
Account Director

Marina is a hard-working professional in an international communications firm. Due to her high profile clients, and the sensitive nature of their business, she often travels internationally to meet them in person to build trust and rapport. Her 8Gi enabled smart device provides the most efficient option to get her to her meetings on time, while allowing her to access work and entertainment on the go.

As the EuroTrain glides out of Gare Central at 10:35, Marina settles into her seat. She is heading to Berlin for a meeting with an important corporate client. She spent a couple of hours that morning in one of the station's office suites so that she could have a coffee and work undisturbed. Her membership card gives her convenient access to office suites at stations and airports around the world.

As she boarded the train, the separate cabin she had booked detected her arrival and displayed a welcome message on a blackening glass partition panel. Now, Marina barely notices the train's departure, or that it is part of a convoy of nuclear-powered trains heading east out of the city.

Her device connects to the 8Gi network as she double-checks the best route to her meeting, and informs her that she'll get there in good time. Relaxing back into her seat, she HoloCalls her daughter, Larissa, who she catches eating her breakfast back at home. The holographic image floating in front of the glass is one of the sharper ones she has seen in recent years. After a light breakfast, Marina downloads a number of documents from the cloud to review in preparation for the meeting.

The morning sunlight blazes through the window and reflects off her tablet, so Marina presses a button on the partition panel, and activates the window auto-adjust which blocks out the worst of the glare.

As the train glides quietly across the border, Marina reclines her chair for a refreshing nap. She notices the journey time remaining on the smart glazing in front of her before closing her eyes.

Half an hour later, she disembarks onto a shiny platform and blinks twice to turn on her infoLens™. The contact lens in her left eye is activated and the way-finding instructions guide her out of the station to the AutoPod station. Her device has already called for a pod and the vehicle number flashes into Marina's vision. She sees a family with two small boys disembark from number 87 before it glides up to her and stops in the pick-up bay. Marina gets in, synchronises the address from her device, and then sits back as she is ferried to her meeting south of the Spree River.

(Top) Arup provided infrastructure design for the world-first Ultra PRT Heathrow pod. (Inset) The pods in Milton Keynes will be booked using a smartphone app and will be equipped with touchscreens.

CASE STUDY: PERSONAL RAPID TRANSIT (PRT) PODS

PRT systems, like the one in use at Heathrow Airport in London, may find more applications in the future. PRTs can be powered by clean energy, and some proposed systems use magnetic levitation to connect vehicles to a high-speed guideway, eliminating vibration, pollution, noise and the usual wear caused by moving parts.

Arup, in collaboration with Transport Systems Catapult, Cambridge University and the Automotive Council, is working on a futuristic autonomous pod system for the city of Milton Keynes. The scheme will see autonomous pods, large enough to accommodate two people, run on special pathways in the city. It is envisioned that by 2017 one hundred fully autonomous pods will run alongside people and employ sensors to avoid obstacles. The vehicles would travel at a maximum speed of around 20km per hour and would allow passengers to check emails or read newspapers while travelling to their destination.

CASE STUDY: STATION OFFICE SUITES

© Regus

Regus, the world's largest provider of flexible workspaces, has drop-in satellite work places at major stations around Europe, such as those at Luxembourg Central Station, Amersfoort Station in the Netherlands, and Geneva Station in Switzerland. The Regus station network offers a variety of facilities for the mobile professional worker, making working in noisy public areas a thing of the past. Members can use the business lounge or a private office to meet, email, print, and conduct business. These spaces can be booked at short notice and on a flexible basis.

CASE STUDY: RESEARCH FRONTIERS INC. PATENTED SPD-SMARTGLASS TECHNOLOGY


© Research Frontiers Inc

SPD-SmartGlass is Research Frontiers' patented electronic solar control glazing, which provides instantly customisable shading fully controlled by the passenger. It can be operated individually to create the effect of a shade being raised or lowered to precisely control incoming heat and glare. The light-control technology allows passengers to instantly, precisely and uniformly control the shading of glass or plastic. The smart glazing enhances passenger comfort and also reduces maintenance costs and saves energy by reducing climate control usage.

(Top) An impression of the proposed HS2 rail link between London and Birmingham.

(Inset) The Japanese Maglev bullet trains have reached speeds of up to 580km per hour in test runs.

CASE STUDY: DESIGNING FOR SPEED

Building on experience gained through proposing the High Speed 1 route in the UK, and the design and project management of the delivery, Arup is providing route engineering design for a new 400kph high-speed rail line between London and the West Midlands.

High-speed can offer a sustainable, progressive means of managing the economic and environmental cost of travel. It can also offer fast connectivity, a positive passenger experience, and can result in economic benefits. It is estimated that trains will be running on HS2 Phase 1 between Birmingham and London by 2026.

The first test runs of the Japanese Maglev trains, designed to reach speeds of around 500km per hour, took place in June 2013. The trains are expected to be in commercial use by 2027. The ultimate aim is to establish a maglev track from Tokyo to Osaka by 2045, which will provide a high speed link between the north and south of Japan, slashing the journey time between the two cities to 67 minutes.

The Khoslas, family of 4
Tourists

The Khoslas, with their 6-year old twins Rahul and Vijay, are spending their summer holiday in a country they have never been to before. The family uses a variety of technology to help them on their travels, including translation apps, augmented reality software that overlays historical information on the sites they visit, and wayfinding devices to guide them around the city.

The Khosla family alight from the number 87 pod at 12:07 and gather up their belongings. They have arrived at the Berlin station multiplex early to take in a show, to shop and let the kids play before taking the train to a nature park on the outskirts of the city for the next two days. Over the past week they have enjoyed seeing all the historical sites in the city. Even the kids have been kept entertained as the augmented reality apps on their tablets have overlaid the sites with photos and videos depicting a bygone era. Vijay couldn't believe how congested the streets once were and that the poor people had to drive themselves around in big metal cars! Very dangerous and bad for the environment, he decided.

As Mr. Khosla arranges to put their luggage in a holding room for a couple of hours, Rahul and Vijay jump up and down on a floor that lights up under their feet. Mrs Khosla explains that the floor is generating energy from people's footsteps that then helps provide power to the station. She saw this at a station in Mumbai too — although the colourful lighting and energy display underfoot are fun gimmicks.

Mr. Khosla takes the kids to the play area near the station theatre, while Mrs. Khosla browses the shops. Based on her preferences shopping elsewhere in the city, her smart device suggests products and brands she may be interested in. She scans the code of a dress to find out more about the fabric and to see sizing and colour options. In another store she finds a 'build-a-rocket' model and holds it up in front of the augmented reality screen to see an overlay of the built toy. The twins will love this! She pays with a touch of her smart device and then re-joins the family in time for the show.

At 15:15 Mr Khosla leads his family efficiently to their platform from the theatre using his device's wayfinding software, and they jump onto the train. As Vijay is boarding he is distracted by a red dot appearing under another passenger's feet which indicates that he doesn't have validation to travel and, without noticing, his new toy rocket falls out of his backpack onto the station platform.

Aboard the train, Rahul discovers a button which transforms the seats in to a set of four facing each other so that the family can interact on their journey. The train is soon on its way out of the city, and it is only ten minutes later that Vijay discovers that the toy rocket is missing. Mrs Khosla wipes away his tears and touches a few buttons on the interactive display. She quickly finds the operator's lost property service and enters the details of the missing item and the address where they will be staying in case it turns up. There is nothing more that they can do now, so they settle in for their journey.

Rahul surveys the old couple across the cabin with interest — the old man has the coolest hover chair with lots of glowing buttons! Mr Khosla gives Rahul a warning look that says "don't touch those!"

CASE STUDY: STATIONS AS DESTINATIONS

Rail stations will become destinations and lifestyle centres that further blend our commute with our lives. People are increasingly using stations, not just as places to catch a train, but as centres for leisure and business. Of nearly a million weekly visitors to London's St Pancras station, a quarter come to eat, drink or shop rather than take a train. This trend will continue as stations become places of experiential retail and also provide facilities such as gyms, hairdressers, meeting spaces and offices.New York's Grand Central Terminal is also a destination in its own right. Some features of the station include the ceiling mural above the vast main concourse, the famous Oyster Bar, and The Campbell Apartment, an elegantly restored cocktail lounge. The stations also has delis, bakeries, newsstands, a gourmet and fresh food market, an annex of the New York Transit Museum, and more than forty retail stores.

(Top) London's St Prancras station
(Inset) New York's Grand Central Terminal

CASE STUDY: ENERGY FROM FOOTFALL

A unique method of harnessing renewable energy is about to be trialled in Russia's railway stations. The Russian Railway Research Institute has struck up a partnership with Netherlands-based Energy Floors to harness energy from the footfall of its busiest stations. Electricity from footsteps will be used on site or fed into the grid, meaning that just by going about their daily commute, people will be creating a cleaner energy environment. A similar trial is underway in St Omer, France, where part of a pavement outside a busy station has been fitted with 14 of Pavegen's energy tiles. These tiles harness and convert kinetic energy from passers-by into electricity that powers parts of the station.

Ticketless technology will remove gate-lines in stations. Authorisation to travel will be universal and payment processed automatically when the journey is taken.

Kaito and Hinata Nakamura, 84 and 78
Retired

The Nakamuras are travelling to see their daughter who has moved to a new house outside the City and works from home. Although they are older, travel is a lot easier than it once was and far more accommodating to those with disabilities. Kaito uses a hover chair to move around while his wife, Hinata, has an ear implant to improve her hearing. A mobility app removes the stress of travelling by automatically booking the different stages of their journey and providing clear instructions to get from t heir city apartment to their daughter's house.

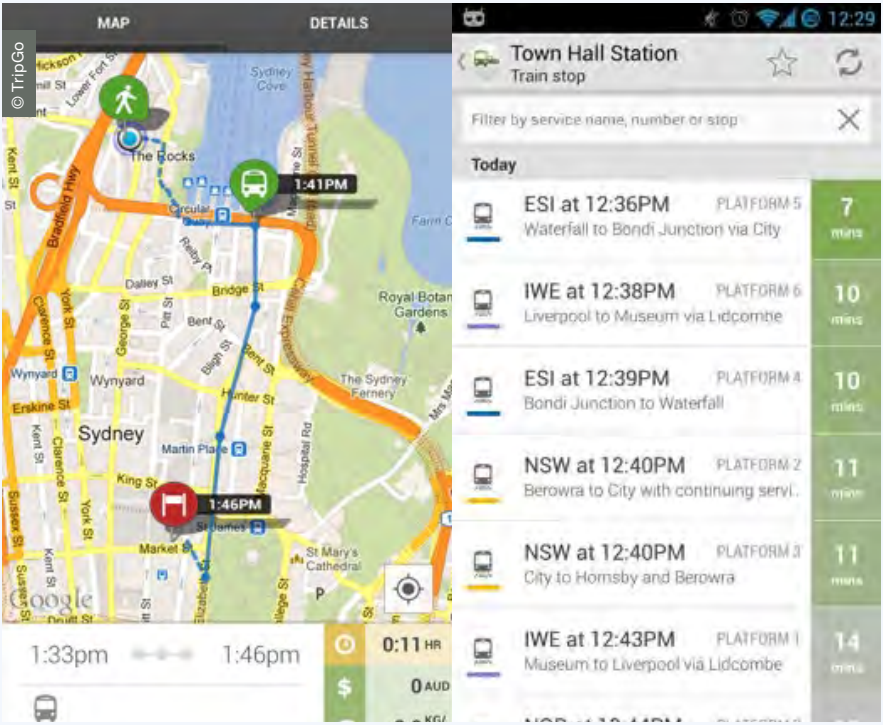
Kaito notices the small boy crying and smiles at him. He remembers taking his daughter on a train for the first time 35 years ago, but it had been crowded and hot — she hadn't liked it and had cried too. Luckily trains and platforms had better climate control these days. The Nakamuras had arrived at the station earlier via light rail from their apartment in the north. The interchange had been easy despite Kaito having problems with his hips. Thanks to his Titanium Foam hip implants, he can walk slowly, but on longer journeys he still prefers to take his chair from home to his destination. There is more space on the trains to manoeuvre these days and no need to deploy ramps to get on and off the carriages.

Hinata has booked through to their end destination via a mobility app, without requiring separate travel authorisation or separate charges for the different modes. The journey is chosen for optimal pricing and convenience and the trains automatically register the Nakamuras presence via their smart devices when they get aboard. The app also keeps them informed in real-time of any changes to their journey.

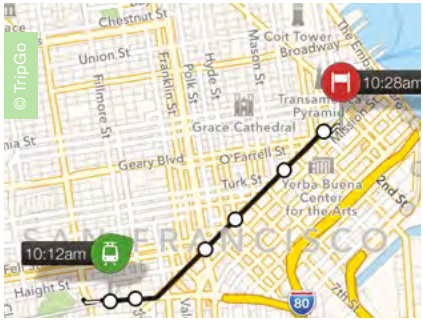
Kaito's chair manoeuvres itself into position at a height-adjustable table and locks into position. Kaito relaxes as he scans a discrete digital display beside him and sees that he can easily call on the train guard for assistance. He is offered a free induction charge, which he gladly accepts. Comfortably settled in, he closes his eyes for a nap.

Hinata started to lose her hearing almost a decade ago, but her ear implant allows her to hear almost perfectly. Nevertheless, the display in front of her keeps her up-to-date on the progress of the journey, so she doesn't need to listen to the station announcements. She flicks through the news of the day online, and is disheartened to read of yet another hurricane sweeping through the Philippines. Maintenance teams are working around the clock to get transport systems back up and running, so that those stranded by the storm can move to safer areas. Luckily drones are able to deliver much-needed aid supplies to the areas cut-off by the powerful storm. Still, these events are happening far too often.

A while later Kaito wakes up to see that the snacks that Hinata pre-ordered have arrived and that they are now travelling at full speed. The tinted window looks onto intermittent flashes of a blurred landscape. They agree that they will HoloCall their daughter to let her know they will arrive at the station as planned at 16:36. She'll be anxious to know that they are okay.



CASE STUDY: INTEGRATED JOURNEY APPS



Integrated transport apps allow trips to be chosen according to optimal pricing and convenience. In the future it will also be possible to book and pay for journeys across all modes, providing a seamless journey-planning tool.

TripGo is an app for iOS, Android and the Web that provides real-time and multimodal journey information for planning door-to-door journeys. It also provides various comparisons on price, trip duration and carbon emissions, and allows the user to prioritise which is most important to their journey. The app is supported in over 50 locations worldwide, including Ho Chi Minh City, Dublin, Sydney, Vancouver, Auckland and Chicago.

Nuno Tavares, 29
Software Developer

Nuno lives quite far out of the city where he works every day, but his commuter service gets him into work in just 50 minutes. He takes a maglev commuter train and then switches to a feeder train (moving platform) that takes him to the station close to his office. While a lot of people these days work remotely, his company still prefers their employees to work from a central hub. The perks of going into the office are good, including free meals, gym, and socialising. His journey is usually spent productively, connected to the train's superfast WiFi.

At 18:05 Nuno is on his way home from work. He makes a quick stop in the station at the LaundryLocker service then heads to his regular platform. As he steps through the barrier-free entrance and makes his way towards a carriage near the front of the feeder train, a bright red toy catches his eye. He bends down to pick up a 'build-a-rocket' and looks around. He can't see anyone looking for it, so he steps back to the platform entrance and hands it to the first member of rail staff he sees. The station guard will take it to the office, log it on the system and see if it matches any lost property alerts.

Nuno returns to the level access carriage and steps aboard. This feeder train, or moving platform, connects him to a high speed suburban maglev train which will take him to his local station. It means a faster, more energy-efficient service as the high speed train doesn't stop at every station. Although slightly more expensive than other options to get to his office, this service offers Nuno the quickest route along with superfast WiFi, and he is willing to pay more for the convenience.

The feeder train soon moves off and Nuno feels a buzz as an alert informs him that a delivery drone will be dropping a parcel off at his house that evening. "Someone did remember my birthday!" he thinks happily.

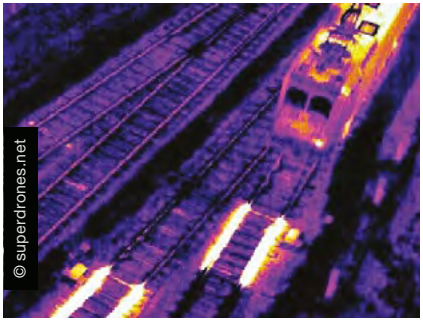
As his shuttle approaches the maglev service to dock, Nuno notices a micro-drone monitoring the tracks alongside the train. This drone helps the rail operator perform predictive maintenance of the tracks and those lengthy delays and maintenance schedules are thankfully a thing of the past.

Aboard the high speed service, Hugo is just settling into his seat when a familiar musical sound alerts this section to the fact that a pregnant woman has just alighted. She must have updated her profile with news of her condition. The train is busier than usual this evening and she's grateful for his seat.

It's a nice warm evening and still light when Nuno arrives at his local station. He could take a bicycle at no extra cost just by scanning his fingerprint at the shared bicycle scheme dock, but this evening he decides to walk.

At 19:10 Nuno dials Hugo from his home entertainment system and Hugo's image pops up on his 3D screen. He thanks Hugo for his parcel which has just arrived and hopes that it won't be another two years before they can catch up in person.

CASE STUDY: MONITORING DRONES



Dutch railway company ProRail uses drones equipped with infrared sensors to check the switch point heating systems on its tracks. Using the drone's images, the company can see whether the switch point heating systems are operating correctly. If switching points are frozen, trains can no longer use the track, which can result in substantial delays. Checking the switch points manually is labour-intensive and also dangerous for employees, so drones can offer a number of advantages.

In Germany, the national railway company Deutsche Bahn is trialling micro drones to help combat graffiti on its property that cost the company over £6 million to remove in 2012. These micro drones will be able to hover 150 metres above the company's train depots and maintenance facilities, equipped with high-resolution infrared cameras to gather evidence on trespassers. Inspecting railway tracks by drones will be further improved in the near future, making predictive maintenance a reality.

Anna Green, 68
Freight Forwarder

Anna works in a freight forwarding company based in London. Her job requires a range of skills such as data analysis and interpretation, contract negotiation and consulting across freight, logistics, customs management and insurance. She has seen a lot of changes in her 32 years as a freight forwarder. The supply chain is far more transparent these days and goods delivery more efficient. She has also had to reskill a number of times during the years to manage faster delivery times and the increasing reliance on IT systems and automated freight transport.

As Nuno activates his sleep cycle lamp and settles in for the night, two kilometres away a freight train glides through his suburb. The driverless train has travelled from Zhengzhou, China, carrying raw materials as well as ready-to-assemble parts for a new range of wind turbines. The train, which started its journey measuring over 5km in length, shed its wagons of iron ore and recovered copper at two delivery points in Russia. Without stopping, the shorter train carrying the wind turbine parts then continued to Europe.

The turbine parts were transported to the Zhengzhou loading station via a freight shuttle system designed to move high volumes of freight traffic over medium distances. The electrically powered shuttle runs on an elevated, dedicated right-of-way to avoid interfering with other transportation systems, making it suitable for densely built-up areas.

The parts were then loaded onto the driverless train which can automatically adjust to gauge changes, making the journey across borders far more efficient. The electronic tagging of the cargo means that it carries all the required information, allowing reliable tracking and also reducing border delays.

The freight logistics system automatically selected the most efficient use of the cross-border rail infrastructure without disruption to passenger services, providing 24-hour utilisation of the network. The wind turbine parts have made the journey from Zhengzhou in just 5 days, which is more efficient and flexible than if the goods were shipped by sea.

Anna scans the bank of screens in front of her as she monitors, in real-time, six trains speeding along their freight routes. She sits up suddenly as she notices that one of the trains is losing speed and an alert indicates that an obstruction has been detected on the track some 20 miles ahead of the train. She can see the clear-up process unfolding on the screen in front of her as a satellite image shows two teenagers running away from a section of track. There doesn't appear to be any obstacle left on the track itself. Anna watches as Central Control dispatches a high-speed helicopter drone to assess the section for potential hazards. It doesn't seem like too much time will be lost through the disruption.

Relieved, Anna leans back in her chair and notices that the China Railway Corporation hydrail train is nearing its destination. She pulls up the train's freight details with a swipe of her finger.

Looking at the data, Anna notes that this freight journey is relatively cheaper and more sustainable than it would have been a couple of decades ago, when she started assessing freight rail performance. The hydrogen powering the train has been produced from nuclear power and emits only water at the point of operation. It also allows the train to travel through more remote areas where the electrification of lines would be difficult.

An alert tells Anna that the train has pulled into the depot at its destination and she downloads the journey report with performance metrics and forwards it to her client. Within an hour, robotic arms are unloading the heavy turbine parts onto autonomous trucks for the short journey to the assembly plant. The parts, unloaded according to their electronic tagging codes, will be conveyed alongside another shipping consignment destined for the plant for maximum efficiency.

CASE STUDY: REDUCING FREIGHT TRANSIT TIME

Arup is providing operational planning and railway safety advice for a proposed high speed rail link and 20km tunnel/ bridge fixed crossing between Copenhagen and Hamburg. This new direct connection between Scandinavia and continental Europe is seen as a catalyst to regenerating the Fehmarnbelt region. The route, expected to be completed in 2021, will significantly reduce times for freight trains running between Scandinavia and Germany/ continental Europe.

CASE STUDY: HYDRAIL

In 2012, Engineering students and staff at the University of Birmingham designed and built a prototype hydrogen powered locomotive, the first of its kind to operate in the UK. This narrow gauge locomotive is a hybrid design, combining a hydrogen fuel cell and lead acid batteries similar to the ones used in cars. The fuel cell is used both to power the permanent magnet electric motors and to charge the batteries, with the batteries helping to meet the peak power demands when accelerating under load.

In another hydrail development, in 2013 China rolled out its first hydrail locomotive, a project of Southwest Jiaotong University in Chengdu, Sichuan.

CASE STUDY: DRIVERLESS FREIGHT TRAIN

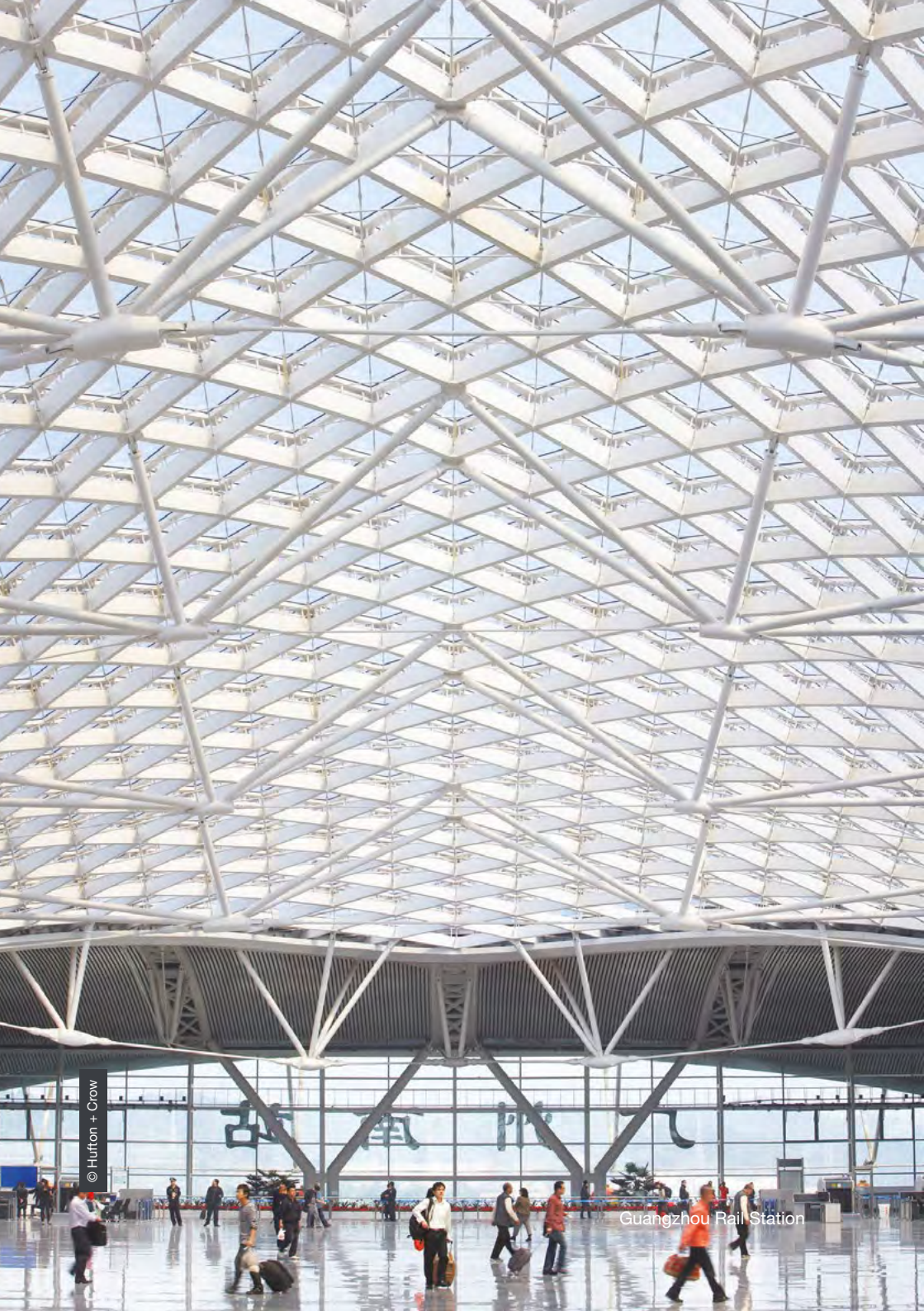

© Rio Tinto

In Western Australia, mining company Rio Tinto is planning to use driverless trains to deliver its iron ore to ports in what will be the world's first automated, long-distance, heavy-haul rail network. This is expected to increase rail throughput significantly - shortening journey times by eliminating stops for crew changes - and reducing energy consumption and CO2 emissions through more efficient operation. The fully automated freight trains will begin their progressive rollout in 2014.

CASE STUDY: FREIGHT SHUTTLE SYSTEM


© Texas A&M Transportation Institute

The Texas A&M Transportation Institute (TTI) has developed a freight transportation system called the Freight Shuttle System (FSS). The idea behind the FSS is to resolve one of freight transportation's most pressing issues: the lack of a suitable system for high-volume traffic between two points located less than 1000kms apart. Inspired by rail, FSS transporters use steel wheels to carry either a standard-size freight container or an over-the-road trailer. The FSS consists of automated transporters, an elevated guideway, high-efficiency terminals, and a communications, command and control (C3) system that effectively manages shipments in facilities and in transit. It also uses efficient, linear induction, electrically powered motors.



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Guangzhou Rail Station

Conclusion

In examining current trends, the future of rail appears to be a bright one. Rising demand for passenger and freight capacity, along with global concerns about climate change, is leading to something of a rail renaissance globally. Even regions that traditionally haven't had a culture of rail travel, such as the Gulf Cooperation Council (GCC) countries, or parts of Asia where there has been historical underinvestment, are investing in rail with enthusiasm.

There are challenges to overcome, not least in building the needed capacity in a timely fashion and at a cost that the market can support. Rail will need to focus on being more competitive and having less reliance on government subsidies. Congestion, operational efficiency and reliability, structural and competition issues, and safety and security are other challenges that will need to be faced. And of course, rail will be operating in a 2050 world that will likely be quite different from today.

The desired future for rail requires a bold vision and a strong will to implement change on the part of governments, the rail industry and those training the rail engineers of the future.

Our vision is this: In 2050, passenger and freight rail will form the backbone of the transport system, linking major urban hubs and feeding into multi-modal local transport networks. Rail services will be able to cross borders without delays or technical barriers, providing a competitive option to air or road travel. As the industry moves towards 2050 and beyond, rail will become increasingly dynamic, innovative, sustainable and competitive, ensuring a bright future as part of truly integrated transport networks.

In 2050, passenger and freight rail will form the backbone of the transport system, linking major urban hubs and feeding into multi-modal local transport networks.

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San Francisco, California: The Transbay Terminal

About Arup

Arup is an independent firm of designers, planners, engineers, consultants and technical specialists offering a broad range of professional services. Through our work, we aim to make a positive difference to different communities. We shape a better world.

Founded in 1946 with an initial focus on structural engineering, Arup first came to the world's attention with the structural design of the Sydney Opera House, followed by its work on the Centre Pompidou in Paris. Arup has since grown into a multi-disciplinary organisation. Its work, such as the National Aquatics Center for the 2008 Olympics in Beijing has reaffirmed its reputation for delivering innovative and sustainable designs that reinvent the built environment.

The Future of Retail explores how drivers of change are shaping the future of retail. It reveals important trends shaping new consumer behaviours and looks at some of the likely impacts that these will have on future retail environments and services.

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.

Libraries are evolving to meet the changing needs of the cities they serve, in terms of the social infrastructure they provide and the services they offer. *Future of Libraries* examines the key trends that are influencing the transformation of libraries in terms of the social infrastructure they provide and the services they offer.

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.

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Image Credits

Megatrends such as rapid urbanisation, population growth, technological advances and climate change have far-reaching implications for the future world in which rail will operate. Beyond these macro forces, changes will also be driven by the evolving needs and expectations of future passengers. How will rail cope with rising demand for passenger and freight capacity? How will rail fare in a world experiencing more frequent and more intense weather events? And how will an industry that hasn't traditionally been known for being especially fleet-footed keep up with rapid technological change?

The 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. The hope is that the rail industry will move forward with innovation based, not solely on past experiences, but also on future possibilities and preferred outcomes.

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