Infrastructure Future Scenarios

Global Infrastructure Hub

WORLD ECONOMIC FORUM

BCG BOSTON CONSULTING GROUP

Executive Summary

Historically, the infrastructure sector has been slow to evolve. As infrastructure investment policy becomes increasingly important, with other forms of economic stimulus reaching the limits of their effectiveness, there is a growing need to improve the way governments prioritise projects and optimise every dollar they spend. As cities grow and densify, there is an obligation to better use technology to connect services and improve outcomes for communities. As existing infrastructure assets become fully priced, there is demand for investors to find new ways to direct capital into the creation of new assets. Given the long lifecycle of infrastructure assets, long-term strategic thinking and decision-making is required to take advantage of opportunities and manage emerging challenges.

To support the development of strategic responses to some of these opportunities and challenges, the Global Infrastructure Hub (GI Hub), working with the World Economic Forum (The Forum) and Boston Consulting Group (BCG), has investigated possible future scenarios for the infrastructure community and their potential implications.

These future scenarios were constructed from two sources. First, an analysis of megatrends. These are trends that are large scale, transformative, and well established, and they have the potential to fundamentally re-shape end user need where value is created, and the nature of competition. These megatrends cut across all segments of society, including communities, workforce, markets and customers, as well as geopolitics, regulation, technology, sustainability and resilience. Second, a survey of the infrastructure community was conducted in more than 70 countries to identify which megatrends had the highest impact, the highest levels of uncertainty and low perceived levels of preparedness.

This report puts forward four extreme yet plausible versions of the future:

The Islands: a multi-polar, isolated world with limited international cooperation and the rise of national infrastructure champions.

The Rise of Tech Giants: a corporate-dominated, highly digitised world where the adoption of technology is hyper-accelerated across all infrastructure sectors.

Green Revolution: a world where sustainability is the new main decision criterion, in which the circular economy reshapes the infrastructure industry.

Adaptation & Resilience: a world in which environmental change has become irreversible despite concerted global effort, and the infrastructure industry must focus on resilience.

These scenarios are intentionally extreme. They are not predictions of the future; instead, they are designed to stimulate thought. Decision makers can use these scenarios to test how they would respond to different futures, or perhaps more importantly, what actions they can take now to ensure that we evolve towards a more positive version of the future.

Based on this analysis, we have identified four prioritised areas for further investigation that could prove valuable moving forward:

1. Change will happen quickly; therefore, business models will need to be more adaptive
2. The use of large volumes of data to make informed decisions will become a critical source of advantage; data security, standardisation and transparency will be increasingly important
3. New business models and government policies will need to focus on social impact to avoid greater social division
4. The future requires new skills and talents, hence it will be important to strategically plan workforce and build organisational capacity

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1 Introduction

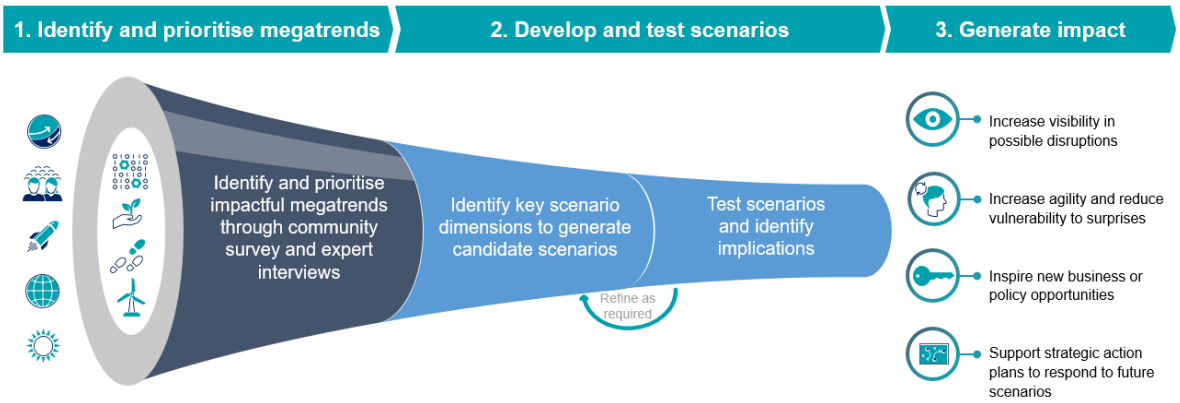
Trends such as urbanisation, shifting demographics, climate change and security concerns, will change how infrastructure is designed, financed, built and maintained. At the same time, new digital technologies, such as wireless sensors, autonomous equipment and artificial intelligence are disrupting a range of industries, including infrastructure. In addition, industry-specific trends, such as the growing infrastructure financing gap and ageing infrastructure assets, complicate the picture, as there is currently a US$15 trillion gap between projected infrastructure investment and the amount needed to provide adequate global infrastructure in the future.[1]

Amidst these uncertainties and disruptions, the infrastructure industry has generally been slower to adopt and adapt to new technologies than other global industries.[2] This is partly attributable to its longer asset lifecycles, and to the industry's reliance on manual labour, mechanical technologies, and established operating and business models with low margins and constrained budgets.[3] Moreover, as an industry based on project-by-project, 'one-shot' procurement models, infrastructure companies have historically taken a conservative approach to evolving product design and delivery. This has led to a culture of conservatism, baked into processes and systems. While innovation has occurred to some extent at the enterprise or company level, overall productivity levels have fallen behind those in other industries.[4]

The Global Infrastructure Hub (GI Hub), working with the World Economic Forum (The Forum) and Boston Consulting Group (BCG), conducted a scenario planning exercise to analyse how these present-day megatrends could lead to different versions of a future world, and to draw out the implications of these scenarios for the infrastructure industry. Scenarios are defined broadly as different visions of the future, wherein each scenario is on the cusp of being plausible and extreme. They are not predictions of the future; instead, they are designed to stimulate thought.

We generated the scenarios using a structured approach in three stages:

Figure 1: Structured approach for scenario generation



- Stage 1: Identify and prioritise impactful megatrends through the community survey and expert interviews

- Stage 2: Identify key scenario dimensions to generate candidate scenarios, then test the scenarios with global experts and identify their implications
- Stage 3: Suggest prioritised areas for further work and action to create positive impact for the industry

Scenario planning helps to anticipate possible outcomes to allow stakeholders to prepare for different futures with the following benefits:

- Increased visibility of possible disruptions within the infrastructure industry structure and competitive landscape
- Increased agility and reduced vulnerability to surprises
- Inspiration for new business or policy opportunities
- Support for strategic action plans to respond to future scenarios

2 Megatrends shaping the future of infrastructure

2.1 Introduction to megatrends and their purpose

Megatrends are large-scale, transformative, well-established trends that proceed exponentially. They have the potential to fundamentally change users' needs, shift where value is created, and re-shape the nature of competition.

Government, private investors, and industry leaders can use megatrend analysis[5] to inform critical decisions. More specifically, states can leverage them to test the robustness of current policies to decide whether they are adequately prepared for different future challenges. This could help governments ensure that infrastructure is developed sustainably, promotes social inclusivity and supports economic growth, and, at the same time, fulfils national and global goals of better serving citizens.

Megatrends also allow private investors to connect the dots to see broader patterns around risk and opportunity. Understanding megatrends relevant to the industry helps investors make informed decisions on funding and financing mechanisms for infrastructure projects, to ensure maximum returns can be realised.

Industry leaders can utilise insights from megatrend analysis to anticipate global risks within the infrastructure industry, improving internal foresight capabilities. This will facilitate the development of long-term strategies that are proactive rather than reactive, helping to make sense of where their companies stand currently, but also make sure they have appropriate plans to thrive in the future.

2.2 Infrastructure community survey on megatrends

For this report a survey of the infrastructure community was conducted to gather perspectives on the megatrends most relevant to the sector. Megatrends were categorised under five domains: society and workforce, market and customers, geopolitics and regulation,

technology, and sustainability and resilience. The Appendix provides a definition of each trend, as we have used it in this report.

The survey received more than 400 responses from respondents in 70 nations, with 35% of respondents from emerging markets, and 65% from developed markets. All G20 nations were represented. Respondents came from diverse organisational types, including government, academia and think tanks, international organisations and multilateral development banks, contractors and operators, private investors, and technology firms. Survey participants represented all organisational levels, including CEOs and directors.

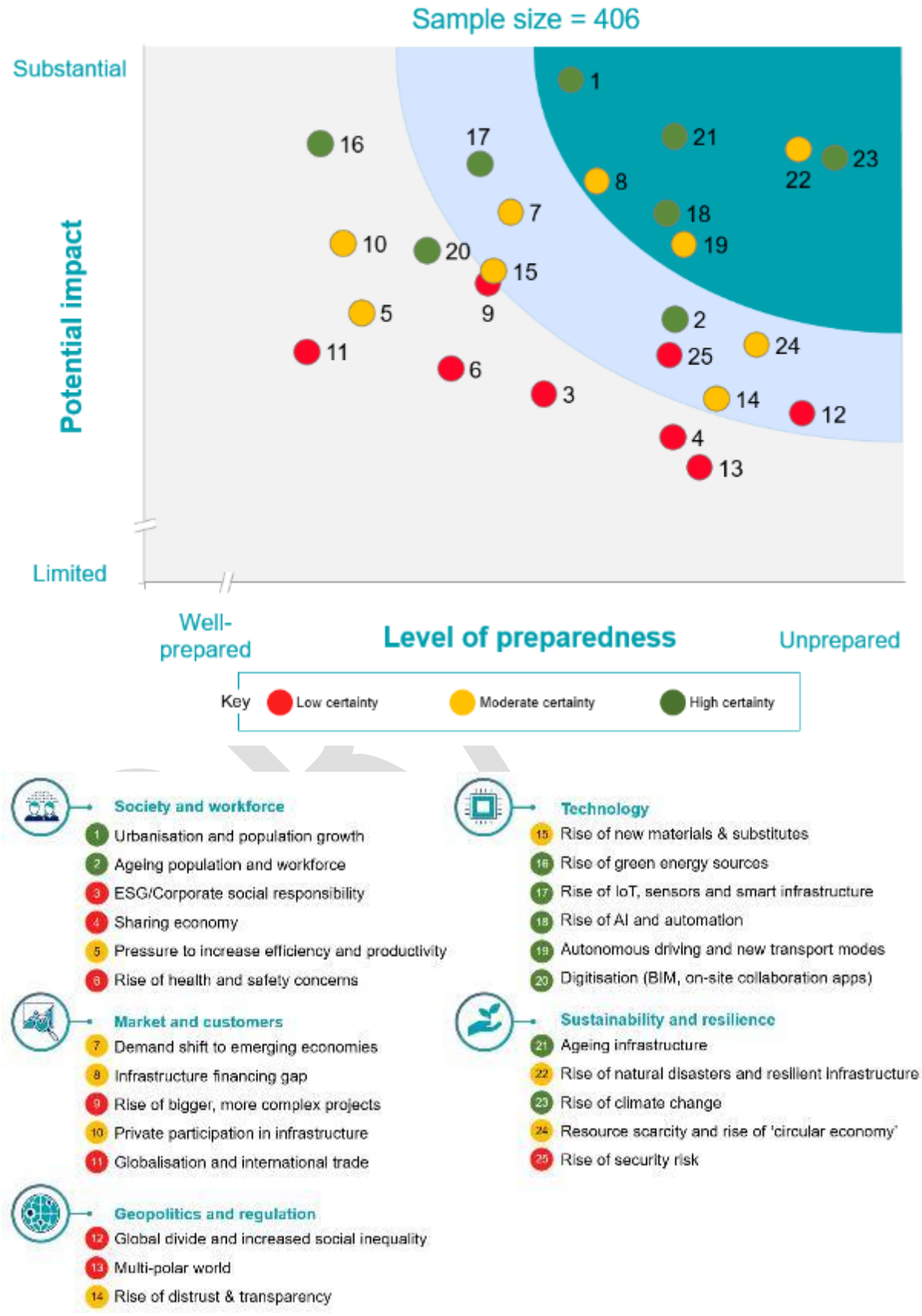
The survey asked for the community's opinions on three topics for each trend:

- The certainty of the direction these megatrends will take
- Their potential impact on the infrastructure sector
- The infrastructure community's preparedness to address these trends

We also asked respondents to identify megatrend(s), either from among those listed in the survey or others not included, that offer the biggest opportunities and pose the most significant risk for the infrastructure community, globally, over the next 30 years.

The survey aimed to prioritise trends with the highest impact, lowest preparedness, and highest level of uncertainty in direction, and to use these trends as the basis for the scenarios. The results are summarised in Figure 2.

Figure 2: Infrastructure community survey results

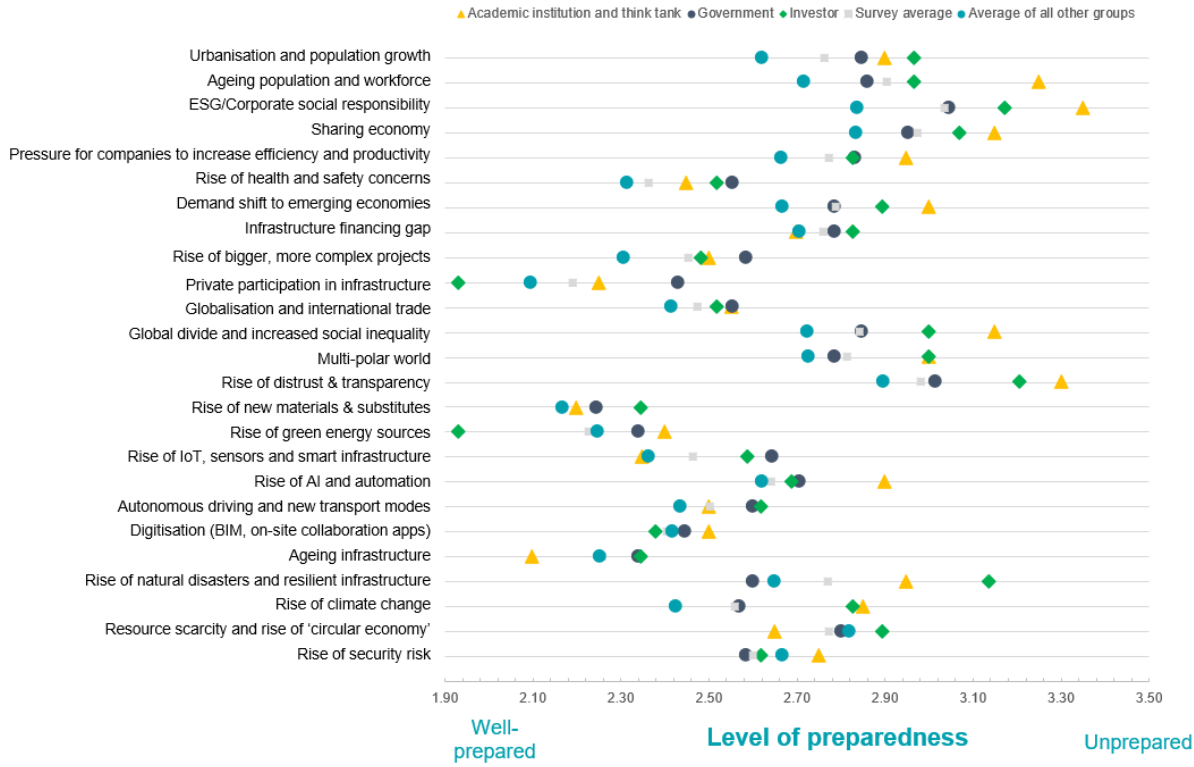


According to the respondents, the trends that have the highest potential impact in the next few decades, and for which the community feels least prepared, are urbanisation and population growth, the rise of climate change and natural disasters, ageing infrastructure, the rise of AI and automation, and new transport modes. In fact, almost 50% of respondents stated that these trends present the highest risk for the infrastructure community. They also felt moderately or highly certain about the direction of these trends, which suggests a high level of agreement that these are priorities for investigation and action.

In addition, the infrastructure community reported relatively low levels of preparedness to address certain sustainability and resilience issues, such as resource scarcity and the rise of the circular economy. Moreover, respondents felt a relatively low level of preparedness for certain geopolitical trends, such as rising security risk and geopolitical instability, the emergence of a multi-polar world, growing distrust of institutions and an increasing demand for transparency from consumers. These trends represent potential blind spots which should be monitored and investigated so that levels of preparedness are proportionate to the trend's potential impact.

The survey revealed that responses from different groups of respondents showed some variation.

Figure 3: Perception of industry's preparedness from different groups of respondents



For example, investors, government officials and academics generally feel that the infrastructure community is less prepared for the 25 megatrends compared to other groups of respondents, such as technology firms, or contractors and operators. More specifically, 88%, 76%, and 80% of the 25 megatrends were ranked by investors, government officials, and academics, respectively, as more 'unprepared' than the average across all respondent groups.

Interestingly, one area where investors feel more prepared is private participation in infrastructure; however, this confidence is not shared to the same extent by the other stakeholder groups, such as government, academia or others.

Across the survey results, academia often perceives the infrastructure industry as less prepared compared with how other survey respondents perceive preparedness. This could indicate that academic circles are considering risks that other market participants are not considering, which may highlight a need for greater academic involvement in decision making.

Variances among stakeholders in perceptions of preparedness might indicate that there should be greater levels of communication and collaboration between different groups of stakeholders in these areas to achieve greater alignment across the market.

The survey results indicate that there are megatrends with a high potential impact on the infrastructure sector in decades to come, but about which respondents also felt uncertain in terms of direction and pace. It is difficult to respond to the potential combination of trends and to imagine the possible futures that the cumulative impacts of these trends will create. Scenario analysis helps us tackle this complexity through investigating 'extreme yet plausible' possible futures and identifying potential implications.

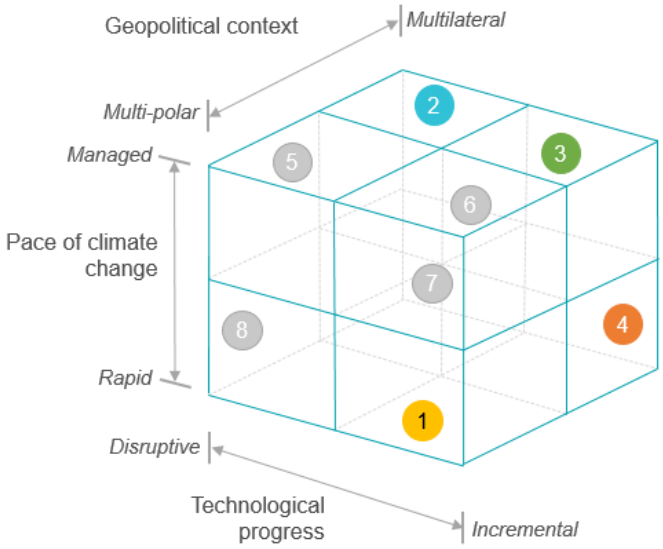
3 Infrastructure future scenarios and implications

Uncertain and impactful trends identified from the survey are used to create 'scenario dimensions'. Survey dimensions are a framing device used to develop scenarios. The three dimensions used were:

1. Geopolitical context (multi-polar vs. multilateral)
2. Pace of climate change (managed vs. rapid)
3. Technological progress (incremental vs. disruptive)

Different extremes of these three dimensions were combined to develop eight initial divergent future scenarios.

Figure 4: Different scenarios created from three dimensions



The full set of scenarios should cover a comprehensive range of topics, such as politics, society, sustainability, and technology. They must be fundamentally different from one another, and none should be significantly more extreme than the others.

Additionally, each scenario developed must be internally consistent, with no inherent contradictions. They paint a clear picture, illustrating a plausible evolution of the megatrends, with challenges and success stories embedded. Considering these criteria, the top four scenarios with the highest potential of interesting implications were developed further.

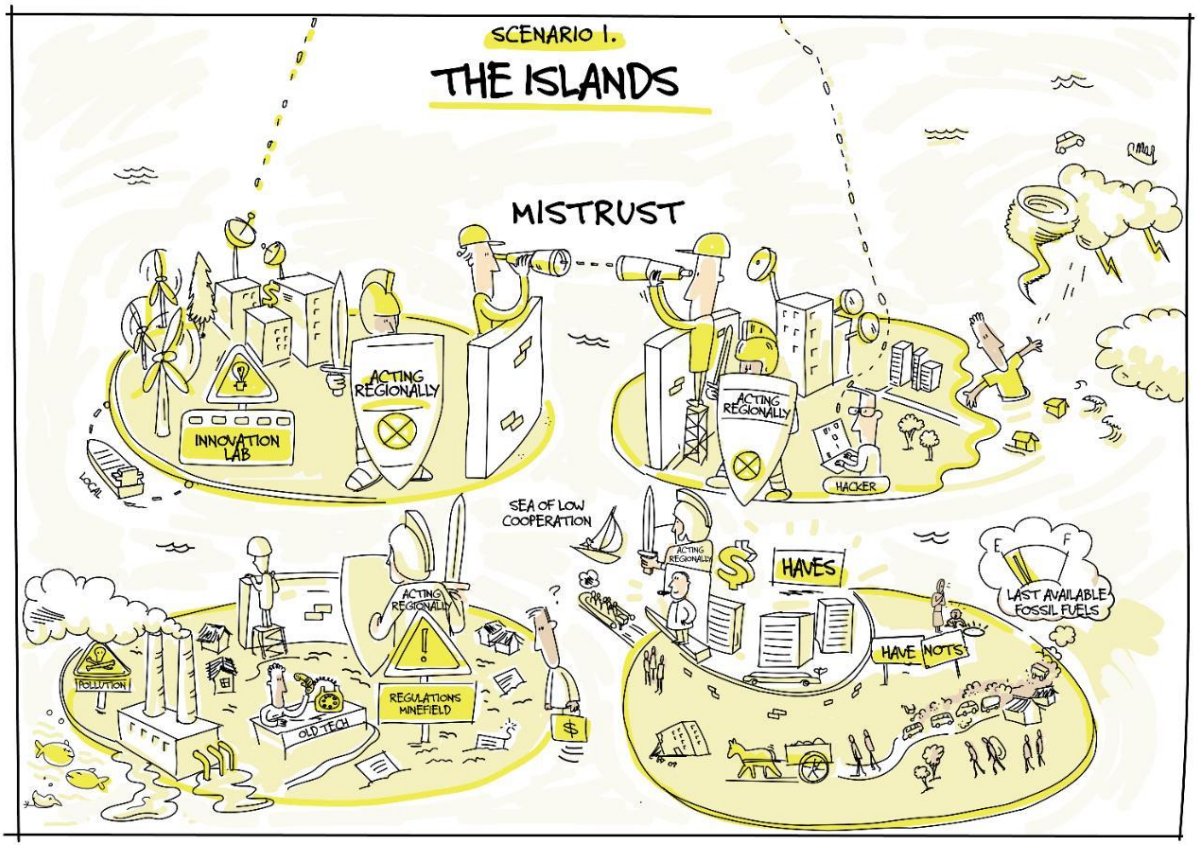
It is important to keep in mind that these scenarios are not predictions of the future. Rather, they demonstrate a broad spectrum of possible futures. In the actual future, the infrastructure industry will most probably include elements of all four scenarios, and the infrastructure industry will need to respond to these. The scenarios are deliberately described on the extreme end of possibility and serve as a provocative thought experiment. Decision makers can use them as food for thought to test how they would respond to these scenarios, or perhaps more importantly, what strategic responses they can take now to ensure that we evolve towards a more positive version of the future.

For each scenario, we have developed a high-level description, followed by implications for the infrastructure community. These implications are organised around changes to the business model for the infrastructure community; market segments; the infrastructure value chain and technology; and policies and regulations. These implications are summarised in Figure 5. Certain megatrends will be more prominently featured in some scenarios than others, however, they all influence each other and interact in a dynamic manner.

Figure 5: Summary of scenario implications

	The Islands	The Rise of Tech Giants	Green Revolution	Adaptation & Resilience
Business model for the infrastructure industry	Infrastructure business models shift to reflect the need to focus locally and regionally, with the re-emergence of infrastructure national champions	Private companies assume the role of infrastructure providers, with competitive advantage occurring upstream in the planning and design stages	A circular economy policy drives new business models which focus on environmental services, the sharing economy, and recycling local materials	Business models focus on local trading and self-sufficiency, as trade logistics are increasingly difficult due to climate change
Market segments	National security infrastructure becomes more critical, with a focus on strategic sectors such as energy and telecommunications	There is a shift in the profile of demand for infrastructure assets: fewer physical assets are needed for work, and demand increases for leisure assets and data centres	An active sharing economy and focus on sustainability reduce demand for built assets and infrastructure, while promoting renewable energy assets and recycling	Transport and built infrastructure and water management assets become much more adaptive and resilient to cope with climate change
Infrastructure value chain and technology	Infrastructure investment focuses more on maintenance and improving resilience, and less on inclusivity	Infrastructure value chains become dominated by technology, particularly where automation and artificial intelligence have greatest impact	The infrastructure industry shifts to sustainable technologies and methodologies across planning, design and construction	Climate change impact must be taken into account at every stage of the project cycle for infrastructure
Policies and regulations	Governments around the world cannot agree on any common regulatory framework; instead they prioritise domestic needs and economic growth	A highly digitised economy with rapid automation forces governments to respond with policies that address multinational taxation issues and reduction in available jobs	Government policy supports the transition to renewable energy, discourages greenfield projects, and brownfield projects are heavily regulated	All nations codify strict climate change requirements in national legislation, with a strong focus on resilience

3.1 Scenario 1 – The Islands



3.1.1 Scenario description

Imagine a multi-polar, isolated world with limited international cooperation and the rise of national infrastructure champions

This scenario is characterised by:

- Geopolitical tensions which hinder global trade, dominant regional trade blocs and spheres of influence, and goods and services sourced locally at high cost
- Inequality between different classes within society and a widening wealth gap between developed and emerging markets
- Increasing occurrence of extreme weather events, which increases safety concerns around inadequate and ageing infrastructure
- Slow adoption of new technology, limited GDP growth and low productivity gains in infrastructure

In Scenario 1, The Islands, regional trade blocs and spheres of influence replace global patterns of trade, and many goods and services are sourced locally at higher cost. Regulations vary from country to country, and infrastructure national champions focus on their local or regional market.

The Islands scenario is characterised by growing inequality between social classes, and a widening wealth gap between developed and emerging markets. This is exacerbated by the scarcity of exploited natural resources, fostering cross-border tension and conflict between markets with abundant resources and those without. Climate change has led to mass migration, further increasing national and regional security concerns. [6, 7]

Inadequate and ageing and infrastructure, especially in emerging markets, causes safety concerns. Adoption of new technologies is slow because innovation sharing is limited by a desire to protect intellectual property and cybersecurity concerns. As a result, GDP growth is slow, and the infrastructure industry demonstrates low productivity gains.

3.1.2 Implications for the infrastructure community

1. **Infrastructure business models shift to focus locally and regionally, with the re-emergence of infrastructure national champions**

In this world, global efforts to invest in major infrastructure projects slow, as major powers scale back international infrastructure investments, except in countries with which they are strongly aligned. In addition to sovereign investment, cross-border capital flows from the private sector see a significant reduction.

Increased costs and lack of market access has led international organisations, such as global construction firms, to focus their efforts on domestic markets. Global conglomerates, such as shipping companies, no longer exist as governments seek to control their national infrastructure. There is limited knowledge exchange between countries or even within industries across borders.

In response to an unfavourable international trade environment, national champions and brands emerge in the infrastructure industry. National champions are major companies with a large workforce in their domestic market and strong regional demand in strategic sectors, such as security and defence, utilities (particularly power generation), telecommunications service providers, key manufacturing industries, and technology. Strong national brands in developed and emerging markets benefit from greater domestic demand, particularly in populous countries, like China, India or Indonesia. With the support from their respective governments, these infrastructure national champions become more integrated, and gradually become quasi-mono/oligopolies in their home markets. They dominate multiple segments of the supply chain, working across project lifecycle stages from construction to operations and maintenance (O&M) and beyond, particularly in sectors such as airports and roads. While this reduces the fragmented nature of the infrastructure industry, it also could potentially lead to complacency and stifle innovation, as protection from the government reduces competition.

2. **National security infrastructure becomes more critical, with a focus on strategic sectors such as energy and telecommunications**

Focused on security, governments invest in strengthening national infrastructure, particularly

in energy, telecommunications and cybersecurity. Countries with aligned interests build their own telecommunications networks, including satellites and cables, to reduce their vulnerability to outside intervention.

Cybersecurity for the telecommunications and energy sectors becomes imperative, in particular the security and ongoing maintenance of data centres or hubs.[8] Limited trust in institutions creates an unwillingness to share data and prevents data standardisation, which hinders productivity gains in the industry.

Many countries develop their own energy networks to reduce dependency on external energy resources. As a result, there is less competition in national energy markets for the production, supply and ownership of energy infrastructure, and newer energy technologies have few providers or alternatives. This increases energy costs for consumers exacerbating existing social inequality.[9]

3. **Infrastructure investment focuses more on maintenance and improving resilience, and less on inclusivity**

Extreme weather events occur with more frequency and with greater intensity, and low-quality, ageing infrastructure requires frequent maintenance and retrofitting.

In more developed parts of the world, the focus is on ensuring the resilience of infrastructure assets, from design to construction. Digital twins (highly complex virtual representations of a physical object or system) are used at the planning stage of infrastructure projects to assess an asset's ability to withstand harsh weather conditions. AI-enabled software is used to generate designs that demonstrate resilient characteristics across multiple scenarios, however an unwillingness to share data and a lack of data standardisation mean that design and engineering firms struggle to generate truly optimal solutions.

Construction materials are chosen based on longevity and resilience but they are expensive. The use of technology in construction varies greatly from region to region, as firms are unwilling to share their intellectual property.

For emerging markets, economic growth is the utmost priority, and infrastructure projects and programs are designed and planned to cater to the minority of wealthier communities where a more secure return on investment is guaranteed. Disadvantaged groups are often left out of the stakeholder engagement and planning process. They have to live with outdated public infrastructure that was built with minimal cost and low quality, despite the fact that these groups are often the most impacted by climate change-related extreme weather events.

4. **Governments around the world cannot agree on any common regulatory framework; instead they prioritise domestic needs and economic growth**

Environmental legislation, including carbon emission targets and sustainability standards, vary significantly across regions to reflect national (or regional) priorities. There are also

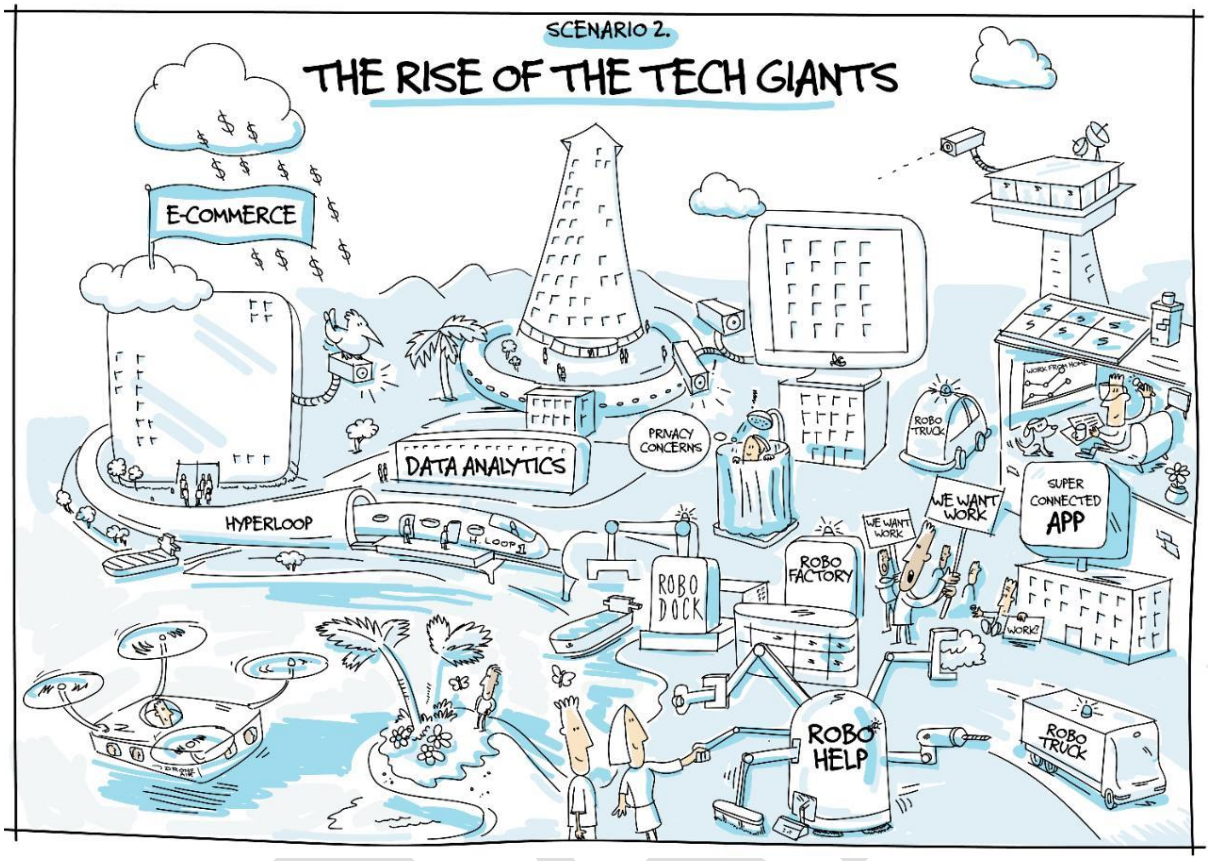
substantial differences in environmental policy responses between developed economies, which had already begun transitioning to lower carbon economies, and emerging economies, which still rely heavily on traditional sources of energy, such as oil and coal.

Developed economies focus on building the resilience of their existing infrastructure assets in the face of increasingly frequent and intense natural disasters. Meanwhile, emerging economies prioritise economic growth at the expense of attempting to manage environmental change. The level of greenhouse gas emissions is still increasing across both developed and emerging economies as governments do not intervene to curb this growth. The lack of specific regulatory action in emerging economies will have second- and third-order impacts, which, in turn, exacerbates many socioeconomic issues, and exerts further strain on existing infrastructure networks

At the same time, governments create structural reforms that shift support to national champions who establish themselves as monopolies in protected industries. National champions have an inherently profound structural impact which politicians can capitalise on, such as in domestic job creation and national security improvement. In return, national champions receive government support with easier access to higher levels of financing, and even oligarchy or monopoly status in protected industries.

Sizeable workforces shield these companies from regulation, making protectionism more likely if it proves favourable to them. They often create so-called ‘national brands’ – an extension of the national champions themselves. These brands are typically shielded against protectionist measures thanks to their diversified, loyal and less price-sensitive customer base, and their global reach. Increasing fiscal stimulus in domestic markets may also be used to support national champions.

3.2 Scenario 2 – The Rise of Tech Giants



3.2.1 Scenario description

Imagine a corporate-dominated, highly digitised world where the adoption of technology is hyper-accelerated across all infrastructure sectors.

This scenario is characterised by:

- Automated machines, robots, connected systems and cloud technology, which drive economic growth and productivity, and reduce demand for low-skilled workers
- High levels of global cooperation, diminished importance of national borders, and economic domination by the private sector, particularly the tech giants
- Capital access through crowd funding, direct investment platforms and global crypto currencies
- People spending more time on leisure activities than at their place of work

This is a world in which dominant corporates and tech giants disrupt incumbents in many sectors, gradually assuming the role of government in providing infrastructure, with on-demand service for water, electricity, transport, and waste on a city-wide scale. National sovereignty diminishes in importance, as do national borders in this increasingly virtual world, shaped by the actions of global technology companies.

Self-improving AI applications drive economic growth. Global crypto currencies are integral in

the global financial system and capital is easily accessed, often from crowd funding and direct investment platforms. Technology fuels a thriving sharing economy. All data is held by giant tech companies, which creates privacy and rent extraction concerns.

Technological advances have improved infrastructure quality and productivity in the sector. Leaps forward in software, AI and automation mean infrastructure sectors are primarily digitised. Automated machines, connected systems and cloud technology are prevalent. Across-the-board automation has decreased demand for low-level skills and people spend more time on leisure activities than at their place of work. Resource consumption has decreased slightly due to a reduction in physical assets.

3.2.2 Implications for the infrastructure community

1. **Private companies assume the role of infrastructure providers, with competitive advantage occurring upstream in the planning and design stages**

Private sector corporations, including tech giants, technology-enabled construction firms and other infrastructure contractors, own and manage large urban precincts and offer 'infrastructure-as-a-service' to their customers. Tech companies in particular begin to play the lead role in infrastructure design and delivery, and control data pools and interfaces. This leads to a diversity of new services, but also to increasing power concentration for technology companies within the infrastructure community, and significant implications for investors. This includes significant political influence over the infrastructure development process. One particular way in which this influence is demonstrated is an increase in unsolicited proposals in infrastructure, which reduces project identification costs and is an incentive to innovation, but also skews development towards projects that maximise commercial return for technology companies and their partners.

Infrastructure assets now incorporate interconnected intelligent systems with seamless data flows and interoperability across the asset's life span. Industry players integrate planning, design, construction and maintenance to control the data and systems used on their projects. Players outside the emerging common data systems and proprietary pools are disadvantaged because they cannot process data from upstream activities, and the data they produce is less valuable for downstream activities. Independent contractors and pure O&M companies are most at risk because much of their work is now automated, and they increasingly depend on data from partnerships with design and engineering firms. They are forced to increase integration and collaboration across the value chain, or risk failure.

2. **There is a shift in the profile of demand for infrastructure assets: fewer physical assets are needed for work, and demand has increased for leisure assets and data centres**

In this technology-dominated world, most business activities are conducted virtually and there is a drastic decrease in demand for physical assets, such as commercial, office and public buildings. Seamless connectivity allows people to work and study remotely and e-commerce retail has overtaken bricks-and-mortar shopping activity. In contrast, the need for communications assets has increased significantly to facilitate this new level of connectivity.

In a largely automated economy, people spend more time pursuing leisure activities, creating demand for recreational structures and facilities, such as fitness centres, theatres and arenas, and other large assets, such as stadiums and amusement parks. This also boosts demand for individual passenger transport infrastructure as people travel more for leisure, including robot taxis, hyper-loops and taxi drones.

3. Infrastructure value chains are dominated by InfraTech

InfraTech (automation, Internet of Things, distributed ledger technology, visualisation, image recognition and 3D scan, BIM and digital twins, AI and other advance analytics) almost completely replaces manual work across the entire infrastructure value chain, every stage of which is connected through sophisticated networks and full interoperability. The human element in the value chain remains with highly skilled technical experts with deep knowledge of areas such as AI, robotics engineering, and algorithm programming.

AI-based systems leveraging big data are used to forecast demand in the development and planning of every infrastructure asset. Digital twins support goal-based network/system/asset planning, and enhanced asset simulation is available for life-cycle value optimisation. Predictive modelling is used for finance processes and monitoring, such as to optimise variable user charge rates based on a range of dimensions. This helps to inform investor decisions. The rise of investment funds focused on infrastructure technology in partnership with venture capitalists, as well as the rise of big data, creates new revenue and financing models for infrastructure.

Intelligent design automation is fully utilised in the engineering and design phase. Intelligent design software incorporates machine learning and advanced simulation to run algorithms in the cloud that rapidly cycle through possible design solutions to identify which best meets customer needs. Usage data from comparable existing assets can be incorporated into new designs because all assets are connected via smart sensors. The design output is presented as an 8D building information model (BIM) with a set of metrics, including 3D object data, scheduling (4D), OPEX and CAPEX (5D), sustainability (6D), social inclusiveness (7D), and O&M (8D).

During the construction phase, information from 8D BIM models instructs robots and automated construction equipment, including autonomous excavators and trucks, brick-laying robots, 3D printers and drones. Human workers manage and supervise projects, set up robots and perform robot maintenance. Sensors built into asset elements during construction stream information to an O&M module in the asset's BIM to guide facility management robots that perform O&M tasks. These include real-time progress tracking, productivity and quality control; augmented-/mixed-reality-based site management; and AI-based health and safety monitoring.

O&M, services and facility management providers perform a wide range of functions, from automated asset condition monitoring and inspection, to predictive maintenance and energy efficiency optimisation, through to robot service and maintenance. They add further value with automated security and incident monitoring, as well as dynamic flow/usage optimisation and pricing.

4. A highly digitised economy with rapid automation forces governments to respond with policies that address multinational taxation issues and reduction in jobs

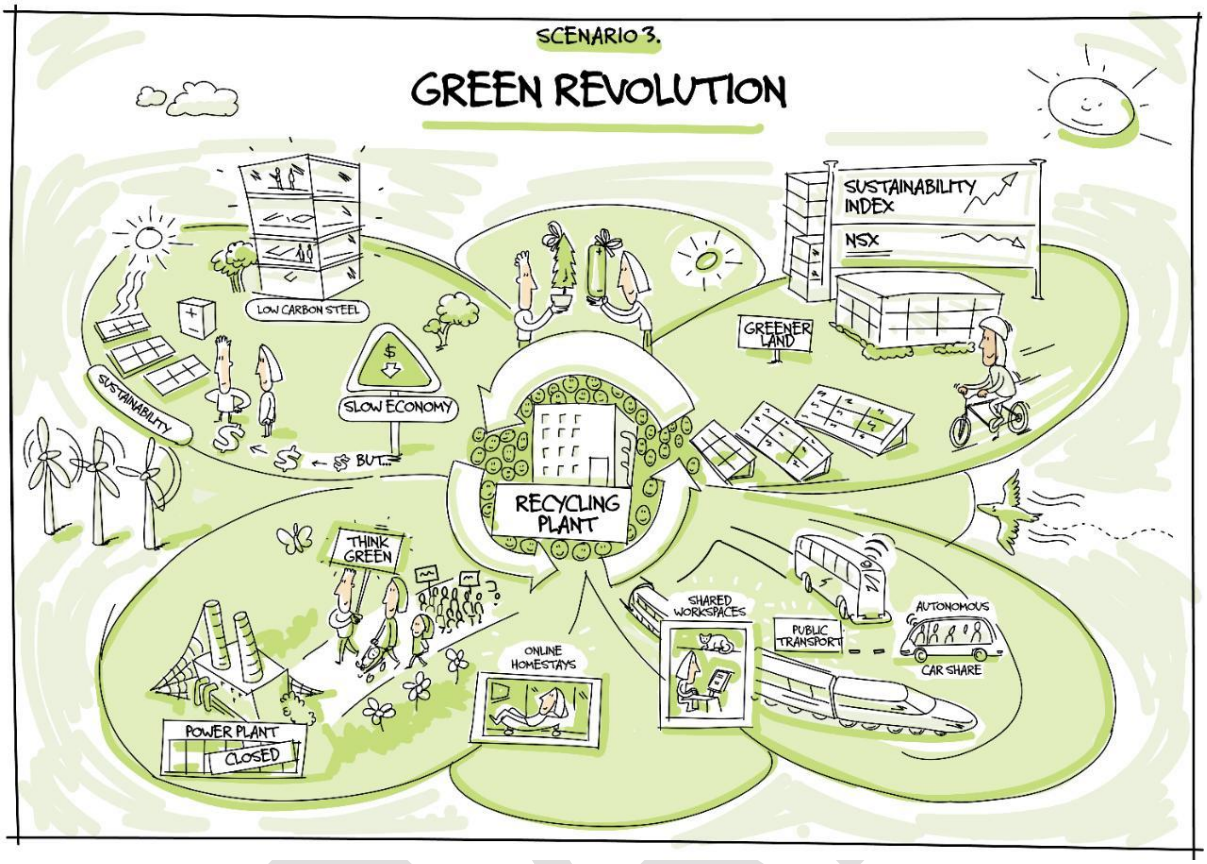
The increasing role of multinational private tech companies in delivering core infrastructure requires governments to amend legislation, particularly where these companies are providing platforms that are essential to everyday life and in monopolistic conditions. Concerns regarding base erosion and profit shifting (BEPS) are intensified in this scenario due to the dominance of the private sector. BEPS refers to tax avoidance strategies that exploit loopholes in tax rules to artificially shift profits to low- or no-tax locations. In this scenario, governments legislate to prevent dominant technology companies from doing this (e.g. under the OECD/G20 Inclusive Framework on BEPS[10]). However, these new regulations have not been successfully implemented across the world and tax avoidance becomes a significant challenge, particularly in emerging economies with limited capacity in tax administration.

Additionally, as technological advances permeate every aspect of the infrastructure industry, human involvement drastically reduces, especially in construction, operating and maintenance. By 2050 more than 40% of today's jobs are obsolete,[11] and hundreds of millions of jobs are lost to automation. Policy challenges to transition workers, especially low-skilled workers in transport (drivers), construction (builders, operators), and factory workers, out of old jobs into new roles overwhelm government capacity.

The impact of technology on individuals varies depending on market (emerging vs. developed), sectors, age group, gender, educational level, and socio-economic background.[12] Technology-driven change causes social tensions, and in response governments have created national policy interventions, including regulation to manage the power of large tech firms, particularly their data-driven platforms.

To minimise the risks associated with large scale automation, governments have adapted local education systems to upskill the traditionally low-skilled workforce employed in the infrastructure industry. In this future world, curricula focus particularly on building creativity and interpersonal skills, which are less vulnerable to automation. Several nations update fiscal and welfare policies, such as a universal basic income,[13] and taxes on technology, to ensure that wealth is not increasingly concentrated in the hands of owners of a small number of commercial entities.

3.3 Scenario 3 – Green Revolution



3.3.1 Scenario description

Imagine a world where sustainability is the new main decision criterion, in which the circular economy reshapes the infrastructure industry.

This scenario is characterised by:

- Environmental considerations, which drive economic and social activity, and substantial public investment in sustainable solutions and inclusive infrastructure outcomes
- Decreased consumption and demand, and a strong sharing economy but stagnating global economy
- Nations cooperating to respond to climate change, and governments pursuing aggressive green policies
- Technology investment and development which is primarily focused on minimising environmental impact

In Scenario 3, Green Revolution, environmental caretaking has become the core social value and a lead consideration in all economic and policy decisions throughout the world. Nations start working together to counter the progress of climate change and significant environmental improvements are evident.

Individual governments pursue aggressively green policies that require investment exclusively in highly sustainable projects. The strength of the sharing economy limits resource consumption and demand, and the global economy plateaus.

Technology investment and development is focused on reducing environmental impacts. The public and private sector invest heavily in the research and development of sustainable production processes and renewable materials in all industries.

3.3.2 Implications for the infrastructure community

1. **A circular economy policy drives new business models which focus on environmental services, the sharing economy, and recycling local materials**

In this green world, business models in the infrastructure industry are designed for the circular economy and there are stringent sustainability requirements on all sectors along the value chain.

The shift in social values and in government regulation promotes opportunities for service-oriented businesses, such as environmental planning for decommissioning and environmental impact auditing. Significant opportunities also emerge in sharing platforms (transport, housing, equipment, etc.) and in recycling building materials.

Design and engineering firms provide experience and capabilities in up-front comprehensive analyses of an asset's environmental impact over the course of its lifetime. This includes construction, commissioning, and operations through to asset decommissioning. Environmental auditing is now a legal requirement for every asset, not only in major developed markets but also in emerging economies, and assessing opportunities to reuse an asset at the end of its lifecycle becomes a lucrative part of the business. O&M business is partly substituted by self-healing materials and sensor data-optimised maintenance schedules.

The sharing economy flourishes and efficient sharing economy platforms exist in many sectors, from ridesharing, accommodation, and talent, to sharing construction equipment. Fiscal policy promotes the use of locally sourced recycled materials and serves as the basis for new, local enterprises created to recycle building materials.

2. **An active sharing economy and the focus on sustainability reduce demand for built assets and infrastructure, while promoting renewable energy assets and recycling**

The rise of socially responsible investments, combined with prohibitively high taxes for private, petrol-driven cars, has shifted transport away from use of petrol to electronic vehicles or alternative mobility devices. Localisation shifts congestion from major arterial roads onto the local road networks. As vehicles become autonomous, and offer greater convenience, comfort and safety, they risk becoming victims of their own success by increasing the demand for road transportation, with passengers using autonomous vehicles more often and in an ad hoc manner to run simple errands, which increases the total number of trips. The result could be more, not less, traffic congestion. [14]

Consumer preference for local production and the overall drop in consumption decrease demand for freight transportation, which reduces the need for new cargo infrastructure. Investment in oil and gas production platforms and terminals also drops.

At the same time, demand for renewable energy assets and recycling infrastructure increases. Renewable sources dominate energy generation, such as solar, wind, and wave energy, and investments in these assets rise. Extensive networks of prosumers generate their own energy and sell it back to the grid; similarly, they recycle their water and sell the excess. This generates competition across infrastructure markets which were previously dominated by monopoly providers and also creates scale for innovative technologies. Waste policy is shaped by the circular economy and compulsory waste separation is in force across the world. Organic waste is repurposed as an energy source, and the vast majority of paper, glass, and other materials are recycled. Single-use plastic is prohibited. Infrastructure assets, such as wastewater treatment plants and waste-to-energy plants, are ubiquitous.

3. **The infrastructure industry shifts to sustainable technologies and methodologies across planning, design and construction**

At the asset planning stage, regulation requires developers to run complex simulations that estimate the asset's potential environmental impact over its lifetime. Simulations also create a better understanding of the demand and need for certain assets, which helps governments to better serve end users with existing limited resources. These simulations take into account the construction impact of the asset, the carbon-intensity of its operations and decommissioning. This estimate is audited by government sustainability agencies against strict qualifying criteria before an environmental licence to build/operate is issued. Furthermore, developers are also legally required to conduct thorough stakeholder engagement activities, particularly at the planning stage but also throughout the project lifecycle, to ensure that disadvantaged groups can have their say and all parties benefit equally from the infrastructure.

Green generative design software evaluates which designs will have the lowest environmental impact over their lifetime. Designs that meet or exceed stated goals receive lucrative tax incentives and non-ecofriendly designs face hefty fines or are not given approval. Simulations are leveraged heavily in this work and experts in sustainability planning and material engineering are intimately involved in the design phase. Expert employees include sustainability planners, resource-efficiency engineers, resilience experts, circular economy consultants, material engineers, and scientists.

A circular economy model has been implemented in construction: materials used are taxed based on origin, recyclability, and the level of maintenance required through their lifecycle. Where possible, locally sourced and recycled materials, such as low-carbon steel and cement, are preferred, and taxes make 'cheaper' materials with a high-carbon footprint prohibitive. In the same vein, breakthroughs in material science focus on regenerative materials[15] to increase an asset's durability and reduce maintenance costs; for instance, asphalt that re-sets itself through induction heating, concrete mixed with living bacterial aggregates that can patch up cracks, and new alloys with self-healing properties. Technologies are also employed

on the construction site to enhance the sustainability of the construction process. For example, AI-powered 3D printing creates building elements with high precision, minimising levels of wastage.

When an infrastructure asset is built, sensors are embedded to deliver real-time data to sustainability agencies. Once construction is finished, operating and maintenance companies monitor sensors to ensure the asset's environmental impact remains within acceptable limits. Due to the full transparency requirements, more types of data will be reported to the government so they can enforce environmental regulations. Sustainability agencies verify that each asset's environmental impact during and after construction matches projections created by design-stage simulations.

4. **Government policy supports the transition to renewable energy, discourages greenfield projects, and brownfield projects are heavily regulated**

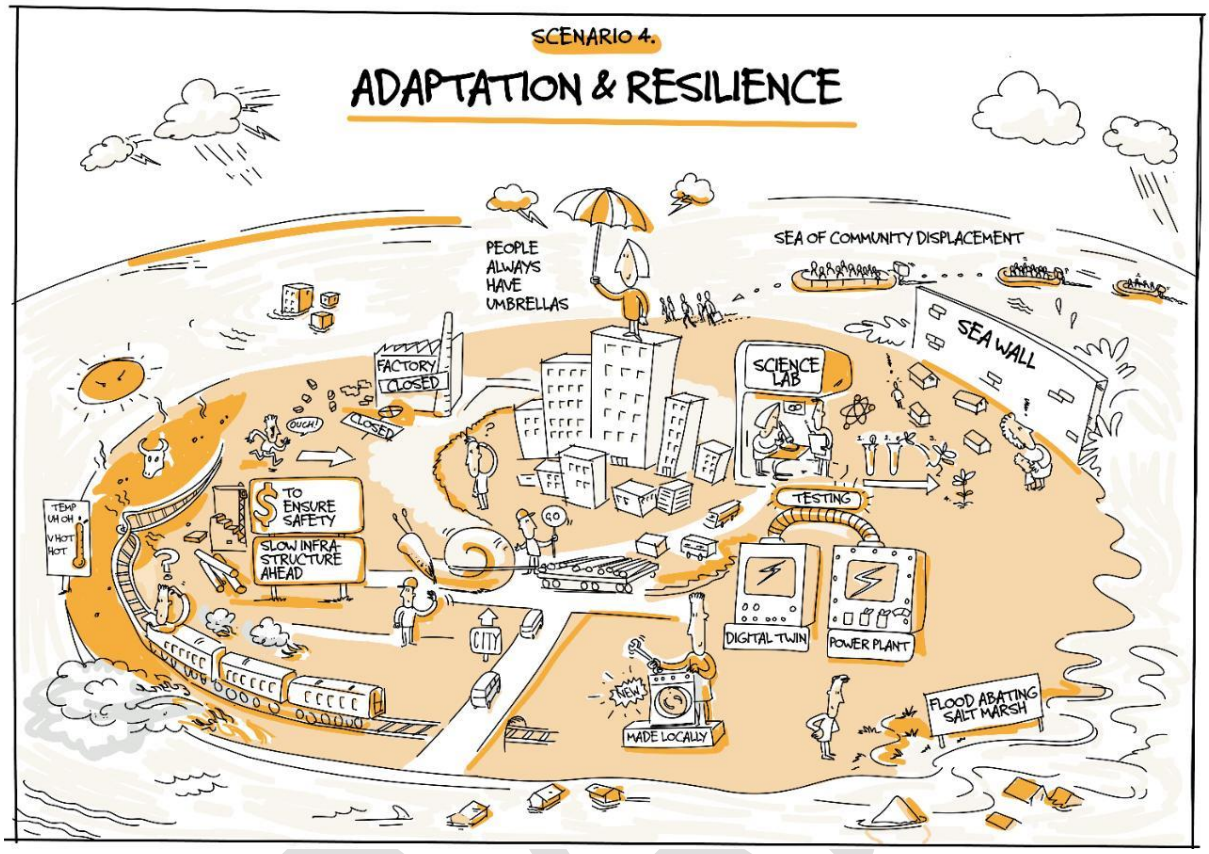
With sustainability a priority in the infrastructure industry, productivity and efficiency are deprioritised. Many governments around the world have passed regulations to support the transition to renewable energy. Significant financial penalties are imposed for non-sustainable material use, excessive energy consumption, and emissions and waste production.

Existing assets are kept operating as long as possible, and therefore require retrofits and maintenance work to extend their useful lives. Greenfield projects are rare especially in developed economies, because of the impact on the environment of constructing new assets, and regulations limit new building. Bids for those greenfield projects that do go ahead are selected according to environmental criteria above potential economic return, while all new infrastructure must be carbon neutral. Global coordination enables exceptions for emerging markets to invest in new assets required to mature the domestic infrastructure stock.

Governments provide ring-fenced funding and tax incentives to investors to encourage a focus on existing assets in what is termed 'smart growth policy'. As part of this, land use policies focus on increasing densification to reduce carbon footprint. Governments assume the risk of funding for those new sustainable technologies which are too risky for investors.

Governments around the world establish independent bodies mandated to provide investors with a visible pipeline of brownfield projects. Government assets are divested to private investors with the strict requirement that they improve the asset using sustainable measures and materials. The focus on brownfield assets helps to relieve fiscal pressure on governments and reduces overall resource consumption due to decreased demand for construction of greenfield assets.

3.4 Scenario 4 – Adaptation and Resilience



3.4.1 Scenario description

Imagine a world where environmental change has become irreversible despite concerted global effort, and infrastructure must focus on resilience.

This scenario is characterised by:

- Mitigation efforts no longer effective against climate change
- Increased urbanisation as many coastal cities and islands are impacted by rising sea levels and desertification, leading to a decrease in habitable land
- Technological innovation shifting toward adaptation strategies, such as building sea walls and flood-abating salt marshes
- Many countries and regions forced to become self-sufficient due to inefficient logistics

In this scenario, the world has past well beyond the climate change 'tipping point', and mitigation efforts are no longer effective. Urbanisation increases, as many coastal cities and islands no longer exist due to rising sea levels. The Sahara and other desert areas have expanded dramatically. People struggle to make a livelihood and must gradually learn to adapt to the new reality. Economic growth has slowed significantly. There are also many dilapidated infrastructure assets around the world.

There is strong cooperation between nations to adapt to climate change, and governments

impose strict regulations to ensure resilience. Technological innovation shifts toward adaptation strategies, such as building sea walls and flood-abating salt marshes, and engineering crops to better withstand harsh environments. However, costs for infrastructure projects tend to be high due to inefficient logistics. Many countries and regions are forced to be self-sufficient despite more widespread international cooperation.

3.4.2 Implications for the infrastructure community

1. **Business models focus on local trading and self-sufficiency, as trade logistics are increasingly difficult due to climate change**

Frequent and intense extreme weather events create supply chain risks. Organisations are expected to generate their own energy supplies and be completely self-sufficient. Major factories and other manufacturing operations have relocated away from areas where the risk of extreme weather events is extremely high.

Construction materials and other resources are predominantly sourced within country or, if this is not possible, from the closest available source. Smaller networks of factories and manufacturing hubs are located closer to consumers, allowing them to better serve local markets and needs.

This leads to a change in consumer perception. The preference for local production, and government-enforced requirements for 80% of infrastructure to be locally sourced and procured, boosts local employment, innovation and economic growth. Responsibility for infrastructure planning is mostly decentralised to local and regional institutions to deliver infrastructure that responds to local needs.

2. **Transport and built infrastructure and water management assets become much more adaptive and resilient to cope with climate change**

As sea levels rise, salt intrusion into freshwater aquifers along coastal regions pollutes accessible reserves, impacting water availability for infrastructure projects. The life expectancy of affected assets may decline or the frequency for retrofitting, replacing and maintaining may increase. High temperatures and ultra-violet radiation hasten the deterioration of road infrastructure and rail lines, impeding transport of goods, including mineral resources.

Changes to rainfall patterns and increased intensity of storm events affect water management assets, such as those designed to capture, store and distribute water. Dam integrity and capacity are at risk from soil erosion and flood waters. Extreme floods increase the flow of nutrients into reservoirs leading to algal blooms. This affects potable water quality, making processing more difficult and expensive. Increased acidification and salinity of oceans accelerates the deterioration of materials and concrete structures in the marine environment.

While these changes pose obvious challenges for the industry, particularly transport and built infrastructure and water management assets, new market segments also emerge. These

include protective structures, such as design and construction of sea walls, beach replenishment, drainage systems, as well as water supply systems in areas of drought.

3. **Climate change impact must be taken into account at every stage of the project cycle for infrastructure**

At the planning stage, developers must consider the potential impacts of the changing climate, such as exacerbated floods, storm surges, inundation, heat, extreme storms and other weather events. Climate change projection models and digital twins are legally required to analyse the impact on people, the environment and physical infrastructure. Better land use planning is also required, as some prospective sites become unviable.

Meanwhile, adaptive capacity for infrastructure assets must be incorporated at the design stage. Designs must be submitted for climate-robustness assessments to assess longevity, and prioritise resilience and adaptability. For instance, adaptive capacity of roads must be enhanced, as resurfacing or upgrades are more frequent during their lifecycle. Greater emphasis is placed on incorporating adaptability and flexibility during the design of long-lived assets, such as taking precipitation patterns into account in location design. Experts in resilience planning are intimately involved in the design phase.

Material used in construction must incorporate greater resilience characteristics. An example of this is the use of semi-porous infrastructure to aid the redirection and minimisation of flood surges. For operating and maintenance, sophisticated sensor networks are embedded to alert and predict impending climate threats. The de-commissioning phase considers the containment of chemical hazards as a new challenge in response to the changing intensity of extreme weather.

4. **All nations codify strict climate change requirements in national legislation, with a strong focus on resilience**

Strict rules impose costs on businesses which produce even moderate amounts of carbon emissions, and government subsidies for fossil fuels are completely withdrawn. Fines paid by businesses producing excessive carbon emissions are recycled from developed nations to emerging economies who struggle to manage environmental deterioration. Similarly, subsidies which previously went to investors in fossil fuels are now recycled into R&D efforts to help mitigate and adapt to the effects of climate change. There are also partially invested subsidies for project investors, as operation, maintenance and insurance costs have increased with sustainable development requirements, and for insurance, against increasingly frequent weather events.

The majorities of companies no longer flout national legal requirements regarding environmental protection measures due to rigid regulatory frameworks and customer expectations. Climate change projection models and digital twins are legally required during a project's planning stage to analyse its impact on people, the environment and physical infrastructure. Climate risk assessments are mainstreamed into infrastructure planning to avoid negative outcomes, such as sub-optimal investment, poorly performing infrastructure, and catastrophic failures.

Project bids are chosen based on longevity and resilience. New facilities, while limited, are constructed to be more resilient. Governments sponsor the education of sustainability experts and project teams are legally required to include at least one sustainability and resilience expert throughout the project's lifecycle.

In order to meet the needs of the poorest and most vulnerable, 'hard' approaches (i.e., physical infrastructure) are combined with policy interventions aimed at building capacity and resilient livelihoods. Local resource and capacity requirements are included in every project to boost local capacity development.

4 Areas for further investigation

Trend analysis and scenario planning provide insight into enduring trends that exist in any version of the future. These enduring trends inform areas for further investigation, upon which actions can be taken by relevant stakeholders, including governments, private sector parties, NGOs and others, to ensure a better future for infrastructure. Four priority areas emerge from this report:

1. Change will happen quickly; therefore business models will need to be more adaptive
2. The use of large volumes of data to make informed decisions will become an increasingly critical source of advantage; therefore data security, standardisation and transparency will become more and more important
3. New business models must measure social impact to avoid greater social division
4. The future requires new skills and talents, hence it important to strategically plan workforce and build organisational capacity

4.1 New business models and partnerships

All scenarios challenge traditional infrastructure business models. In *The Islands*, infrastructure businesses focus on domestic and regional markets, with governments exerting greater control on infrastructure and industry power consolidated with a few national champions. In *The Rise of Tech Giants*, giant global technology companies dominate, to the point of replacing the government's role in delivering infrastructure. In the *Green Revolution*, business models prioritise environmentally responsible activities. In *Adaptation and Resilience*, the emphasis is on extreme measures to adapt to environmental risk and there is a shift of business and community activity to local hubs.

How infrastructure businesses respond will relate to their position in the value chain, but change will be fast and all businesses, in design, construction and service, will need to become more adaptive to remain relevant. New partnership models will need to emerge to support these new business models and to manage rapidly changing situations: between traditional construction firms and tech companies, and between government and business, for example. Businesses must also be ready to respond as global supply chains are tested for resilience in light of geopolitical shifts and environmental impacts.

There will likely also be changes to where the highest value lies within the value chain. Automation will commoditise BIM, site layouts and scheduling functions, and businesses playing in these areas will need to move upstream or to higher value activities. Returns are likely to shift to design, planning and coordination, which will become increasingly software-driven. All infrastructure players will need to consider becoming more ambidextrous, taking long-term views in their core business while fostering internal disruption.

New business models will develop in sustainability and resilience planning, and adaptability. There will be further implications up and down supply chains, for example, into building materials industries and then to minerals and metals (for example, coking coal and iron ore).

Infrastructure design is likely to move towards modularisation and emphasise interoperability, while the trade-off between software- and hardware-based operating models becomes core to strategy. Traditional infrastructure has, by the very nature of the available technology, been focused on hardware, which is integrated and difficult to upgrade. Future technology will likely enable a more modularised and networked infrastructure that can be readily updated and will be more resilient to changing needs. Interoperability challenges will likely arise as technology develops, particularly if competing standards emerge. Businesses will need to make choices around the mix of software and hardware, with upfront design decisions determining lifecycle possibilities.

These business model implications are as true for government and public sector agencies as they are for the private sector. Governments will need to consider how to design flexibility into regulation and contractual models, emphasising outcomes, not just inputs, in the infrastructure sector.[16] For example, there is an opportunity for governments to further improve long-term infrastructure outcomes through properly drafted output specifications in contracts with private sector parties. Output specifications for these public-private partnerships describe the performance requirements that the infrastructure asset must meet, but do not define how they must be met. With this approach, governments can take advantage of expertise and innovation in the private sector, while simultaneously ensuring that the infrastructure asset fully meets the needs of the public.

4.2 Data: security, standardisation, and transparency

The use of large volumes of data to make informed decisions will become a critical source of advantage in the future. Data security, standardisation and transparency will therefore become increasingly important.

In all scenarios, the industry will rely on data as a tool to increase productivity, efficiency and interoperability. In *The Islands* and *Adaptation and Resilience* scenarios, cybersecurity, data security and national security emerge as critical concerns; data privacy features prominently in *The Rise of Tech Giants* scenario; and in *Green Revolution*, data transparency is critical to allow asset monitoring and auditing for environmental impact.

Government-set standards for data collection, management and sharing could rectify poor data collection and quality issues that inhibit knowledge sharing today. National guidelines on which data to collect at each stage of the project lifecycle will be a useful first step, with

multilateral guidelines developed subsequently. Standard sets of data for comparable projects would clarify what good practice looks like and facilitate informed decision-making.

Data standardisation and data sharing will eliminate the need for different industry stakeholders to set their own standards and will increase data interoperability. Data standardisation can also be encouraged through government procurement and contracting practices or funding conditions for grants.

Creating reliable, quality and easy-to-access data for infrastructure assets and projects is a critical area of focus. Infrastructure assets have long lifespans and are often owned by many different organisations over the course of their operational life. The long lifecycle and fragmented value chain limits incentives for data to be captured and shared longitudinally. An example is to stipulate the BIM requirements at the design and construction phases to make the operations and maintenance phases more efficient.

Data transparency is another critical consideration, as it is estimated that between 10% and 30% of infrastructure investment is lost due to inefficiency, mismanagement and corruption.[17]. Data transparency improves disclosure and project monitoring, especially for sustainable and resilient development. Ensuring ethical data usage and monetisation from market participants requires specialised regulations and oversight. The challenge will be to encourage transparency without compromising data privacy, citizen security, and in the case of key infrastructure assets, national security. Regulators need to consider legislation to protect critical infrastructure assets, such as electricity grids, gas pipelines, ports, and water and telecommunications networks, particularly against the threat of espionage, sabotage and coercion.

4.3 Inclusive development of infrastructure

The United Nations' Sustainable Development Goals (SDGs) rely on infrastructure as a critical enabler of social inclusivity. However, the potential for increased social inequality is a recurring theme in the four scenarios described.

In *The Islands*, inequality grows between emerging and developed countries, and between social groups in terms of access to and quality of infrastructure. In *Rise of Tech Giants*, widespread scale automation increases disparities between high- and low-skilled workers. In *Green Revolution,* the circular economy provides disadvantaged groups in society with more accessible and affordable infrastructure services. In *Adaptation and Resilience*, impacts of climate change on remote communities and socially disadvantaged groups are more direct and extreme.

Industry stakeholders and the international community must agree on an inclusive infrastructure framework. A first step is to define a shared understanding of inclusive infrastructure development. Inclusive infrastructure development can be defined as 'any infrastructure development that enhances positive outcomes in social inclusivity and ensures no individual, community, or social group is left behind or prevented from benefiting from improved infrastructure'.[18]

Defining inclusive development indicators and collecting reliable data will create an evidence base for monitoring the wider impacts and benefits of infrastructure projects, and improve the understanding of the value and impact of projects along inclusion dimensions. This could be anchored by including relevant KPIs at the contract level, where contractual requirements stipulate that projects must provide a positive impact or mitigate negative impact throughout the project lifecycle.[19]

Introducing Environment, Social and Governance factors (ESG) factors into asset business case planning will increase visibility and appeal to social impact investors.[20] There is growing evidence that suggests that ESG factors may offer long-term investment performance advantages.

Climate change events are likely to impact socially vulnerable groups more directly, because they often live in remote areas, areas with limited public transport services, and poor access to utilities.[21] Traditional stakeholder mapping and engagement for infrastructure projects tends to overlook these communities, and they risk being under-served or excluded during the development and implementation of the project unless this is addressed.[22] Stakeholder engagement mechanisms should also seek to identify where under-served groups are directly impacted by an infrastructure project and consider appropriate compensation options.

Infrastructure planning and development should seek to identify and engage directly with all impacted communities during stakeholder consultations and throughout the project lifecycle, to ensure infrastructure does not exacerbate social divisions and, in turn, that social divisions do not hinder infrastructure development.

4.4 Workforce planning and capacity building

All four scenarios require substantially different workforce skills than the industry relies on today. For example, security specialists, diplomatic planners and expert negotiators will be in demand in *The Islands* scenario. *The Rise of Tech Giants* requires experts with skills in AI, data analysis, robotics and programming who can train, supervise and maintain construction and maintenance robots. The experts sought in *Green Revolution* include resilience experts, circular economy specialists, sustainability planners, and auditors. *Adaptation and Resilience* will require resilience experts, material engineers and scientists.

Regardless of the future scenario, it is likely that today's infrastructure industry does not have sufficient talent with the necessary skills to meet future needs, nor does it have the processes in place to help employees acquire these capabilities.

Industry leaders need to engage in strategic workforce planning to anticipate the industry's workforce needs and skill requirements well in advance. To forecast future workforce demand, leaders should monitor trends that may impact the infrastructure project pipeline, either increasing or decreasing the workforce as required. Scenario analysis can support this, and can be used to anticipate clusters of skills that will emerge as critical, consider productivity gains from technological advances, and account for skills that might not yet exist.

Once an understanding of future workforce needs is established, industry leaders can

consider simulating future workforce supply to meet demand. This could be done by considering capacity losses through attrition, shifting demographics, and accounting for skills that will become obsolete due to technological advancement.

The next step is to identify the skills gap and devise a strategic response. In light of this, any over- or under-supply of staff can be addressed, and measures, such as recruiting, training, reskilling, upskilling, transfers, in-/outsourcing or lay-offs, can be initiated.

In addition to workforce planning, companies need to focus on building organisational capability, from recruiting to retaining talent. Recruitment outcomes can be improved by revamping the industry's image and reputation to attract talent. Many consider that the infrastructure industry has an image problem that deters high-potential, in-demand candidates.[23] Blue-collar workers may perceive jobs in infrastructure (mainly construction) as dirty and high-risk, and white-collar workers may view the industry as lacking innovation and challenge. Pitching jobs to younger people could emphasise the role of technology, innovation and the societal impact of infrastructure.

Another approach to closing the skills gap is to tap into high-potential, under-represented talent pools from unconventional industries, such as gaming for example, and to under-represented demographics, such as women. One method is to create employment targets for under-represented groups (see the US Bank Stadium Case Study[24] in the GI Hub's Reference Tool on Inclusive Infrastructure and Social Equity for an example of such targets). Companies can also build partnerships, such as university collaborations and student scholarships, to create a pipeline of future talent. The governments might also need to play a larger role in education, by working closely with the industry to better understand the skills requirement in the future to appropriately prioritise investments an allocate resources to education institutions. Governments also need to change the skill sets in the public sector to be a true partner to the private sector and ensure infrastructure outcomes are realised.

Talent retention is also a necessary area of focus for the industry. Measures include: tangible benefits (e.g., competitive remuneration) and intangible benefits (e.g., training and recognition); continuous learning and development practices that prepare employees for the future; messaging and career-development offerings tailored to target groups (women, workers who are not familiar with new technologies, or millennials); inclusive and psychologically safe working environments.

5 The way forward

All four scenarios presented in this report are deliberately 'extreme yet plausible'. They are not predictions of the future; instead, they are designed to stimulate thought and to be used as a wake-up call to think strategically about the future. The intent is for infrastructure leaders, from both the public and private sectors, to test their current strategies against possible future scenarios. Leaders should ask whether their strategies are resilient to these possible developments, or whether different choices are required.

We encourage members of the infrastructure community to investigate potential impacts and implications in these scenarios and take action to ensure their strategies and plans are resilient to the full range of possible developments. It could also be worthwhile for stakeholders to consider their own "ideal scenario" at a local level, and what actions would be required to increase the likelihood of achieving this outcome. For the next steps, the Global Infrastructure Hub and The World Economic Forum encourage interested organisations within the industry, as well as governments around the world, to reach out to us and collaborate on deep-dive analyses on potential implications of these future scenarios.

These collaborations might range from analysis of changes in business models and industry structure, shifting power of players in different market segments and phases along the value chain, to new development in policies and regulations, such as impacts on procurement process, funding and financing models, future skills and capabilities. These analyses should recognise the distinct difference in perspectives of both developed and emerging economies, whose levels of economic and social development vary greatly. As a result, strategic responses for each must be devised in a practical and fit-for-purpose manner. From here, collectively as an industry, we will aim to identify "no-regrets" actions at regional and sector levels, for different actors such as governments (from both developed and emerging economies), businesses (private investors, contractors and operators, technology firms), international organisations and multilateral development banks.

This report is only the beginning of the process, highlighting potential initial priorities for future work. It is intended to inspire discussion and to further the debate about the future of the infrastructure industry.

6 Appendix – details on megatrends

Society and workforce

1 - Urbanisation and population growth

Rising population and the disparity of opportunity between rural and urban areas have led to a worldwide migration to urban areas, fostering new clusters of urban economies, large infrastructure investments, and new challenges from overcrowding and congestion. Much of the emerging infrastructure and planning will revolve around the needs of megacities and tier 2/tier 3 cities that are springing up globally.

2 - Ageing population and workforce

In the developed world, the proportion of the population over age 65 is steadily increasing as life expectancy lengthens. Ageing workers and fierce competition for talent from other industries has resulted in an infrastructure workforce shortfall, which risks increasing costs and delaying project completion times.

3 - Environmental, Social, and Governance/Corporate social responsibility

There is growing evidence that suggests Environmental, Social, and Governance (ESG) criteria, when integrated into investment analysis and portfolio structure, may offer investors long-term performance advantages. Awareness of ESG and CSR has been growing as stakeholders pressure companies for accountability and recognise companies for sustainable practices.

4 - Sharing economy

The sharing economy refers to the ecosystem built around the sharing of human and physical resources including shared creation, production, distribution, trade, and consumption of goods and services (e.g., ride sharing, space sharing, job sharing, etc.)

5 - Pressure for companies to increase efficiency and productivity

Increases in efficiency and productivity have been a critical part of global economic growth and improving standards of living. National productivity growth stems from an interaction of technological change, organisational change, industry restructuring, resource reallocation, economies of scale, and scope.

6 - Rise of health and safety concerns

Civil engineers have raised safety concerns around ageing and inadequate global infrastructure (e.g., structurally deficient bridges, inferior roads and rail lines, ageing drinking water and wastewater systems). These pose a threat to human health and safety, and also can cost billions in lost productivity. Such concerns call for innovative investments and plans in support of safer, sustainable, more reliable infrastructure networks, and establishing procurement resilience.

Market and customers

7 - Demand shift to emerging economies

China has become the world's leading destination for foreign direct investment (FDI), a global manufacturing hub, and is currently engaging in the Belt and Road Initiative, a global development strategy involving infrastructure development and investments in 152 countries and international organisation across the globe. Other rapidly developing economies (RDEs) are working to build similar success stories, resulting in rising demand for infrastructure to support their meteoric growth.

8 - Infrastructure financing gap

Despite the widely agreed upon sentiment that infrastructure is an enormous economic multiplier, the world is facing a $15 trillion gap between projected investment and the amount needed to provide adequate global infrastructure by 2040. This financing gap is linked to issues ranging from corruption to overbearing bureaucracy to growing workforce shortages.

9 – Increase in bigger, more complex projects

In recent years there has been a rise of multi-billion-dollar infrastructure projects, also known as megaprojects. As projects increase in size and complexity, they become inherently more risky. Stakeholders can expect issues stemming from the need for international cooperation, politicisation of megaprojects, and capacity constraints in the face of successful project completion.

10 - Private participation in infrastructure

Historically, governments were the exclusive providers of a nation's infrastructure. Over time, and because of the global financial crisis, lower tax revenues, and higher expenditure governments are increasingly relying on the private sector to help fund these investments.

11 - Globalisation and international trade

Globalisation refers to the growing interdependence of the world's economies, cultures, and populations, brought about by cross-border trade in goods and services, as well as flows of capital, people, and information. International trade, enabled by infrastructure of all types, drives the global economy, allowing countries to expand their markets for both goods and services that otherwise may not have been available or affordable domestically.

Geopolitics and regulation

12 - Global divide and increase social inequality

Global divide refers to the widening gaps in wealth, digital access, education, and even health outcomes within and between countries. In recent years the gap between the rich and everyone else has increased markedly in nearly all countries. Such economic inequality can result in health and educational disparities among populations, which in turn cause a host of social and economic problems.

13 - Multi-polar world

Polarity in international relations involves the complexity of governmental power and its distribution within and across the international system. The historical dominance of the G7 states has been challenged by emerging economies and powerful coalitions, giving rise to a 'multi-polar' world.

14 - Rise of distrust & pressure for increased transparency

Stakeholders are more than ever concerned with an organisation's reputation. Trust is becoming harder to obtain and retain, becoming an indispensable currency to maintain good relations with a wider array of stakeholders.

Technology

15 - Rise of new materials & substances

Researchers have created a range of new advanced materials, which are key building blocks for future devices and systems, and typically have properties that are superior to and outperform conventional materials (e.g. geo-synthetics, reinforced polymer composites and advanced polymers, nanocellulose and wood-based composites). The development of advanced materials may lead to the design of completely new and remarkably resilient infrastructure.

16 - Rise of green energy sources

Concerns about volatile prices, potential scarcity of fossil fuels and environmental issues have led to growing interest in alternative energy sources. Alternative energy sources include new renewable fuels like biofuels or biomass along with power production from renewable sources like wind, hydro, solar, or wave power.

17 - Rise of IoT, sensors and smart infrastructure

As the price and size of sensors and chips drop, they will be placed in a wider range of objects creating smart buildings, smart appliances, the smart grid, smart vehicles, smart packaging, and smart logistics, among other applications. Many companies are working to bring smart products to consumers worldwide, for example self-driving cars have already driven more than 7 million kilometres on real-world roads and millions more virtually.

18 - Rise of AI and automation

Artificial intelligence (AI) and machine learning are forms of 'intelligence' demonstrated by machines. This includes human speech recognition (e.g., Siri), competing in a strategic game (e.g. IBM Watson winning at Jeopardy), and interpreting complex data, among many other applications. AI techniques and applications have advanced rapidly with the rise in computer power, access to large amounts of data, and increased role for autonomous robotics.

19 - Autonomous driving and new transport modes

An autonomous vehicle (AV) can sense its environment and navigate without human input. AVs are a natural evolution of the use of Intelligent Transportation Systems including adaptive cruise control, collision avoidance systems, navigation assistance and semi-automated parallel parking. The rise of AVs is coinciding with and

facilitating the emergence of disruptive new mobility models based on autonomy, sharing, and electric vehicles.

20 - Digitisation (BIM, on-site collaboration apps)

Digitisation refers to an organisation leveraging digital technology to better connect people, processes, and ideas, thereby more precisely addressing their particular needs. For example, Building Information Modelling (BIM) is an intelligent 3D model-based process that gives architecture, engineering and construction (AEC) professionals the insight and tools to more efficiency plan, design, construct, and manage buildings/infrastructure.

Sustainability and resilience

21 - Ageing infrastructure

Ageing and outdated infrastructure is a global issue resulting from the gaps in spending on new infrastructure and maintenance. This widespread problem impacts the effectiveness of transportation networks, water systems, communications networks, and the energy grid. Associated risks with potential failure of critical infrastructure are wide ranging in nature, from social, economic, health and safety, and environmental.

22 - Rise of natural disasters and resilient infrastructure

Natural disasters are the consequence of a natural hazard (e.g., volcanic eruption, earthquake, landslide, flood, wild fire) which affects human activities. Large growth in areas prone to natural disasters (e.g. coastal areas, fire-prone forests, steep mountain slopes, and riverbanks), increase number of people affected, as well as social and economic disruption from their impacts. Given rising incidence of natural disasters, leaders must now track risks and develop resilient infrastructure and deploy rapid response capabilities.

23 - Rise of climate change

Climate change refers to a broad range of global phenomena brought about mainly by the burning of fossil fuels, adding heat-trapping gases to the atmosphere, resulting in fluctuation of regional or global average temperature, humidity, and rainfall patterns over the long-term. Observed impacts include extreme temperatures, rising sea levels, global ice mass loss, and rising incidence of extreme weather.

24 - Resource scarcity and rise of the circular economy

Resource scarcity is defined as a reduction in economic well-being due to a decline in the quality, availability, or productivity of natural resources. Rising population, economic growth, and climate change place increasing stress on natural resources such as fossil fuels, minerals, as well as water and arable land. A circular economy is an alternative to a traditional linear economy (i.e., make, use, dispose). Based on the principles of designing out waste and pollution, resources are kept in use for as long as possible in order to extract their maximum value. The goal is to recover and regenerate products and materials at the end of each service life.

25 - Rise of security risk

The rise of global terrorism, the vulnerability of the Internet, and new perceived harm from physical and cyber-attacks on critical infrastructure are bringing about a renewed awareness of risk, as well as new opportunities for those able to reduce it.

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