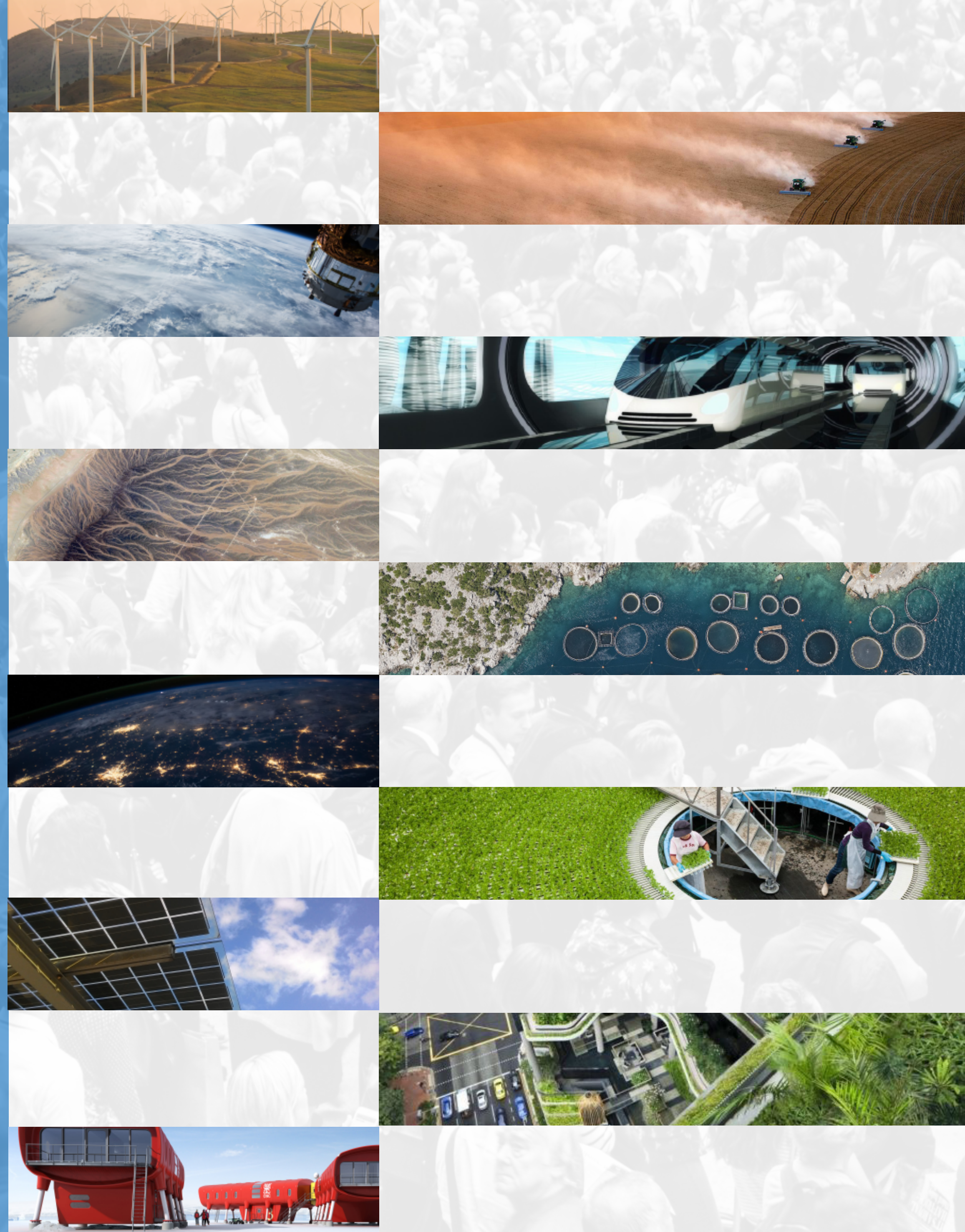


AMERICAN SOCIETY OF CIVIL ENGINEERS

Future World Vision:

Infrastructure Reimagined

May 2019

FUTURE WORLD VISION: Infrastructure Reimagined

HOW TO USE THIS GUIDE

Careful thinking about likely future realities is what civil engineers do every day when planning, designing, and implementing their projects. The goal of this white paper is to examine a variety of plausible future outcomes in our built world, but at a scale much larger than civil engineers typically consider. This glimpse into an array of possible future world scenarios is intended to help civil engineers and the broader infrastructure industry—including project owners and developers, designers, academicians, financiers, constructors, and other allied professionals—make decisions today that will lead to better outcomes tomorrow.

By identifying the common implications among these visions of the future, civil engineers and the infrastructure industry will be better prepared for what lies ahead. The aim of this paper is to help guide planning, policy, and design thinking, both today and into the future.

The following scenarios are presented without bias, although elements of some may seem more—or less—favorable to human health and the environment than others. With this array, civil engineers and the infrastructure industry can formulate strategies and actions to capitalize on opportunities and avoid negative outcomes.

The future world scenarios presented herein are, therefore, representations of the realm of possibility, with guideposts that enable us to shape the future and achieve a safer, healthier, and more sustainable world.

EXECUTIVE SUMMARY

Our world and its peoples will be faced with monumental environmental and societal challenges over the next several decades. One of the American Society of Civil Engineers' (ASCE's) primary goals is to prepare civil engineers today to meet the challenges of tomorrow.

Traditionally, engineering professionals' roles have been well-defined. But in the future, the effects of climate change, increasing population, and rapid deployment of new technologies will force civil engineers to reconsider their roles and responsibilities. To be successful in tomorrow's world, civil engineers and the infrastructure industry will need to be at the forefront of changing trends and will need to properly translate these changes into leadership, communication, and education efforts.

ASCE has undertaken a rigorous examination of future macrotrends, then narrowed the large list into a group of six trends that are most relevant to the industry. A range of possible outcomes from these six trends was combined to develop four possible future world scenarios. For each scenario, an in-depth analysis was performed to understand the implications to the infrastructure industry over future timeframes (10, 25, and 50 years from today).

This paper presents projections of the significant evolution the infrastructure industry will undergo in the face of major world challenges. This paper also provides civil engineers with possible strategies to address a range of future-based scenarios, along with ideas on how to integrate new technologies, ideas, and ways of doing business into their work processes.

TRANSFORMATION OF THE CIVIL ENGINEERING PROFESSION

The following high-level key themes have emerged regarding what civil engineers do now and what new and ongoing skills will be required of them in the future.

TODAY

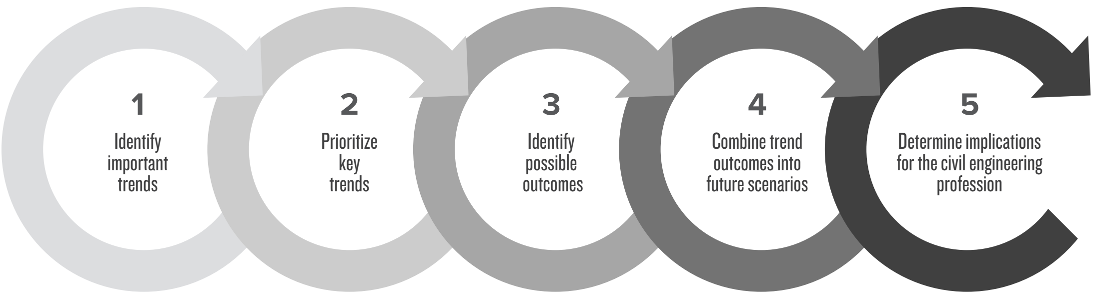
- Advance ethical standards in the civil engineering industry, including prioritizing safety, health, and welfare, and working to serve both the public and private good.
- Design, build, and maintain public and private infrastructure, such as buildings, roads, ports, and utility systems.
- Plan, budget, and supervise small- and large-scale projects, and work with stakeholders to incorporate community needs.
- Research new design techniques and materials, expanding the frontier of what is possible with engineering.
- Foster adoption of new project delivery models through improved risk-sharing contracts that allow for more innovation and promote performance standards and life-cycle accounting.
- Educate new civil engineers through teaching civil engineering at colleges and universities and providing on-the-job training.

IN THE FUTURE

- Harness advances in technology and computing power to improve tasks performed by humans.
- Respond to changing environmental and societal trends, including increasing environmental resilience under diverse conditions and preparing for changes in urbanization and demographics.
- Create new specialty disciplines to respond to new challenges and technologies.
- Given growing system interdependencies, develop multi-disciplinary skillsets and a wider range of expertise for integrated infrastructure.
- Assume more leadership and management roles within non-traditional places and teams; foster entrepreneurial thinking to develop innovative solutions.
- Take a systems integration approach to projects by using big data and autonomy to design more efficient systems for digitally connected utilities, transportation, and other infrastructure. Create linkages to and alignment with emerging engineering and non-engineering technologies and partners.

ABOUT THIS ANALYSIS

ASCE, led by the ASCE Industry Leaders Council (ILC), embarked on this scenario planning exercise to identify strategic actions that ASCE and its members should take to strengthen its leadership role in programs and projects that benefit the environment and human-kind. The ASCE ILC is comprised of senior leaders from industry, academia, government, and non-governmental organizations. With assistance from consultant Altman Vilandrie & Company, ASCE undertook this effort through a series of steps, as described in the following sections.



IDENTIFY AND PRIORITIZE KEY TRENDS

To develop the future world scenarios, the team identified 25 to 30 important sociopolitical, economic, environmental, and technological macrotrends that are pertinent to the infrastructure industry. These macrotrends included, for example, population dynamics (population growth and wealth distribution), cyber-security, aging infrastructure, rising populism, internet breakdown, human augmentation, and degraded space assets.

A difficult challenge for any future scenario planning exercise is to bound the set of trends. If the set is too large, analyses become unwieldy and relationships between trends become extremely complex. Focusing the scope enables a deeper dive into research and analysis. Limiting the number of trends also enables a deeper understanding of how each trend interacts with other trends.

Therefore, the larger list was narrowed into a priority list of six key trends that have a wide range of potential outcomes and a high degree of impact on the built environment. The six priority trends chosen include:

CLIMATE CHANGE

Climate change refers to a broad range of global phenomena created predominantly by burning fossil fuels that add heat-trapping greenhouse gases to Earth's atmosphere. Transportation and electricity production currently represent approximately 58 percent of greenhouse gas emissions in the United States. The resulting phenomena include global warming, extreme weather events, sea level rise, and coastal flooding, among others.

The Intergovernmental Panel on Climate Change estimates that global temperatures will rise 2.5 to 10 degrees (F) over the next century. The extent of the resulting effects will vary across regions, partially due to the ability of regions to mitigate or adapt to climate change.

ALTERNATIVE ENERGY

The energy industry today is dominated by high-emission fossil fuels like oil, coal and natural gas. Energy is centrally generated and distributed over long-distance networks.

Technological breakthroughs may lead to more widespread deployment of alternative energy sources that will economically replace fossil fuels with low- or no-emission sources. Small-scale local energy generation may replace centralized systems.

The analyses in this paper focus on possible future trends in electricity generation. The exact nature of technological breakthroughs – whether for solar, biofuel, wind, or nuclear fusion, for example – is not as relevant as the benefits that will be derived. Possible benefits include reduced greenhouse gas emissions, increased energy abundance at a lower cost, and reduced reliance on current energy grids.

HIGH-TECH CONSTRUCTION/ADVANCED MATERIALS

The construction industry is traditionally risk-averse and tends to only gradually embrace new innovations in collaboration, automation, and resiliency. The primary driver of this trend will be overcoming risk aversion, ensuring safety, and improving efficiency through more collaborative project delivery techniques and partnerships. Adoption of construction innovations can be a major enabler if embraced by the construction industry, and a major inhibitor, if not.

If adopted, increased automation, prefabrication, and large-scale 3D printing have the potential to reshape construction processes with a dramatic increase in how quickly infrastructure can be built and rebuilt. Augmented reality and virtual reality (AR/VR) have the potential for making construction more efficient through new collaboration platforms, offsite parts assembly, and improved worker training. New ultra-strong, ultra-light construction materials will enable critical infrastructure to last longer and better withstand disasters.

AUTONOMOUS VEHICLES

Autonomous vehicles are advancing quickly, and what they look like in the future will depend on several drivers: the nature of government regulation and standards; whether vehicles can truly be driverless; the degree to which rides are in individual vehicles or shared; and whether vehicles are privately versus publicly owned.

A fully autonomous vehicle system has the potential to transform cities and transportation. Rider and pedestrian safety could increase; vehicle-related deaths and traffic congestion could decrease. Car-related infrastructure currently takes up half of the typical American city's land area. Autonomous vehicle systems may require significantly less space, thereby freeing up large swaths of land for development.

Alternatively, if autonomous vehicles only supplement human-driven vehicles, congestion may increase and there may be new demand for infrastructure facilities to support autonomous vehicles.

SMART CITIES

Many cities are now building out sensor networks and a host of applications to collect data with which to make decisions and monitor services, but deployments are still in the early stages. In the future, smart city applications will have a profound influence on building management, transportation, energy and utilities, public safety (such as video surveillance and communications), municipal services (such as street lighting and wastewater and water management), and citizen engagement (citywide public wi-fi, for example).

Key decisions about the level of integration—including whether applications will be operating within a single vertical use or part of a streamlined comprehensive system—will determine the ubiquity of smart city deployments. Privacy and cybersecurity concerns will also shape the future of smart cities, as will the level of personalization.

POLICY AND FUNDING

Most of the other five trends are influenced by local and federal policymaking and regulation and are contingent on some level of available funding. Without clear policy goals, creative funding, and financing methods (including leveraging private investment), outcomes of the other five trends may be less favorable and may break down altogether.

Achieving more favorable outcomes requires coherent regulation of new technology, private sector funding cooperation, and an eye towards promoting equity of access that will increase quality of life for all.

IDENTIFY POSSIBLE DRIVERS AND OUTCOMES

Once priority trends were identified, in-depth research and expert interviews were conducted to better understand what factors drive possible future end states and what types of impacts these drivers could cause.

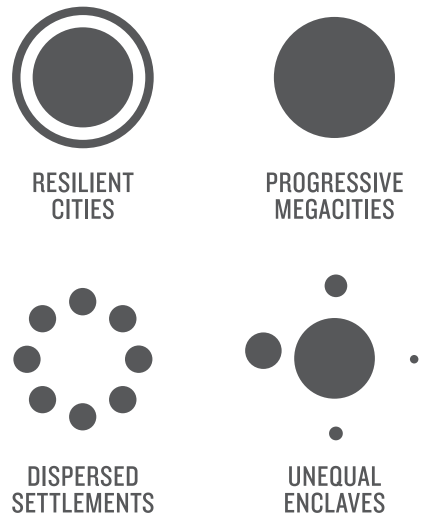
Key issues were then extrapolated to identify a set of three to four divergent, interesting, and plausible outcomes for each trend. The goal was not to predict the future, but rather to develop distinct outcomes that could then be combined into distinct future world scenarios.

DEVELOP FUTURE SCENARIOS

Scenario planning is an important method to prepare for the future, particularly when dramatic future changes are anticipated. By mapping out combinations of key trends and potential outcomes, four distinct and specific possible future-based scenarios were developed, despite uncertainty in exactly what the future holds. Each scenario presented here is the result of a deep analysis of the future-based trends described above.

These scenarios are purely hypothetical—yet reasonable—models of how society might interface with cities, infrastructure, and operational systems. The selected scenarios also combine possible outcomes in such a way as to create different end states. Each scenario is depicted with two primary trends and supporting secondary trends.

The four scenarios—Resilient Cities, Progressive Megacities, Dispersed Settlements, and Unequal Enclaves—were formulated primarily for illustration purposes as a reasonable representation of the confluence of various trends. The analysis includes an explanation, within each scenario, of how events may unfold over the next 10, 25, and 50 years. The end goal was to develop a framework by which to evaluate what the future holds for civil engineers and leaders shaping the built environment.



DETERMINE IMPLICATIONS FOR CIVIL ENGINEERS AND THE INFRASTRUCTURE INDUSTRY

For each scenario, specific insights and implications were formulated by asking four questions about the impact of that scenario on different types of infrastructure:

- → What is required to build safe and resilient structures?
- → How can the sustainability of infrastructure be improved?
- → How will infrastructure be designed to take advantage of new innovations?
- → How can costs and efficiencies in the construction process be improved?

FUTURE WORLD SCENARIOS

The four scenarios presented below do not represent all-or-nothing models. Rather, in the future world, components or aspects of one scenario will likely coexist with those of another scenario. Some parts of the world might experience conditions that more heavily favor one scenario, whereas a nearby community might favor a different scenario.

Many aspects of the formulated trends and outcomes are present today in varying degrees, as are aspects of the four scenarios. Some scenarios are well underway, and some are yet to emerge. The scenarios should therefore be considered both conceptual and evolutionary.

SCENARIO 1: **RESILIENT CITIES**

In this scenario, climate change causes devastating impacts to both inland and coastal cities. At first, society disregards or downplays climate change and discounts extreme weather events. Over time, however, the increasing severity of climate change impacts will increase the demand for substantial investments in long-term protective measures.

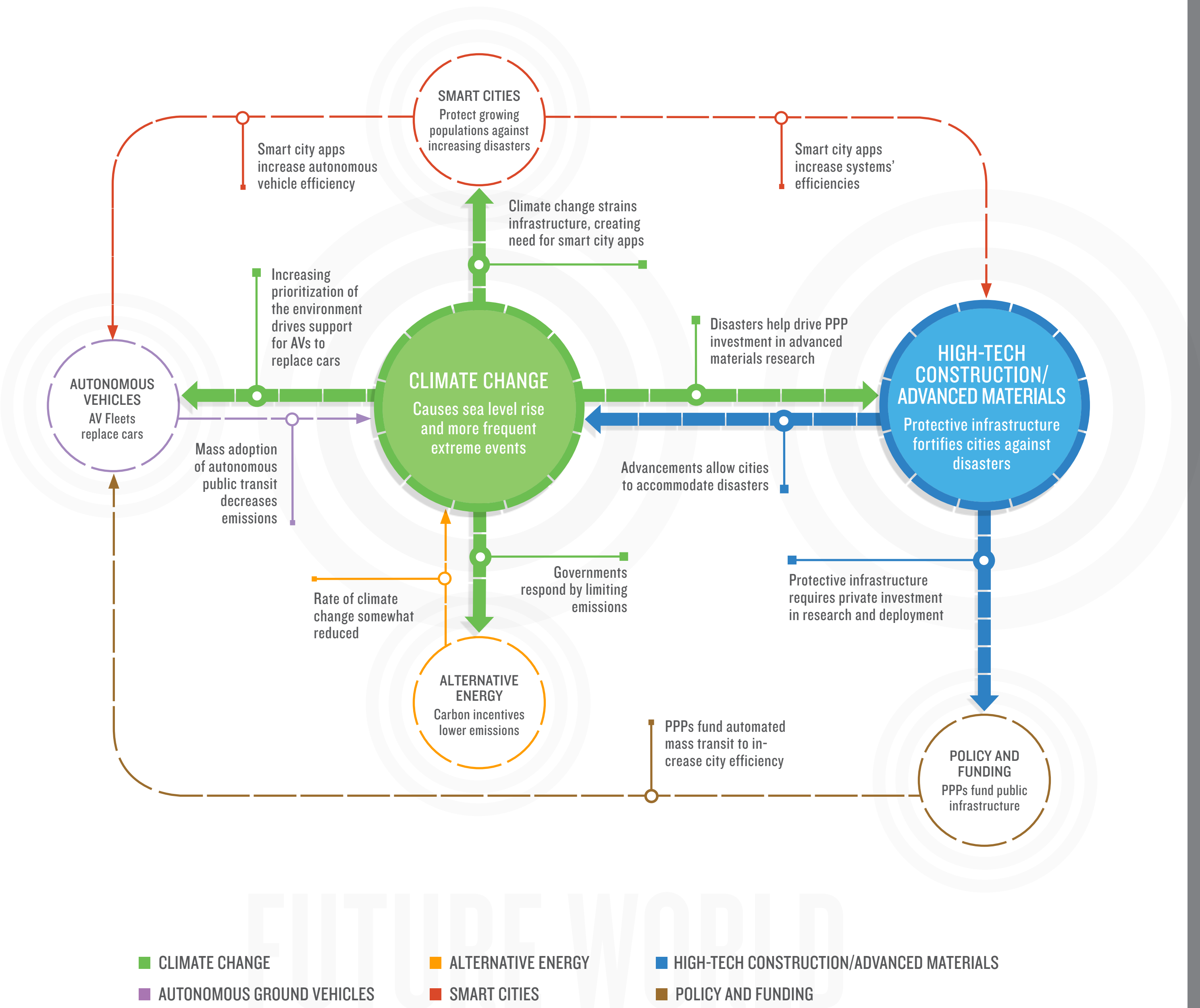
Eventually, governments will be forced to take more focused action and will mitigate and/or prevent damage through smarter and more resilient infrastructure and systems. However, delayed response will amplify the eventual mitigation costs.

Outcomes Over Time

PRIMARY TRENDS	10 YEARS	25 YEARS	50 YEARS
Climate Change	The impacts of climate change are increasingly apparent through extreme storms, intense droughts, and reduced agricultural productivity. Limited preventative action is taken.	Widespread droughts and agricultural collapse cause major strains on food and water supplies. Sea level rise threatens coastal cities. As rural populations migrate to urban environments with more secure jobs, food, and water, cities strain under the burden. Support builds for energy-efficient, carbon-neutral solutions.	Public and private actors are united in helping populations adapt to the new harsh environment, although delays cause higher costs.
High-tech Construction/ Advanced Materials	Governments and companies invest more in material science research with the hope of combating the impacts of climate change and potential disasters.	New resilient, sustainable materials hit the commercial market, although at extremely high prices.	Widespread advances in material science enable infrastructure and systems to better withstand the impact of climate and extreme events.

SECONDARY TRENDS	↓	↓	↓
Alternative Energy Autonomous Ground Vehicles Smart Cities Policy and Funding	Interest grows for public-private cooperation to upgrade city infrastructure to be more resilient.	Early inaction forces governments to invest heavily in climate change mitigation. Governments move to expand smart city technology to deal with threats and growing populations. Governments introduce broad carbon incentives to try to reduce carbon emissions.	Public-private partnerships (PPPs) are key in facilitating resilient infrastructure upgrades. Ubiquitous smart city technology, including autonomous public transportation, responds to the needs of growing urban populations.

RESILIENT CITIES SCENARIO
DYNAMICS OF TRENDS



RESILIENT CITIES: Implications for Civil Engineers and the Infrastructure Industry

Because the focus of this scenario is on the possibility of extreme climate change, the implications for the infrastructure industry are heavily focused on climate response. Industry professionals will need to further strengthen their expertise in climate resiliency and mitigation.

Infrastructure design will need to account for encroaching sea water, extreme storms, droughts, and growing populations. Digital systems that control and optimize potable water networks will need to be designed in a secure and integrated manner that responds efficiently to increased demand. Roads, bridges, and ports will need to be elevated and re-designed to minimize environmental damage, while seawalls, levees, and barriers will need to be built to protect cities from higher sea level and more frequent natural disasters.

The construction industry, including owners, engineers, and contractors, will need to move away from a short-sighted focus on construction costs in favor of life-cycle costs, requiring changes to procurement law and buy-in from policymakers. Otherwise, the costs of climate response will quickly become overwhelming, as infrastructure is replaced after one disaster only to be brought down again by the next.

Material science advances, which spark the development of more resilient building materials, will enable a more effective approach to mitigating adverse environmental impacts in this scenario. While more expensive at first, these solutions will benefit from a shift in mindset towards life-cycle costs. Infrastructure professionals in planning, design, and construction roles will need to keep abreast of these advances and be prepared to integrate them into future projects. Resilient materials will also be useful beyond areas most prone to natural disasters, as society and engineers grapple with issues associated with increasing urbanization and overcrowding.

While governments and policymakers in this scenario are slow to react to climate change, the infrastructure industry need not be. There are many areas where the industry can be leaders in sustainability. Promoting Envision standards and other analytical tools, along with a shift towards life-cycle costs will both help. Research into carbon sequestration, negative emissions technology, and alternative energy advancements will help as well. Civil engineers will need to articulate the benefits of sustainable designs to owners and developers and act as trusted advisors to determine the most cost-effective sustainable measures.

The onus will increasingly be on the infrastructure industry to understand the systems dynamics of climate defense and sustainability. Improved materials will help, but not without integration into new mass transit infrastructure, smart buildings, and improvements on traditional defenses like levees and seawalls.

SCENARIO 2: **PROGRESSIVE MEGACITIES**

In this scenario, extreme mass urbanization drives governments' direct action, through technology and city planning, toward development of progressive megacities. City services are augmented with technology to enable services to be personalized to individuals. In densely populated urban centers, cars are completely replaced with ubiquitous, autonomous public transit; car infrastructure is repurposed for housing and green space. Numerous construction advances lead to automated building processes and stronger materials.

These progressive, expansive megacities are fueled by abundant alternative low- or no-emission energy due to breakthroughs in nuclear fusion and other advances. Clean energy and smart city applications allow cities to support larger populations in a world facing scarcities of food and water due to climate change.

Outcomes Over Time

PRIMARY TRENDS	10 YEARS	25 YEARS	50 YEARS
Policy and Funding	Urban populations grow rapidly, straining city resources. Governments partner with private sector organizations to develop strategies to support the expanding populations.	Through PPPs, megacities finance and build autonomous transit systems and new nuclear fusion power plants.	Megacities with resilient systems and infrastructure will become hubs for millions of people, requiring larger local governments and funding streams.
Smart Cities	Large-scale smart city projects are undertaken to address the needs of growing populations to manage scarce resources and maximize efficiencies of city services.	Smart city technology is more pervasive, although still focused on impersonal efficiency initiatives to help stretch and preserve city resources.	Smart city technology is abundant and personalized. Apps and services cater to the needs of each citizen individually.

SECONDARY TRENDS	↓	↓	↓
Climate Change Alternative Energy High-tech Construction/ Advanced Materials Autonomous Ground Vehicles	Flooding is minimized in cities with defensive infrastructure. High-tech construction and materials advances enable resilient structures to be built quickly. Alternative energy research is a focus. Autonomous vehicle technology advances rapidly.	Rising temperatures and changing precipitation patterns wreak havoc on agriculture and water supply, although flooding is minimized through advances in construction that enable megacities to build resilient housing and infrastructure. The world sees revolutionary breakthroughs in nuclear fusion in laboratories.	Nuclear fusion infrastructure is built out, powering megacities cheaply and efficiently. Construction advances allow for cheap, fast, and automated building processes; city infrastructure can quickly adapt to populations' needs.

PROGRESSIVE MEGACITIES SCENARIO
DYNAMICS OF TRENDS

PROGRESSIVE MEGACITIES: Implications for Civil Engineers and the Infrastructure Industry

Because the focus of this scenario is on coping with rapid urbanization in growing megacities, the implications for the infrastructure industry are heavily influenced by the importance of technology. Infrastructure professionals will weave technology into all facets of traditional infrastructure while advancing designs that are only possible with automated construction and sensors that monitor the real-time conditions of vast, interconnected infrastructure assets.

A focal point will be deployment of smart city technologies and the ubiquity of autonomous transportation. Road safety will increase with dedicated autonomous vehicle infrastructure that will separate pedestrians and vehicle networks. However, fully-connected infrastructure systems will also increase the potential for external cyberattacks, necessitating the hardening of digital infrastructure.

Designing and marketing these physical and digital networks will require a full systems integration approach, spanning disciplines both within and outside traditional civil engineering. For example, developing a broad knowledge set around “Internet of Things” technologies and autonomous vehicle systems will be critical for rolling out infrastructure and the corresponding standards to support them. Designing autonomous public transit will be an enormous optimization challenge involving many different stakeholders and varying levels of priorities.

The private sector will play a crucial role in partnering with governmental agencies to help accommodate increasing populations. Convincing governments to spend more on research will be important, as the successful end state involves breakthroughs in renewable and abundant energy generation, autonomous vehicles, smart city technology, and construction materials and processes.

Within construction, the progressive megacities scenario features the same material science advancements as the resilient cities scenario, in addition to a transition away from human-driven construction towards more automated processes. Robots will be commonplace, and humans will work with the assistance of augmented reality to decrease downtime and cost while increasing worker safety. New technologies will enable roads, utilities, and buildings to be built, rebuilt, or upgraded rapidly and based specifically on changing societal needs.

High-tech construction and advances in materials science represent significant opportunities for the infrastructure industry; however, automation poses challenges. Civil engineering firms will need to re-imagine the best use of their human resources for planning and executing projects where the actual construction process itself may be handled by robots.

In this scenario, climate change is less extreme than in the resilient cities scenario but will still pose significant challenges. Advocating for total life-cycle costs will be important here, as will building up water efficiency expertise to prepare for more stringent government requirements. Concurrently, the infrastructure industry will prepare designs for newly available public/private spaces vacated by vehicle infrastructure such as parking lots and spaces, integrating both green spaces and more vertical cities to increase housing density. Infrastructure industry professionals will need to optimize the potential of smart utilities to serve these megacities, supporting an overburdened energy grid and distributing vast amounts of energy to its citizens and businesses.

SCENARIO 3: **DISPERSED SETTLEMENTS**

In this scenario, degradation in the quality of urban life, driven by ineffectual policymaking and inadequate funding, leads to emigration from traditional cities into new, relatively isolated settlements. These settlements generate their own clean energy, with an emphasis on distributed solar systems. Advances in telecommunications infrastructure enable widespread virtual commuting rather than actual transportation networks, and the amount of overall travel declines.

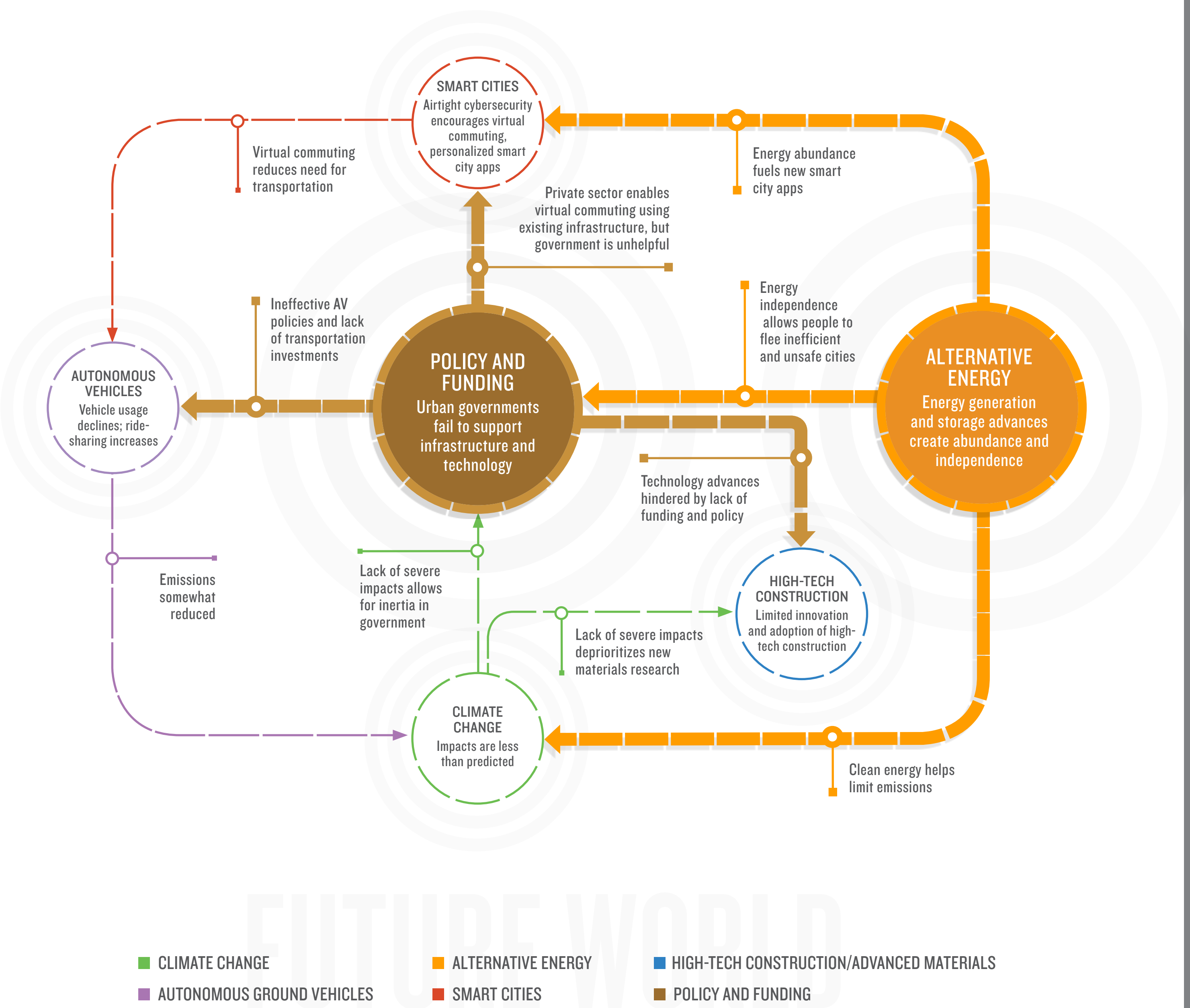
Citizens find these new settlements especially attractive given stagnating conditions in traditional cities. This scenario features relatively fewer technological advancements but focuses on shifts in governmental structures and efficiencies.

Outcomes Over Time

PRIMARY TRENDS	10 YEARS	25 YEARS	50 YEARS
Policy and Funding	Critical infrastructure continues to age; no significant plans are made to secure funding to repair or replace it, leading to widespread safety concerns. A mix of unhelpful policy and neglect stifles technological progress, making cities increasingly overburdened and inefficient. A longstanding trend of urbanization slows, and unhappy residents begin to leave.	Local groups build out new settlements away from traditional cities. Smaller governments are more effective at providing services.	Populations become more evenly distributed across these new settlements. Local governments are adept at addressing their constituents' needs.
Alternative Energy	Energy storage becomes commercialized. A focus on emissions and climate change continues to drive alternative energy research and innovation.	Advances in energy storage enable development of communities away from traditional energy grids.	Advances in alternative energy technology create energy abundance in new settlements.

SECONDARY TRENDS	↓	↓	↓
Climate Change High-tech Construction/ Advanced Materials Autonomous Ground Vehicles Smart Cities	Progress is made in combating climate change. Progress in autonomous vehicles and construction is limited by inefficient policy and funding mechanisms. Strong cybersecurity and investments in telecommunications infrastructure set the stage for technology and smart city developments.	Climate change impacts turn out to be far more limited than traditional models predicted. Some smart city apps are integrated into new, local infrastructure projects. Robust telecommunications systems built on top of existing infrastructure and managed to limit cybersecurity risk, which allow robust virtual commuting.	Settlements integrate smart city technology ubiquitously. Actual travel is mostly replaced with virtual travel as communities become mostly self-sufficient.

DISPERSED SETTLEMENTS SCENARIO
DYNAMICS OF TRENDS



DISPERSED SETTLEMENTS: Implications for Civil Engineers and the Infrastructure Industry

Because the focus of this scenario is driven primarily by the exodus of urban populations into smaller, disparate, and self-contained settlements, instead of planning for megacities, the infrastructure industry will need to help plan and design hyper-efficient, isolated, very small cities.

Telecommunications networks will be relied upon for an increasing portion of communication needs. Cybersecurity will be a key concern. This will require civil engineers to embrace non-traditional fields to best understand the digital interconnections of various infrastructure assets and microgrids.

Energy networks will look very different as these new settlements adopt solar energy and new solar storage technology. Instead of one-way distribution grids, grids will need to be able to adapt to surplus and droughts in different locations. Civil engineers will be involved in developing this technology and planning how to best and most efficiently lay out a small community with fully distributed energy generation and predominantly pedestrian transportation.

Construction will not see drastic technology improvements; the focus instead will be on marginal improvements such as how to increase risk-sharing and efficiency. Civil engineers will need to advise on best practices, to educate on life-cycle costs and propose sustainable, affordable, and safe infrastructure.

SCENARIO 4: **UNEQUAL ENCLAVES**

In this scenario, like the dispersed settlements scenario, deteriorating urban conditions drive an exodus from traditional cities. As a result, traditional cities struggle to deliver services to remaining residents.

Advances in autonomous commuting technology enable wealthy individuals to leave cities and set up new affluent settlements, thereby creating unequal enclaves. Those who can afford it commute long distances in autonomous vehicles from their new enclaves back into traditional city centers. However, cyber-security remains a huge risk, derailing attempts to move to more virtual commuting.

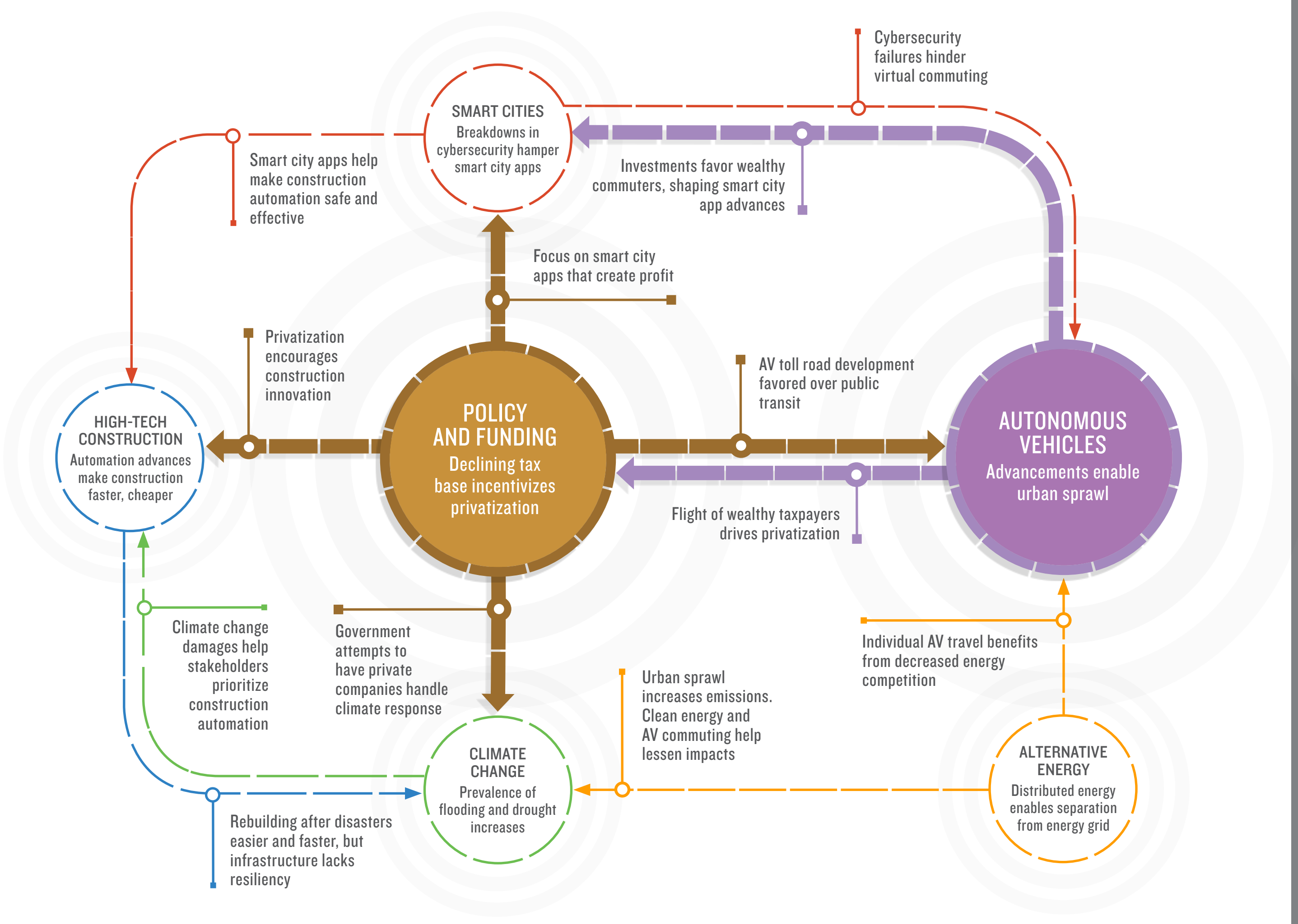
As traditional cities are battered by the impacts of climate change, devastating cyberattacks, and the lack of a ratepayer base to fund services, governments run out of funding and aging infrastructure suffers further neglect. In response, they increasingly turn toward privatizing services as one solution. Some privatization efforts of city services will yield innovative construction designs, but without proper government controls, the benefits will not be evenly distributed among society. For example, most smart city applications end up targeting wealthy commuters rather than suffering city residents.

Outcomes Over Time

PRIMARY TRENDS	10 YEARS	25 YEARS	50 YEARS
Autonomous Ground Vehicles	Autonomous vehicle technology improves, becomes commercially viable but very expensive. Long commutes via autonomous vehicles become viable for the wealthy who live in smaller communities far outside of cities.	Autonomous vehicles are mobile workstations. Wealthy residents of new enclaves use completely autonomous transportation to commute into traditional cities.	Revolutionary autonomous vehicle technology dramatically cuts commute time from wealthy enclaves. Benefits of autonomous vehicle efficiencies trickle down to city residents.
Policy and Funding	Governments lose valuable tax base as wealthy individuals leave cities for new enclaves. With lack of funding, governments cannot keep up with aging infrastructure and are unable to mitigate or effectively respond to natural and manmade disasters.	Governments, further cash-strapped by a declining tax pool, increasingly rely on privatized services to support the public, with mixed results.	Traditional cities implement premium services geared at wealthy commuters. Profits supplement some services for less-wealthy city residents.

SECONDARY TRENDS	↓	↓	↓
Climate Change Alternative Energy High-tech Construction/ Advanced Materials Smart Cities	Cities are increasingly battered by climate-related disasters as limited preventative action is taken. Digital developments (smart cities, virtual commuting) are slowed by cyberattacks.	High-tech construction enables wealthy enclaves to build new infrastructure quickly and cheaply. Smart city systems do not benefit urban residents. Impacts of climate change drive alternative energy research.	Climate change continues to batter cities. Mitigation efforts are focused on the most profitable areas. Wealthy enclaves feature highly optimized infrastructure, distributed solar energy, and smart city technology.

UNEQUAL ENCLAVES SCENARIO
DYNAMICS OF TRENDS



- CLIMATE CHANGE
- ALTERNATIVE ENERGY
- HIGH-TECH CONSTRUCTION/ADVANCED MATERIALS
- AUTONOMOUS GROUND VEHICLES
- SMART CITIES
- POLICY AND FUNDING

UNEQUAL ENCLAVES: Implications for Civil Engineers and the Infrastructure Industry

In light of the rising inequality stemming from this scenario, civil engineers and other infrastructure industry professionals will have an opportunity to help shape, rather than just react to, a future world with more equitable outcomes. Advocating and working for equitably distributed resources can help preclude this scenario, or at least avoid its obvious downsides.

Consider, for example, the development of policies that favor autonomous transit versus individual-owned autonomous vehicles. The argument need not center on inequity, but rather on the revolutionary possibilities for a city to replace traditional car infrastructure (roads, bridges, parking lots) with more efficient autonomous vehicle infrastructure (maximum two lanes roads, elimination of most parking), thereby opening up vast amounts of land in the city for green space or other opportunities. If autonomous vehicles are individually owned and exist alongside human-driven cars, however, most parking lots and multi-lane highways will have to remain, in addition to new autonomous vehicle infrastructure, possibly increasing (rather than decreasing) overall car infrastructure.

There are several important implications if this scenario does come to pass. For autonomous vehicles, for example, the infrastructure industry will need to design and implement super-efficient long-distance commuting routes and figure out how to allow autonomous vehicles and human-driven cars to coexist once inside the city.

Physical construction will be highly automated in these enclaves, enabling flexible roadways that can shift based on changing environmental conditions or as new communities pop up. These roadways will also require new codes and standards to regulate them.

Within aging cities, civil engineers and the infrastructure industry will need to help make the best of a bad situation. Limited government funding and natural and manmade disasters require tough decisions on funding and how to prioritize recovery and resiliency efforts versus critical infrastructure repair or replacement. Inadequate maintenance budgets will be expected to suffice for aging critical infrastructure upgrades.

Civil engineers will need to have systems dynamics experience to lead teams with cross-functional expertise in widescale rebuilding efforts. This could include cybersecurity experts, climate risk experts, robotics experts, and city planners.

Construction risks and costs will be exacerbated by extreme storms and flooding due to climate change. To improve costs and efficiencies in construction, infrastructure industry professionals will need to develop automated construction expertise, along with expertise in automated repair and resilient materials. To improve the sustainability of infrastructure, they will need to further develop their energy and water efficiency expertise, including expertise on advanced rooftop solar integration.

Privatization of city services will further emphasize life-cycle costs. Bidding for the right to offer those services would allow civil engineers to implement some advances in efficiency, from renewable energy generation and storage to smart city applications that cut down on costs and increase safety.

CONCLUSIONS

THINK ENTREPRENEURIALLY ABOUT THE FUTURE

This report presents a range of potential future scenarios and how each scenario may affect civil engineers and infrastructure industry professionals over the next 50 years.

The challenges facing our world in the coming decades could reasonably be considered unprecedented. These challenges will require steadfast commitment to using knowledge and skill for the enhancement of human welfare and the environment. These challenges will also present infrastructure industry professionals with unlimited opportunity to advance the industry and continue their leadership in the world to come. Not all challenges will be urgent in the near-term. However, it is urgent for us to begin preparing for them.

While it may be tempting for some professionals to concern themselves with only one part of the supply chain, understanding the entire system is essential. By taking a multifaceted approach, they will gain important insights about the challenges that lie ahead and how their future practice may be impacted.

We have identified four opportunities that, with innovation and willingness, will enable civil engineers to advance as the world evolves over the next 10, 25, and 50 years:

→ Civil engineers will incorporate new technological innovations and design infrastructure systems to enable new modes of living and transport, while adapting to significant demographic changes and increasingly harsh environmental conditions and events.

→ The pervasiveness of technology and the interconnection of previously distinct disciplines will create a greater need for civil engineers to understand the broader set of systems dynamics impacting their area of focus.

→ Construction companies will need to be set up to incorporate advances in both types of materials and in the construction process itself.

→ Civil engineers will become increasingly important partners with policymakers as new societal challenges that require engineering solutions arise. Civil engineers will take a leadership role in systems integration.

Regardless of how the world unfolds in the future, civil engineers must shift to accommodate change, address a new set of challenges, and continue to serve the public good. They must learn from other professions and each other, keep abreast of how other industries and organizations are managing change, and, most of all, be willing to lead toward better solutions.

ABOUT OUR RESEARCH PARTNERS:

Altman Vilandrie & Company is a strategy consulting and investment advisory firm experienced in strategy, marketing, finance, M&A, technology, regulatory, and operations disciplines. Altman Vilandrie & Company enables clients to seize new opportunities, navigate mounting challenges, improve business performance, and increase investor value within complex and converging industries.

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