Learnings from ASCE’s Future World Vision Project

Planning for Future Scenarios

October 3, 2019

Prepared for

Road Infrastructure Reimagined Conference
About AV&Co.

We work with leading technology, telecom and media companies on growth strategies, innovation and performance improvement

**Sample Clients**

![Client Logos]

**Background**

- Founded in 2002 in Boston
- Led by 13 Directors and 19 Principals
- 150+ consultants in North America; additional 50 in Europe (as Solon Consulting)

**Expertise Overview**

- Strategy and innovation
- Advanced analytics
- Private equity due diligence
- Performance improvement
- Fact-based, analytical and economics-driven approach
Scenario planning allows for strategic decision-making under uncertainty by accounting for many possible outcomes.

**Scenario Planning Definitions and Approach**

**Drivers** are the things that change over time to shape the trends of the future.

**Outcomes** describe distinct end states which will have different impacts on the broader world.

**Simplified Scenario Planning Process**

**Trend Outcomes**

**Possibility Space**

The **Possibility Space** is the set of all combinations of trends and their potential outcomes.

**Scenarios**

A **Scenario** is a specific, internally-consistent combination of potential outcomes.

**Scenario Planning Process Diagram**

- **Climate Change**
  - Extreme Sea Level Rise
  - Limited Impact
  - Severe Climate Change
  - Food and Water Scarcity
- **Alternative Energy Generation**
  - Distributed Energy
  - Carbon Tax
  - Infinite Energy
- **High-tech Construction**
  - Rapid Rebuild Infrastructure
  - Limited Innovation
  - Protective Infrastructure
  - Rapidly Evolving Infrastructure
- **Autonomous Ground Vehicles**
  - Autonomous Urban Sprawl
  - Driver-based Sharing
- **Future of Smart Cities**
  - Hyper-efficient Urban Core
  - Incremental Progress
  - Population-Centric Smart City
- **Government / Financial Support**
  - Pay-for-Government
  - Absent Government
  - Crumbling Infrastructure

Scenarios are chosen to highlight and bring to life key areas of uncertainty, "painting the corners" to challenge strategic thinking and test a broad set of future implications.
In order to generate future world scenarios, we combined a small number of trends which will have large impacts, albeit in meaningfully uncertain ways.

### Project Workflow

1. **Identify Important Trends**
   - ASCE team identified ~25-30 important macro trends to start with

2. **Prioritize Key Trends**
   - Filter down to 6 key trends
   - **Weigh variance of trend outcomes AND scale of impact to society**

3. **Identify Possible Outcomes**
   - Identify key drivers and impacts for important trends
   - **Use these to identify a set of divergent, interesting, and plausible trend outcomes**

4. **Combine Trend Outcomes into Scenarios**
   - Create scenarios by combining different trend outcomes
   - Develop details, assumptions, metrics, and storyline for each scenario

5. **Determine Implications for ASCE**
   - For each scenario, determine implications for ASCE
   - Identify new needs for civil engineers and legacy concerns
We conducted interviews with the ASCE working team and with experts in industry, academia, and government.

### Focus Trends

<table>
<thead>
<tr>
<th>Focus Trend</th>
<th>Representative Logos</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Change</td>
<td>[Logo]</td>
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<tr>
<td>Government / Financial Support</td>
<td>[Logo]</td>
</tr>
</tbody>
</table>
After identifying the major potential impacts of a trend, we arrived at a set of plausible, divergent, and interesting outcomes.

**Trend Outcomes – Autonomous Vehicles**

- **Ubiquitous Autonomous Public Transit**
  - AVs reach all neighborhoods, increasing socio-economic equality

- **Autonomous Urban Sprawl**
  - Personal AVs encourage urban flight and long commutes

- **Ride Sharing Reliance**
  - Increased urbanization facilitates growth of ride-sharing as AVs never fully develop

- **Car Ownership**
  - Extent to which cars are owned individually

**Trend Drivers**

**Trend Impacts**

**Trend Research**
Scenario creation relies on then combining these outcomes into a possibility space and selecting an outcome for each individual trend.

**Key Trends**

- **Climate Change**
  - Extreme Sea Level Rise
  - Limited Impact
  - Severe Climate Change
  - Food and Water Scarcity

- **Alternative Energy Generation**
  - Distributed Energy
  - Carbon Incentives
  - Infinite Energy

- **High-tech Construction**
  - Rapid Rebuild Infrastructure
  - Limited Innovation
  - Protective Infrastructure
  - Rapidly Evolving Infrastructure

- **Autonomous Ground Vehicles**
  - Autonomous Urban Sprawl
  - Driver-based Sharing
  - Ubiquitous, Autonomous Public Transit

- **Future of Smart Cities**
  - Hyper-efficient Urban Core
  - Incremental Progress
  - Population-centric Smart City
  - Personalized City

- **Government / Financial Support**
  - Pay-for-Government
  - Absent Government
  - Equitable PPPs

**Notes:**

Once we identified the possibility space of relevant trend outcomes, we created scenarios by picking outcomes from each trend and considering the combined impact to the described future world state.

Notes: While our research and analysis focused on the global development of scenarios and trends, some components (such as govt) emphasized the US.
In this scenario, the government’s direct action in response to mass urbanization drives the development of the megacity.
Implications for Civil Engineering

This exercise indicated that civil engineering as a profession will undergo significant evolution over the next 50 years

As the world evolves over the next 10, 25, and 50 years...

- **Engineers and designers** 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.

- **Governments** will become increasingly important partners for civil engineering firms as new expectations and societal challenges arise and require engineering solutions.

- **ASCE** will want to be positioned at the forefront of changing trends to properly translate these changes into their leadership, communication, and education efforts.
Implications for Civil Engineers

Civil engineers will need to broaden skillsets and work cross-functionally while relinquishing some tasks to AI, robotic drones, and outsourcing.

**What Engineers Do Today**
- Design, build, and maintain public and private infrastructure
  - E.g. buildings, roads, ports, public utility systems, and dams
- Hold supervisory and administrative positions
  - Plan, budget, and supervise large-scale projects
  - Present project updates to stakeholders
- Research new designs and materials
  - Expand the frontier of what is possible with engineering
- Educate new civil engineers
  - Teach civil engineering at colleges and universities
  - Provide on-the-job training for new hires

**What Engineers Will Do More**
- Harness advances in technology and computing power to improve human performed tasks
- Respond to changing environmental and societal trends
  - Increase environmental resilience under diverse conditions
  - Prepare for changes in urbanization and age of populations
- Advance ethical standards in the engineering industry
  - Prioritize safety, health, welfare, and equity
  - Work to serve both the public and private good
- Foster adoption of new engineering tools and solutions
  - Improve risk-sharing contracts to allow for more innovation
  - Promote performance standards and life-cycle accounting

**New Things Engineers Will Do**
- More formally focus on rising engineering challenges
  - Create new specialties to respond to new challenges and technologies (e.g., non-terrestrial engineers)
  - Develop or adopt ‘systems of systems’ approach to built environment
- Develop multidisciplinary skillsets needed for integrated infrastructure
  - Require a wider range of expertise given growing system interdependence
  - Civil engineers may need to take leadership and management roles in non-traditional projects and teams
  - Develop entrepreneurial thinking to minimize costs and maximize benefits
- Take a systems integration approach
  - Use 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
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Backup Materials
Trend Prioritization Methodology

From a long list of sociopolitical, economic, and technological trends, we identified 6 key trends that paint a wide range of significant and impactful outcomes.

ASCE identified **major short and long-term trends** across different categories... and AV&Co. worked with the ASCE Core team to prioritize them based on their **range of potential outcomes and magnitude of impact**.

<table>
<thead>
<tr>
<th>Category</th>
<th>Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technological</td>
<td>1. Alternative energy demand and availability including nuclear fusion, atomic and synthetic fuels, and distributed generation and energy storage (also 10 &amp; 25 year)</td>
</tr>
<tr>
<td>Environmental &amp; Natural Resources</td>
<td>2. Changing climate or degraded environment, failure of climate change mitigation and adaptation, rising sea levels – including man-made water crises (also 25 year)</td>
</tr>
<tr>
<td>Social</td>
<td>3. Megacity: massive urban expansion planning, rising urbanization, including mega-projects such as stratospheric commuting, maglev trains, Concord 3.0, etc.</td>
</tr>
<tr>
<td>Technological</td>
<td>4. Generalized artificial intelligence, including supporting: data science capabilities, and potential unintended consequences</td>
</tr>
<tr>
<td>Technological</td>
<td>5. Space Age - commercial space, mining, transportation, colonies, etc.</td>
</tr>
<tr>
<td>Technological</td>
<td>6. Flying vehicular transportation</td>
</tr>
<tr>
<td>Technological</td>
<td>7. Medical breakthroughs: DNA engineering allowing new human capabilities, human augmentation like cognition enhancing, neural or exoskeletons, synthetic biology, underwater O2 breathing, changes in aging, reduced hunger and obesity, limb or organ regeneration, designer babies, senses increased by 10x, etc.</td>
</tr>
<tr>
<td>Social</td>
<td>8. Population dynamics, such as changing demographics: population growth, urbanization, growing middle class in emerging economies, aging populations in some countries, including growing pension liabilities and also including the life extension through cryo, genomics, drug therapy, or cure for cancer (also 25 year)</td>
</tr>
</tbody>
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**Climate Change**
- Significant changes in global climate systems driven by greenhouse gases

**Alternative Energy Generation**
- Innovations in alternative energy generation and energy distribution

**High-tech Construction**
- Technological and material innovations in construction industry

**Autonomous Ground Vehicles**
- Development and implementation of autonomy for ground vehicles

**Future of Smart Cities**
- Development and implementation of advanced smart city applications

**Government / Financial Support**
- Government tendency to support new technology and use innovative funding methods
We conducted in-depth research on each trend to better understand which factors will drive their development and what types of outcomes they could cause.

### Trend Drivers – Climate Change

<table>
<thead>
<tr>
<th>Drivers</th>
<th>Details</th>
<th>Possible Future End State</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GHG Emissions</strong></td>
<td>Will GHG emissions decline or continue to grow?</td>
<td>Countries collaborate to severely restrict GHG emissions and undertake wide-scale carbon sequestration, limiting climate change’s impacts</td>
</tr>
<tr>
<td><strong>Temperature Rise</strong></td>
<td>How much will global temperatures rise?</td>
<td>Reduced precipitation events leaves the southwestern US in a state of chronic drought</td>
</tr>
<tr>
<td><strong>Precipitation Patterns</strong></td>
<td>How will changing precipitation patterns impact populations and agriculture?</td>
<td>Reduced precipitation events leave the southwestern US in a state of chronic drought</td>
</tr>
<tr>
<td><strong>Sea Level Rise</strong></td>
<td>How quickly and to what extent will sea levels rise?</td>
<td>Ice sheets melt much faster than previously anticipated, causing extensive coastal flooding</td>
</tr>
<tr>
<td><strong>Extreme Weather</strong></td>
<td>How will extreme weather impact populations?</td>
<td>Extreme weather events increase in severity, leading to extensive infrastructure damage when they hit</td>
</tr>
</tbody>
</table>
This scenario features devastating climate change and a functional government working to mitigate the damage through more resilient, smarter infrastructure and systems.
The rise of autonomous commuting drives wealthy individuals out of urban centers, forcing governments to get creative with less funding.

Dynamics of Trends in Unequal Enclaves Scenario

1. **Government lacks funding**, *incentivizes privatization*
   - **Privatization encourages innovation in construction**
   - **Government overwhelmed, attempts to have private companies handle climate response**
   - **Climate change causes frequent flooding of coastal cities**
   - **Urban sprawl, lack of car reduction contributes to increasing emissions, but impact limited by growth of AVs & solar energy**
   - **Distributed energy enables separation from energy grid**
   - **Rebuilding from disaster is easier and faster, but infrastructure lacks resiliency**

2. **Alternative vehicle advancements enable urban sprawl**
   - **Supports AV toll roads over public transit use cases**
   - **Individual AVs benefit from less competition for energy**
   - **Cybersecurity failure forces manual commuting**
   - **Money is in targeting wealthy commuters, which shapes the types of smart city apps (e.g., parking, prioritized routing, etc.)**
   - **Focus on applications that can create profit**

Key Trend(s)
- **Damage from climate** helps focus stakeholders on priority of automation progress
- **Government lack funding**
- **Privatization encourages innovation in construction**
- **Flight of wealthy taxpayers forces govt. to turn to privatizing services**
- **Smart city applications present but localized as cybersecurity breaks down**
- **Advances in automation make construction cheaper & faster**
- **Smart city tools help make with making construction automation safe and effective**
- **Supports AV toll roads over public transit use cases**
- **Cybersecurity failure forces manual commuting**
- **Advances in automation make construction cheaper & faster**
- **Smart city applications present but localized as cybersecurity breaks down**

Other Trends
- **Distributed energy enables separation from energy grid**
- **Rebuilding from disaster is easier and faster, but infrastructure lacks resiliency**
- **Urban sprawl, lack of car reduction contributes to increasing emissions, but impact limited by growth of AVs & solar energy**
- **Government overwhelmed, attempts to have private companies handle climate response**
- **Flight of wealthy taxpayers forces govt. to turn to privatizing services**
- **Money is in targeting wealthy commuters, which shapes the types of smart city apps (e.g., parking, prioritized routing, etc.)**
Degradation in the quality of urban life, driven by ineffectual government, leads to emigration from traditional cities into new settlements fueled entirely by solar.

**Dynamics of Trends in Dispersed Settlements Scenario**

1. **Traditional government fails to support both infrastructure and technology**
   - **Stifling AV regulation**, lack of infrastructure support
   - **Lack of severe impacts causes de-prioritization of new materials research**
   - **Lack of necessary funding makes breakthroughs less likely**

2. **Energy storage helps create both abundance and independence**
   - **Virtual commuting & energy independence allow people to flee inefficient and unsafe cities**
   - **Energy abundance fuels new smart city applications**

**Other Trends**
- **Vehicle usage declines, ride-sharing increases**
- **Airtight cybersecurity encourages virtual commuting and personalized smart city services**
- **Virtual commuting led by private firms on existing infrastructure (gov. unhelpful)**
- **Limited innovation and adoption of high-tech construction**
- **Solar revolution helps limit emissions**

**Key Trend(s)**
- **Climate change impacts are limited, flooding and ag. failure not cause of concern**
- **Somewhat reduces emissions**

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Once scenarios have been generated, the final piece was understanding the implications each would have for ASCE and for civil engineering.

### Key Implications for Civil Engineering from Each Scenario

*Note: This is selected list of key implications, not comprehensive*

<table>
<thead>
<tr>
<th>Infrastructure Design / Innovation</th>
<th>Infrastructure Construction</th>
<th>Infrastructure Safety</th>
<th>Infrastructure Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dedicated AV infrastructure creates space for parks, buildings, and wider sidewalks</td>
<td>Increase efficiency to maximize usable fresh water due to scarcity</td>
<td>Road safety increases</td>
<td>Contaminated water runoff a key focus area due to water scarcity</td>
</tr>
<tr>
<td>Augmented Reality-assisted field workers and robots decrease downtime, increasing worker safety, and decreasing cost</td>
<td>Update energy grid for increased throughput; improve water sanitation to maximize yield</td>
<td>Long-term durability less concerning due to ability to rapidly build new infrastructure</td>
<td>Water use efficiency a high-priority due to increased population, water shortages and food scarcity</td>
</tr>
<tr>
<td>Roads, utilities, and buildings built rapidly and moved based on changing yearly needs</td>
<td>Smarty city technology integrated into traditional infrastructure during construction</td>
<td>Harden digital infrastructure to withstand external threats</td>
<td>Energy efficiency de-emphasized due to infinite energy availability</td>
</tr>
<tr>
<td>Vertical construction accommodates increased populations</td>
<td>PPPs will provide funding for new infrastructure</td>
<td>Smart city communicates with drones to make on-demand repairs</td>
<td></td>
</tr>
</tbody>
</table>