discharge water quality will result in reduced nutrient pollution and improved downstream habitat.
The SMCWP also scored well in the Quality of Life and Leadership categories. This is a result of a strong public outreach plan, meaningful resiliency and sustainability goals of both the City and the SMCWP, and California Environmental Quality Act (CEQA) guidelines to mitigate a project's environmental and social impact.

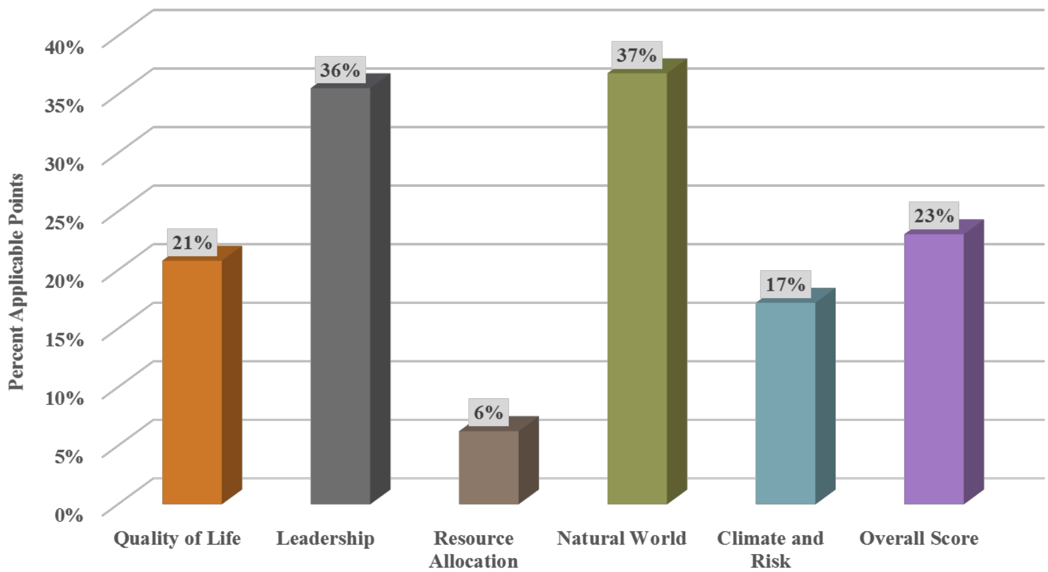

Figure 6. Phase 2 Results for San Mateo Clean Water Program.

The SMCWP scored reasonably well in the Climate and Risk category because the planned infrastructure accounts for future growth projections and is being developed with long-term risks incorporated into the design, so it is inherently future-focused and has a well-developed risk management plan. In this category, the SMCWP could improve by covering additional risks or conducting a life-cycle assessment of greenhouse gas emissions.

Like many Envision® projects (Arrasate, 2016), the SMCWP did not excel in the Resource Allocation category. To attain an initial score in many of the Resource Allocation credits, a project must first complete a variety of life-cycle assessments (including net embodied energy and energy use) and other calculations (including percentage of recycled materials). Because these calculations are not currently a standard industry practice, they can be cost-prohibitive (that is, not economically resilient and sustainable) when compared to other resilient and sustainable actions or design alternatives a program, organization, or project might pursue.

As shown in Figure 7, the baseline score for the SMCWP was 23%. In Phase 2, additional actions or design alternatives identified (approximately 60) could increase the level of resiliency and sustainability by 29%. A cost evaluation and prioritization screening will help SMCWP select targets. Next steps would include narrowing the list of potential targets by integrating organizational priorities (Figure 2b, Phase 3). Once complete, this evaluation would help SMCWP leadership select targets (Phase 3) to operationalize and institutionalize (Phase 4). Because SMCWP has a single overarching infrastructure outcome, Phase 5 would not add significant value.

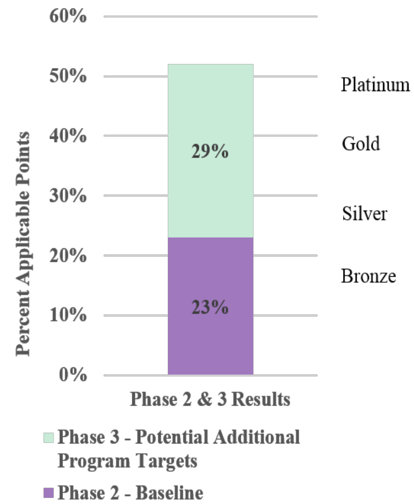

Figure 7. Phase 3 potential additional score for the San Mateo Clean Water Program.

City of Los Angeles Bureau of Engineering, Environmental Engineering Division, Los Angeles, California. Los Angeles (LA), at 470 square miles, has a population of approximately 4 million. Within the City of LA's (City's) Department of Public Works, the Bureau of Engineering (BOE) delivers stormwater, street, bridge, wastewater, parks, and transportation infrastructure. The Environmental Engineering Division (EED) is responsible for the planning and design of new construction and O&M upgrades at LA's four wastewater treatment facilities.

Following the effective implementation of LEED® requirements for buildings, the BOE moved to fill the gap for infrastructure, and in 2013, piloted Envision® at the South LA Wetland Park, receiving the Envision® Platinum Award (ISI, 2014). In November 2016, the LA City Council passed a motion to formally adopt Envision® for its projects. To support this effort, the BOE, which designs more than 100 projects per year, now has more than 50 credentialed Envision® Sustainability Professionals (ENV SPs). EED began working with CH2M in 2016 to pilot a customized approach to CH2M's Programmatic Framework with Envision® that will provide tools for project teams to easily evaluate projects for Envision® award potential, and streamline the documentation efforts for individual projects. EED's goal is to consolidate its current requirements, institutionalize Envision® priorities, and drive forward project certification for EED's planning and design projects.

CH2M provided a training workshop for 30 staff; reviewed projects previously evaluated for Envision® awards; and facilitated project and program team meetings to discuss EED's resiliency and sustainability goals, priorities, and drivers (Phase 1). As with the SMCWP assessment, during this phase, EED identified and provided documents relevant to Envision® criteria.

Because EED's goal centered around streamlining project certification, CH2M's Programmatic Framework with Envision® was customized to combine relevant aspects of Phases 2 through 5 (Figure 2b), with a focus on providing credit coversheet templates – one for each of the 60 Envision® credits – for use on EED project certification.

To submit a project for an Envision® award, a credit coversheet is prepared for each credit that summarize how a project meets the requirements of that credit, as outlined in the Guidance Manual (ISI and Zofnass, 2015). The coversheet includes annotated supporting documentation and a score based on what was achieved and documented. This information is compiled and summarized for each project seeking an award.

To streamline this process for EED and consolidate relevant details, CH2M is developing templates that summarize the city-, bureau-, division-, and facility-level guidance documents and requirements that govern all EED projects as related to each Envision® credit, and assigning a program level score. Each coversheet is accompanied by the relevant documentation, and includes prompts for project teams to evaluate projects for Envision® awards and gather additional documentation. For each project, the team will use the credit coversheet prompts to identify and document areas for improved resiliency and sustainability above the program baseline.

In developing credit coversheet templates, the program baseline is established (Phase 2), additional targets are defined for the program (Phase 3), program standards are operationalized and institutionalized (Phase 4), and tools for individual project review are provided (Phase 5).

CONCLUSION

Like a program's or organization's risk or quality management processes, CH2M's Programmatic Framework facilitates knowledge transfer and creates a new and proven method to standardize an organization's resiliency and sustainability priorities. The Programmatic Framework was designed to help organizations select the highest impact targets (highest level of social and environmental resiliency and sustainability) with the lowest overall cost (most economically resilient and sustainable). For organizations interested in Envision®, CH2M extended the Programmatic Framework, integrating the Envision® principles to facilitate knowledge transfer, support decision making, and standardize Envision® across all of a program's or organization's infrastructure projects, creating a comprehensive program development, management, and decision support system.

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Using Scenario Planning for Identifying Major Future Trends and Their Implications for State Transportation Agencies

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Abstract

The objective of this study is to demonstrate how scenario planning can be used for identifying forces and drivers that could influence the future of transportation system over a 30 year period. The researchers also used qualitative and quantitative methods to develop key implications for state transportation agencies for addressing underlying challenges and siege potential opportunities that the transportation industry might face. The method combines a causal loop diagram and cross-impact matrix to understand the interactions among the drivers and then hierarchical cluster analysis to identify how drivers can be grouped, representing expected behavior of the drivers in a particular way in future. These expectations are described in the baseline scenario and six multi-driver scenarios representing alternative futures. Transportation agencies may use these scenarios to assess the performance of their plans or assumptions against potentially radical shifts in future and develop strategies that could make the transportation system resilient to a wide variety of uncertain but possible future conditions.

INTRODUCTION AND BACKGROUND

The transportation industry continually faces new challenges that influence transportation needs and priorities. These challenges may arise from the impacts of major global trends, such as new technology, changes in the cost of fuels, and climate change, or from domestic trends, such as limitations in current transportation finance methods, changes in land use patterns, changing demographics and lifestyle expectation (ICF International 2008).

Future forecasting is vitally important to help state transportation agencies (STAs) think deeply and creatively about the future and address these challenge, or else they run the risk of being surprised and unprepared (Bishop et al. 2007). According to the American Association of State Highway and Transportation Officials (AASHTO), research can help STAs be equipped to deal with future challenges facing the transportation industry (ICF International 2008). The objective of this paper is to (1) identify future factors (drivers) of the transportation system and trends that could significantly influence infrastructure maintenance, preservation, and renewal needs in a time frame of 30 years into the future, and (2) present and demonstrate application of a team-based, stepwise research methodology that can be used by transportation researchers and practitioners to identify future scenarios and craft strategies to address challenges and siege opportunities that the transportation industry might face.

Use of scenario planning in transportation industry goes back to early 2000s when metropolitan planning organizations launched scenario planning initiatives to develop strategies for coordinating land use and transportation plans (John A. Volpe National Transportation Systems Center 2011). While forecasting future and trying to prepare for different potential outcomes is a complex task, it is even more difficult for governmental organizations and specially transportation agencies. This is main due to two reasons: (1) decision-making in public sector requires consensus across a wide variety of diverse and competing stakeholders, and (2) the planning and the design lives of transportation infrastructures are very long and needs to be measured in decades (Caplice and Phadnis 2013; Twaddell et al. 2016). Accordingly, using scenario planning in transportation future studies fits well to the characteristics and nature of work performed by STAs. In the last 10 years, Federal Highway Administration (FHWA) has been encouraging transportation agencies to use scenario planning for enhancing the traditional planning process (John A. Volpe National Transportation Systems Center 2011).

More recent application of scenario planning in transportation has been beyond land use and transportation and have included goals and objectives related to transportation system performance, adapting to climate change, energy and water conservation, housing affordability, economic competitiveness, fiscal sustainability, and public health (Twaddell et al. 2016). In 2011, the U.S. Department of Transportation John A. Volpe National Transportation Systems Center prepared a Scenario Planning Guidebook for the FHWA to assist transportation agencies with carrying out scenario planning to help agencies make better decisions about how to develop a transportation system that responds to a wide range of factors and trends (John A. Volpe National Transportation Systems Center 2011). In 2013, a study of sustainability as an organizing principle for transportation agencies published by researchers from Massachusetts Institute of Technology, scenario planning methodology similar to that presented in FHWA’s guideline was employed to develop a framework to help STAs evaluate their current and future capacity to support a sustainable society (Caplice and Phadnis 2013).

METHODS

In this study we relied on collective knowledge, experience, and expertise of various subject matter experts from academia, private industry, and selected transportation agencies. We followed the scenario planning methodology developed by FHWA in the Scenario Planning Guidebook (John A. Volpe National Transportation Systems Center 2011). Given the complexity of the U.S. transportation system and the broad nature of the research—maintenance, preservation, and renewal of transportation infrastructure - the topic was divided into six major transportation areas: pavements and materials, structures, construction, traffic services, roadside drainage, and connectivity with other transportation modes.

Furthermore, because of the breadth of the topic and the number of transportation areas covered, the study required engagement of a team of multidisciplinary experts. The team involved in this study can be described as follows:

- Core research team: The team in charge of leading this study included nine senior and junior researchers with diverse background and expertise in highway traffic services, pavements and materials, construction, bridges and structures, roadside and drainage, and connectivity to other transportation modes.
- Subject Matter Experts: Two groups of individuals provided subject matter expertise to the core research team:
    1. Two advisors with extensive experience as a former Department of Transportation executive managers.
    2. Panel of eleven individuals with various backgrounds, including academicians, consultants, and former and current government employees (program managers, directors, and a former deputy secretary) from FHWA, the U.S. Department of Transportation, and Department of Defense. The external panel members were selected from all across the nation by the program officer with consultation from peers within the study's national-level funding agency and had diverse backgrounds in design, research, construction materials, geotechnical engineering, structural engineering, planning, project management, construction, construction management, operations and maintenance, and asset management.

Step 1. Review of Literature

The main purpose of the literature review was to identify likely changes in the world that would affect future transportation needs. Further, reviewers attempted to identify the probability that the change discussed in the publication would actually happen. The research team performed a literature search using key words representing different technical disciplines or fields that can affect preservation, maintenance, and renewal of the highway infrastructure. These technical areas included the followings:

1. Technology and innovations (e.g., high-performance materials, construction equipment and methods, and information and monitoring systems).
2. The environment (e.g., climate change and sustainability).
3. System performance (e.g., accelerated deterioration and accountability).
4. Security (e.g., terrorism, piracy, organized crime, illegal drug manufacturing and trafficking, cybercrime, and smuggling)
5. Natural-resource availability (e.g., fuel and construction-material availability).
6. Finance and budget (e.g., global economics, contracting methods, revenue sufficiency, and costs).
7. Human resources (e.g., skills, education, and training).
8. Coordination (e.g., among transportation modes and related industries).
9. Regulations and policies (e.g., environmental regulation and the changing role of governmental identities).
10. Demographics (e.g., population characteristics and land use, including urban/rural differences).
11. Customer needs and expectations.

12. Traffic (e.g., speed, loading, density, and volume).
13. Safety (e.g., work zones and construction).

The initial search was conducted by a librarian and resulted in a list of 389 publications, which included books, journal articles, and magazine articles. Members of the core research team used judgment to determine the value of the proposed publications to this research, based on the publication abstract. This reduced the number of potential publications for review from 389 to 163. Of the 163 publications, approximately 132 were reviewed, covering the 13 technical areas. The rest of the publications were not reviewed; some were unavailable, while others were not found relevant upon inspection. The research team separated the publications into the 13 technical areas, based on the main focus of each publication. They also identified other related technical areas the publications covered. This action was necessary because the large number of publications required the collective effort of the entire research team.

The research team synthesized findings of literate review to identify pertinent characteristics of our world, in terms of uncertainties or forces that determine the direction in which we are headed. Direction as used here means positive or negative outcomes. For example, adequate funding is a force that can affect how much capital is invested in new transportation technology. In general, this literature review provided minimal information relevant to the future picture of what a technical area might look like 30 years from now. In fact, the majority of the publications did not provide sufficient information about the technical area to make such assessments. If there was a projection, it typically focused on a five-year timeframe. However, the reviews did provide information that was useful in describing the characteristics of each of the 13 technical areas in future. Table 1 summarizes uncertainties and forces associated with each technical are that determine the direction in which the transportation industry is headed. In summary, literature review helped the research team identify a set of 67 drivers that would affect the future of transportation needs in each technical area.

Step 2. Identify key drivers that influence the future

It was challenging to use all 67 drivers derived from step 1 to assimilate the interrelatedness among them in the context of future transportation industry. Consequently, in step 2, the research team aimed to identifying the major forces or key drivers among the 67 drivers of step. A minimum of two research team members were assigned to each technical area and used findings of literature review to develop an overview of the technical area in relation to the transportation industry. The overview was developed in the form of white papers and covered identified forces associated with each technical area and a spectrum of plausible futures. Plausible futures were expressed in terms of an optimistic future, a business-as-usual future, and a pessimistic future. Each white paper was then vetted by at least two other technical experts both within and outside the research project and eventually by the two advisors.

Table 1. Uncertainties and forces influencing the future of technical areas

Technical Area	Forces and Drivers
Technology and innovations	Demand for efficiency and capacity, demand for safety measures, demand to meet legal and regulatory requirements, adequate funding
The environment	Policy and regulation , environmental quality, green construction, climate change
System performance	Infrastructure maintenance , infrastructure expansion, land availability for infrastructure, energy, vehicle technology
Security	Travel demand and supply, technology development, funding, globalization
Natural-resource availability	Geopolitical conditions, primary energy sources, alternative sources of crude oil and crude-oil substitutes, transportation vehicle energy sources, binders and aggregates, other raw materials (metals, precious metals, precious materials, trace elements, and other materials)
Finance and budget	Level of domestic spending, adoption of new vehicular technologies, national energy policy, national financing structure
Human resources	Skills required, university education, technical education, trade education, transportation skills capacity
Coordination	Intermodal considerations, related industries, policy and regulatory agencies
Regulations and policies	Level of domestic spending on transportation, planning processes, reliance on user fees, private-sector infrastructure provision
Demographics	Population growth in relation to urban form, rate of acculturation of foreign-born populations, changes in household size and dependency ratios, effects of ubiquitous connectivity
Customer needs and expectations	Acceptance of private-sector involvement, acceptance of user fees, globalization, movement toward sustainability
Traffic	Highway demand in relation to capacity, transit alternatives, freight alternatives, vehicle type and technology,
Safety	Funding, public demand for safety, technology, government regulation

After vetting the 13 technical white papers, the research team participated in face-to-face workshop to develop a summary-level assessment of the composite impact of all 13 technical areas on the transportation industry. The workshop was facilitated by experts in scenario planning and future studies and helped the research team consolidate and identify the following core set of 18 key drivers and forces common throughout all of the 13 technical areas: climate change, economic growth, Priority on environmental sustainability, funding amount, proportion of private funding, government role (elative roles of federal versus state and local entities in transportation policy), demand for mobility, mobility network capacity and access, urban versus rural population density, resource and energy supply (restriction or expansion in the amount of primary sources of energy that producers are willing to provide), resources and energy demand, gas or carbon tax, energy price, demand for road freight, security threat (number and level of sophistication), availability of infrastructure technology by public and private sectors, availability of information technology by public and private sectors (e.g., technology such as ubiquitous sensor networks, voice recognition, natural language processing, huge databases, and nanotechnologies), and transportation choices/complexity.

The research team also discussed the trend and rate of change at which key drivers would affect the expected future state (30 years), and the impact of alternate