The Civil Engineering Body of Knowledge: Supporting ASCE's Grand Challenge

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With five decades of construction and project management experience as a civil engineer, split equally between the public and private sectors involving projects with a total value of several hundred billion (US$s); my goal has always been to deliver solutions that are customer focused and performance that adds value.

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Abstract

ASCE's Grand Challenge to civil engineers is to significantly enhance the performance and value of infrastructure project over their lifecycles. [1] ASCE wants to drive transformational change in infrastructure projects from planning to design to project delivery. How does ASCE move from the strategic vision to the detailed implementation? The paper's objective is to answer that question in part by highlighting the role played by proposed changes to the civil engineering knowledge framework, specifically, ASCE's Civil Engineering Body of Knowledge (BOK) as it undergoes revision for a Third Edition.

Knowledge may be the most strategically significant resource the profession can possess. The traditional view of civil engineering has always been about the importance of knowledge and its application to solve challenging problems. Civil engineering's role in the economy is to create, transfer and apply knowledge for the betterment of society. Civil engineering's ability to manage its knowledge is a result of its continuous effort to engage in learning. The authors argue that ASCE's ability to deliver on the Grand Challenge is supported equally by its unique knowledge base and depends on the profession's ability to create, innovate, and apply this knowledge throughout project and asset life-cycles. The roadmap to successfully answering the Grand Challenge includes (1) taking appropriate levels of risks, (2) being proactive, (3) being innovative, (4) developing, maintaining and using dynamic core competencies, (5) building sustained competitive advantages, and most important of all (6) creating value for our stakeholders. [1]

The authors argue BOK3 should incorporate changes that are driven in part by a clear desire to fulfill the Grand Challenge, specifically in outcomes Design, Project Management, Risk and Uncertainty, Engineering Economics, Sustainability, and Professional Responsibilities. The BOK3 should specifically include language on how it supports the Grand Challenge. The core concept in these BOK3 changes are to recognize a knowledge-based view of future civil engineering practice where civil engineers develop solutions to the ever increasingly complexity of delivering 21st century projects.

This paper discusses the specific linkage of the BOK3 to the Grand Challenge and the development of select outcomes supporting this linkage.

ASCE's Grand Challenge and other Strategic Foundations

ASCE's Grand Challenge to civil engineers is to significantly enhance the performance and value of infrastructure project over their lifecycles. [1] ASCE wants to drive transformational change in infrastructure projects from planning to design to project delivery. How does ASCE move from the strategic vision to the detailed implementation?

The first part of answering this question is to look at how our concept of infrastructure and its function has evolved over the profession's history. Infrastructure been characterized as the

mechanism that delivers the "fundamental needs of society: food, water, energy, shelter, governance" and "without infrastructure, societies disintegrate and people die." [2]

As a society, Americans enjoy the use of "highway, waterway, air, and rail systems that have allowed the unparalleled mobility of people and goods. Water-borne diseases are virtually nonexistent because of water and wastewater treatment, distribution, and collection systems. In addition, telecommunications and power systems have enabled our economic growth." [3] Therefore, for any society, its economy is "inextricably linked with the infrastructure that supports it (and) the social, political, and economic structure of a society can magnify or mitigate the effects of a failure in infrastructure and vice versa." [2]

In the 21st century, the complexity of these infrastructure demands will require the use of new engineering management forms such as civil infrastructure programs to align multiple projects on major objectives, transfer knowledge between projects, adapt strategies to subtle shifts in goals or objectives, mediate conflicts between project sponsors and stakeholders, and deliver more specialized forms of management controls. For large-scale societies, these demands for civil infrastructure require analogous institutions to sustain and regulate it and deliver needed infrastructure. [2] These are not all to be found in a government organization and the United States economy could not have "developed without the co-evolution of professions such as civil engineering." [2]

Civil engineering as a profession seeks to sustainably deliver programs and projects for the progressive well-being of humanity and often expresses the nation's aspirations for its infrastructure [2]. The intent and purpose of the profession is to deliver products, services and projects in a manner that meets or exceeds stakeholder expectations thereby earning social trust and gaining recognition as environmental stewards. To generate this value and social acceptance, the civil engineering profession must be able to identify, create and continuously manage professional knowledge, the most strategically significant resource any profession can possess [4]. Therefore, the practice of the civil engineering discipline by civil engineering professionals under the overall direction of a professional society such as American Society of Civil Engineers (ASCE) acting as the organized civil engineering profession, impacts the health and vitality of a nation as no other profession does [5]

The second part of the answer lies with the most strategically significant resource that the civil engineering profession can possess, knowledge. The traditional view of civil engineering has always been about the importance of knowledge and its application to solve challenging problems. For civil engineering, competition will become knowledge-based and the sources of the profession's competitive advantage will shift to knowledge-based capabilities in the 21st century rather than solely from physical models or systems as it was for civil engineering in the 19th and 20th centuries [4]. The question of civil engineering being able to develop, maintain or nurture and exploit its competitive advantages in the 21st century depends on the profession's ability to create, diffuse and utilize knowledge throughout the project life-cycle. In this sense, knowledge is central to how civil engineers practicing in project organizations and project management offices, control complexity, organize data, produce information and knowledge.

This knowledge is also key to solving engineering problems, sequencing critical decisions, sharing and reusing knowledge thereby allowing the civil engineer to demonstrate mastery of the professional's role in project execution and delivery.

The third part of the answer lies in the recognition that the project is the primary vehicle for successfully delivering civil infrastructure. Civil infrastructure like canals, railroads, bridges, etc. quickly became singular and substantial ventures for their sponsors. Not all succeeded in these endeavors as the state bankruptcies in the 19th canal building in the young United States demonstrated. Even at the height of the industrial revolution and rise of the modern society, less than a dozen nation states built large-scale infrastructure. Even in the 21st century, infrastructure is still viewed as a hallmark of advanced economic development. Crucially, the unique character of these undertakings marks an "explicit and deliberate disconnection from history and future" in order to create the exceptional circumstances that facilitate the accelerated delivery of this infrastructure given its heavy cost and long schedules [6] This investment also required organizations to manage the "unprecedented scale and complexity of the challenges with regard to capital investments, public attention and stakeholder participation." [6] During the duration of this infrastructure effort, large-scale organizations must be built, and specialized labor recruited and mobilized. The sponsors must secure funding and negotiate with multiple stakeholders while contending with the daily direction of the endeavor [6]. Once the endeavor has been accomplished, the organization is dissolved in what has been termed "institutionalized termination." [6]

These efforts to accomplish the national ambitions for infrastructure gave rise to the modern vision of projects and were a driving social factor in at least two ways; creating an environment which fostered first the rise of the civil infrastructure occupation and then the engineering professions as well as the related industry and professional communities. As such, the notion of project allows a society to organize and manage its infrastructure endeavor as a distinct set of given tasks, separate from the continuity of past/present/future as well as an artificial constraint on its institutional life such as a countdown clock. [7] [8]

This constant pressure to deliver infrastructure effectively and efficiently has forced the development and evolution of the project as the primary vehicle used by the civil engineering profession for successfully delivering civil infrastructure. The role played by the civil engineering profession in delivering civil infrastructure for the nation's well-being requires the application of civil engineering discipline knowledge to be practiced by highly credentialed and sometimes licensed or certificated civil engineering professionals. It also requires civil engineering professionals to increasingly practice in conformance with established/codified sets of practices in the form of professional bodies of knowledge such as ASCE's Civil Engineering Body of Knowledge.

The fourth part of the answer lies in the advocacy efforts that are made by the civil engineering profession to address the Nation's needs for its well-being in terms of civil infrastructure. One such form of expression by the engineering community of infrastructure ambitions was in 1988 with the National Council on Public Works Improvement Report, Fragile Foundations: A Report on America's Public Works. [9] Ten years later, ASCE used the approach and methodology to

publish its first Report Card on America's Infrastructure in 1998 with updates in 2001, 2005, 2009, 2013, and lastly, 2017. [9]

The civil engineering profession provides a special function in our society and economy where investing substantial sums of funding in public infrastructure requires "some assurance that it will perform its intended function." [10] This is not an absolute guarantee, but it is the civil engineer exercising their professional judgement that is "the practical certainty" that makes social investment in public infrastructure feasible. [10] The profession's vision is a "…21st Century America that thrives because of high quality infrastructure; connecting the nation's businesses, communities, and people; driving our economy and improving our quality of life." [11] ASCE cautioned though that while this infrastructure investment is "…needed at all levels and across all sectors, but it must be executed following established project and program management principles in conformance with well-conceived plans including project management plans." [11]

The fifth part of the answer is recognizing the role played by proposed changes to the civil engineering knowledge framework, specifically, ASCE's Civil Engineering Body of Knowledge (BOK) as it undergoes revision for a Third Edition in 2018.

The roots of this change go back into the last century when ASCE organized the Task Committee for the First Professional Degree in 1999 and instructed it to develop an implementation strategy for ASCE's new vision and policy. [12] It had identified the fundamental issue as the increasing inadequacy of the four year bachelor's degree as "formal academic preparation for the practice of civil engineering at the professional level in the 21st century." [12]

The Task Committee for the First Professional Degree report cited examples of this were inadequate communication skills, inability to manage projects profitably and failure to meet stakeholder expectations among others. [13] It also noted that a lack of education in leadership to support the current prevalent career path of "starting from primarily technical work through project management and into management and leadership." [13] There was an intense competition for desired leadership positions that was shared in common with other engineering disciplines, as well as from non-engineers. The best example of this is in project management which requires better educated civil engineers. In the case of the latter, more and more non-engineers are managing "civil engineers with the principal reason being that the non-engineers possess stronger leadership, communication and business skills" and leadership positions with titles such as Director of Public Works, Chief Engineer, City Engineer, Secretary of Transportation, etc. are now being filled by non-engineers "possessing skills which are perceived to be of greater value than those of a typical engineer." [14] ASCE also recognized in 2004, the Committee's work that a body of specialized knowledge was required for the practice of civil engineering in what would become the Civil Engineering Body of Knowledge (BOK).

In 2006, American Society of Civil Engineers convened a "Summit on the Future of Civil Engineering" in response to concerns for the future of the civil engineering profession which recognized that the manner in which civil engineering is practiced must change and articulated an "aspirational global vision for the future of civil engineering. An aspirational global vision

was developed that sees future civil engineers as being entrusted by society to create a sustainable world and to enhance the global quality of life." [15]

This vision served as a framework for expressing the broad aims of the ASCE and a goal for the civil engineering community and in this case as discussed above, delivering national infrastructure. It conceived of civil engineers serving competently, collaboratively, and ethically as leaders in discussions and decisions shaping public environmental and infrastructure policy. [15] The purpose of the "Vision for Civil Engineering in 2025" report was to guide policies, plans, processes, and progress within the civil engineering community. [15]

One of the key features in that effort was the role played by ASCE Policy Statement 465 which "recognizes that the profession's principal means of changing the way civil engineering is practiced lies in reforming the manner in which tomorrow's civil engineers are prepared—through education and early experience—to enter professional practice" [16]. The principal means for achieving this policy was the attainment of a body of knowledge (BOK) for entry into the practice of civil engineering at the professional level. [16]

In this same time period, the National Academy of Engineering introduced its "Grand Challenges for Engineering" project in 2007 with the commissioning of a blue-ribbon committee composed of leading technological thinkers from around the globe charged with the task of identifying "key engineering challenges for improving life in the 21st century." [17] NAE's intent was to develop a set of engineering challenges of such importance that they warranted serious investment and if successful, would "lead to a marked improvement in our quality of life. [18] In February 2008, the committee announced 14 Engineering Grand Challenges one of which was to improve urban infrastructure. [19] Following this development, renowned civil engineering author Henry Petroski published an article in the February 2010 edition of ASCE magazine titled "Great Achievements & Grand Challenges" where he noted that "engineering feats and exploits are really never-ending. Even the greatest achievements comprise indistinct milestones passed on the road to the future." [20]

During this period of time, ASCE published the BOK in 2004 and an updated BOK (BOK2) in 2008.

> "(T)he first edition of the BOK (BOK1) report, published in January 2004, served the civil engineering profession for four years. The second edition, published in early 2008 was a substantial improvement over the first edition and again, served the civil engineering profession for four years. During this BOK2 period, ASCE developed an eight-year lifecycle plan for BOK3 and BOK4, exceeding the accreditation cycle length of six years thus providing stability to accreditation and regulatory processes and procedures." [21]

From ASCE's perspective, the BOK is an ambitious, comprehensive, and future-oriented effort, representing a strategic direction for the profession. [21] Each BOK edition stimulates "curricula review, refinement, and design; encourages accreditation criteria advances; offers guidance for the education and training programs of private and public organizations that employ civil engineers; and supports changes in licensure requirements." [22]

As these NAE materials and previous ASCE conferences indicate, the civil engineering profession faces a broad array of competing issues in achieving its aspirations with respect to infrastructure. Not all of these warrant strategic emphasis by the society. The ASCE Board monitors what it considers to be key issues facing the civil engineering profession, addressing those that most demand civil engineers' attention through the use of strategic initiatives. [23] In 2015, after issuance of the BOK2 and prior to release of the BOK3 next year in 2019, ASCE realigned its strategic initiatives to a set of three—Sustainable Infrastructure, the ASCE Grand Challenge, and Raise the Bar.

Addressing the Grand Challenge in BOK3

The goals for both the BOK3 effort and the Grand Challenge are an ambitious, comprehensive, and future-oriented effort, representing a strategic direction for the profession. ASCE described the Grand Challenge as a call to action for the civil engineering profession to

> "increase the value and capacity of infrastructure and optimize infrastructure investments. Its achievement will include major legislative, regulatory and policy changes, increased infrastructure funding, and leading significant improvements in the delivery of infrastructure investments through innovation, performance-based standards, life-cycle cost analysis, and enhanced resiliency" [24]

ASCE also described the BOK as means of changing the way future civil engineering is practiced. Therefore, the BOK plays a principal role in delivering the Grand Challenge. The BOK provides the conceptual framework and rationale for educating future civil engineers on how civil engineering provides a special function in our society and economy by following established project and program management principles in conformance with well-conceived plans including project management plans, sustainably delivering programs and projects for the progressive well-being of humanity, and expressing the nation's aspirations for its infrastructure as well as being leaders in discussions and decisions shaping public environmental and infrastructure policy.

The BOK delivers this because it is grounded in knowledge, the most strategically significant resource the profession can possess. The traditional view of civil engineering has always been about the importance of knowledge and its application to solve challenging problems. BOK and its forthcoming third edition (BOK3) emphasize that civil engineering's role in the economy is to create, transfer and apply knowledge for the betterment of society. Civil engineering's ability to manage its knowledge is a result of its continuous effort to engage in learning, specifically, life-long learning. The civil engineering's profession's ability to deliver on the Grand Challenge is supported equally by its unique knowledge base, sense of professional and ethical responsibility and the profession's ability to create, innovate, and apply this knowledge throughout project and asset life-cycles.

The roadmap to successfully answering the Grand Challenge includes (1) taking appropriate levels of risks, (2) being proactive, (3) being innovative, (4) developing, maintaining and using dynamic core competencies, (5) building sustained competitive advantages, and most important of all (6) creating value for our stakeholders. [1] BOK3 should incorporate changes that are driven in part by a clear desire to fulfill the Grand Challenge, specifically in outcomes Design,

Project Management, Risk and Uncertainty, Engineering Economics, Sustainability, and Professional Responsibilities. It should review and realign outcomes that has significantly changed such as social sciences and seek to create higher value with more specific engineering content.
BOK3 should specifically include language on how it supports the Grand Challenge in an Appendix as well. The core concept in these BOK3 changes are to recognize a knowledge-based view of future civil engineering practice where civil engineers develop solutions to the ever increasingly complexity of delivering 21st century projects.

Several BOK3 draft materials contain Grand Challenge enhancements. Specifically, these are addressed the outcome rubrics and explanations for the following outcomes: Design, Project Management, Risk and Uncertainty, Engineering Economics, Sustainability, and Professional Responsibilities

Design

The vision for this outcome as outlined in BOK2 was to describe it as an open-ended process, involving a number of approximate or likely to be appropriate solutions, including innovative approaches. The BOK2 states that "successful design requires critical thinking, an appreciation of the uncertainties involved, and the use of engineering judgment." [22] BOK2 also discussed considerations such as risk and uncertainty, societal and environmental impacts, sustainability, constructability, and operability that should be integrated at various stages of the design process. In the intervening period of time since the publication of BOK2, ASCE has increased emphasis on the role certain civil engineering practices including design play in project delivery. In this sense, project phasing and project delivery are critical aspects of civil engineering projects and engineering design. These topics were not explicitly discussed in the BOK2 for either the design or project management outcomes, but they are discussed in ASCE's 2025 vision statement. BOK3 should recognize, just as BOK2 did, that engineering design is an iterative process that is often creative, involves discovery and the acquisition of knowledge but BOK3 should also emphasize the exercise of professional judgment and decision-making in the phasing and delivery of a project.

Project Management

In the years since the publication of the BOK2, there has been an increasing emphasis on infrastructure investment and the role civil engineering plays in delivering that vision and specifically, the call for executing investments following established project and program management principles in conformance with well-conceived project management plans. [11] In the BOK2, the language in the project management rubric was more general and included the statement, "develop solutions to well-defined project management problems." [22] In the BOK3 draft outcome statements and explanation, project management is more closely aligned to that civil engineering vision with language as "formulate components of project management plans for complex civil engineering projects." While it should be noted that engineering students can take management instruction in any number of non-engineering environments such as that those referenced in the BOK2 for project management [22], BOK3 recognizes the importance for civil engineering education programs to ensure that all graduates acquire a particular base of

knowledge in project management for solving civil engineering problems encountered in delivering civil infrastructure; unique to civil engineering. [25]

Risk and Uncertainty

The future presents a high-risk environment with the ongoing threat of large-scale natural disasters and possible acts of terrorism. In delivering a thriving 21st Century America, civil engineers will serve as master builders, environmental stewards, innovators and integrators among other things. They must however, also serve as managers of uncertainty and risk caused by economic scarcity, natural events, accidents, and other threats and must be leaders in shaping public environmental and infrastructure policy

Regardless of the level of care and stewardship invested in a project, a perfect, "risk-free", solution cannot be created. Real projects will always include some level of residual risk that requires quantification, management, and communication. To address these challenges, civil engineers will lead enterprise-wide risk management efforts and routinely make project-specific risk decisions, communicating risks and mitigation options to project colleagues, clients, government agencies, and the general public. At the same time, they will advance new approaches to balance business risk and reward. Working within the public-policy framework, civil engineers will also play a leadership role in shaping public policies for managing risk, how risk should be dealt with in the context of a risk-management strategy, and who should pay the costs of risk management. But to have that intended impact, risk management must become part of every civil engineering project—a step as basic as scheduling and budgeting—and a key ingredient of all communication channels.

In the years since the publication of BOK2, there has been an increasing emphasis on infrastructure investment and the role civil engineering plays in delivering that vision. Specifically, civil engineers were called to develop new forms of risk management with an increasing ability to understand and incorporate risk management into their practice as well as informing the public and governments about risk management. For civil engineering, risk management plays a key role as one of the four guiding principles to inform the planning, funding, design, construction, and operation of critical infrastructure systems. Again, this management of risk would also follow established project and program management principles and in conformance with well-conceived plans.

In the BOK2, the language in the risk and uncertainty rubric was more general and specific only to design uncertainties. For example at the application level in BOK2, the outcome statement was "apply the principles of probability and statistics to solve problems containing uncertainties." And at the analysis level, the outcome statement was very specific to design, "analyze the loading and capacity, and the effects of their respective uncertainties, for a well-defined design and illustrate the underlying probability of failure (or nonperformance) for a specified failure mode." [22] This is inconsistent with the expressed vision for the role civil engineering plays in delivering infrastructure using risk management tools, which specifically includes cost and schedule risk.

In the BOK3 drafts, risk and uncertainty has been more closely aligned to that civil engineering vision. The problems associated with risk can be based in data, knowledge, or choice and uncertainties can be related to design, construction or project management. While it should be again noted that engineering students can take risk assessment and risk management instruction in any number of non-engineering environments, the BOK3 draft outcome and explanation recognizes that it is important for civil engineering education programs to ensure that all graduates acquire a particular base of knowledge in risk management for solving civil engineering problems encountered in delivering civil infrastructure unique to civil engineering.

Engineering Economics

Every entity, public or private, is confronted with the fundamental problem of economics, it wishes to accomplish more than its resources will permit. The problem consists of two fundamental questions that must be answered, namely what objectives should be investigated or explored and how should these be achieved? Economics as a social science answers those questions and is defined as the knowledge used for selecting among technically feasible alternatives for the purpose of a rational allocation of scarce resources. As a subdiscipline, engineering economics narrows the definition of the problem and related questions to that of problems related to the investment of capital, public or private in a broad array of projects, products, processes, and services. Engineers confront more specialized forms of the fundamental problem in the form of inadequate economic evaluation of engineering projects. Civil engineers under constant pressure to deliver infrastructure effectively and efficiently confront complex problems associated with allocating scarce resources for ensuring quality, mitigating risk and controlling project delivery. Engineers must be educated to recognize the role played by engineering economics as part of the evaluations occurring at each phase in the project lifecycle.

Engineers address these fundamental economic problems using specialized engineering economics knowledge as a framework for continuously probing economic feasibility and using a stage-wise approach throughout the project lifecycle. The application of this specialized civil engineering knowledge can be in the form of engineering analyses of life-cycle cost, estimated costs, cost accounting, cost of capital, and economics of engineering solutions for design, construction and project management.

The civil engineer at entry into professional practice must be capable of explaining basic concepts of engineering economics as applied in decision-making. The engineer must have the ability to use engineering economics methodologies for the formulation of objectives, specification of alternatives, prediction of outcomes and estimation of minimum acceptability for investment and optimization. They must also be capable of integrating these economic considerations into appropriate solutions that predictably and reliably meet stakeholder expectations in a sustainable manner.

In BOK2, the scope of engineering economic knowledge was included in the social sciences outcome rubric where economics was recognized as a sub-discipline of the social sciences. [22] In the years since the publication of BOK2, there has been an increasing emphasis on infrastructure investment and the role civil engineers play in delivering that vision. Specifically, the call for executing investments following established project and program management

principles in conformance with well-conceived plans is becoming more important. This in turn can reveal new, underlying economic problems of resource allocation for management, planning and control functions in delivering infrastructure projects. Addressing these fundamental problems requires an expansion of engineering economic knowledge for the engineer at entry into professional practice. These economic problems can be based in project evaluation, project delivery or resource allocation for management, planning and control functions. While it should be again noted that engineering students can take economics instruction in any number of non-engineering environments, the draft BOK3 outcome and explanation recognizes that it is important for civil engineering education programs to ensure that all graduates acquire a particular base of knowledge in engineering economics for solving problems of economic scarcity encountered in delivering civil infrastructure; unique to civil engineering.

Sustainability

In terms of sustainability, the BOK2 noted that "the 21st century engineer must demonstrate an ability to analyze the sustainability of engineered systems—and of the natural resource base on which they depend—and design accordingly." [22] The BOK2 aligns with the Grand Challenge in that both are concerned with project selection, development and delivery. The sustainability outcome in BOK2 argues that individual projects cannot be considered in isolation. The Grand Challenges argues that the profession must work to deliver large sets of infrastructure projects more efficiently in order to close the funding gap. Both represent a commitment by the profession to the resolution of the cumulative effects of individual projects, one from a natural resource base (the sustainability outcome) and the other from a financial capacity base (closing the funding gap as part of the Grand Challenge.) In both cases, ignoring cumulative effects can lead to overall failure. This concern must be expressed in the BOK3 in the sustainability outcome and by the Grand Challenge.

Professional Responsibilities

The BOK2 stated that civil engineers in professional practice have a privileged position in society, affording the profession exclusivity in the design of the public's infrastructure. [22] Civil engineers often express the aspirations of the nation for its infrastructure. [2] The civil engineering profession provides a special function in our society and economy where investing substantial sums of funding in public infrastructure requires some form of professional assurance that it will perform its intended function and responsible individuals held accountable to society for the success of the infrastructure investment. In this sense, both the BOK3 and the Grand Challenge recognize the role played by the civil engineering profession in the nation's well-being that requires the application of an ambitious, forward looking civil engineering body of knowledge such as BOK3 by highly credentialed and sometimes licensed or certificated civil engineering professionals.

Summary and the Next Steps

As a document of strategic importance to the civil engineering profession, the BOK3 plays a critical role in addressing the Grand Challenge by bridging the gap between the evolving vision for the civil engineering profession and the practice of civil engineering. As discussed in this paper,

the ASCE BOK3 should incorporate changes that are driven in part by a clear desire to fulfill the Grand Challenge. Several outcomes, including specifically, Design, Project Management, Risk and Uncertainty, Engineering Economics, Sustainability, and Professional Responsibilities, provide opportunities for linking the BOK3 to the Grand Challenge. The BOK3TC will likely include a comprehensive appendix which details the relationship among the Grand Challenge and other strategic foundations to the Civil Engineering Body of Knowledge.

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