Countering Threats to Licensure with ASCE's Engineer Tomorrow Initiative

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Introduction

We are at an exciting time in the field of civil engineering. The world is facing many challenges, and civil engineers are uniquely qualified and positioned to reimagine our infrastructure to deal with climate change, growing urbanization, resource limitations, and other factors. Civil engineers are designing with new materials and approaches, and incorporating sustainability and resilience into their thinking, solutions, and designs.

Accompanying these opportunities are many new and expanded regulations, new standards, and heightened public expectations. The requirements for the built environment are constantly shifting as new technologies add complexity and expectations that affect how we address societal needs. The civil engineering profession must keep pace with these changes or risk obsolescence. As a result of these and other factors, the engineering profession is dealing with more frequent and fervent attacks on professional licensure. Attacks generally center around two issues; the relevance and need for licensure in society today, and concerns over barriers to entry into the profession.

The American Society of Civil Engineers (ASCE) is keenly aware of these challenges, and has been at the forefront of efforts to protect the licensure and jurisdiction of civil engineers, advance the civil engineering profession, and make licensure of civil engineers more relevant in our changing world. To meet these goals ASCE has two primary objectives:

- To promote the important contributions and value of civil engineers to society.
- To ensure that civil engineers continue to evolve in knowledge and skills to meet their professional obligations in an ever-changing world.

To help achieve the second objective, ASCE published the first edition of The Civil Engineering Body of Knowledge (CE-BOK1) in 2004, to define the necessary depth and breadth of knowledge, skills, and attitudes required of all civil engineers in responsible charge of civil engineering. Strikingly, CE-BOK1 made clear that a civil engineering baccalaureate degree from an ABET-accredited program provides insufficient academic preparation for licensure as a professional engineer. Two subsequent editions followed in 2008 and 2019, which reinforced these earlier conclusions.

To address this deficiency, starting in 2009 – through their Raise the Bar initiative – ASCE attempted to influence licensing laws to increase the minimum educational requirements for licensure to a master's degree (or equivalent) as the first "professional degree". These efforts have been unsuccessful as state licensing boards have refused to seriously consider the need to adapt to changes in engineering degree programs and the rapid expansion of the body of knowledge that engineers must know to practice competently today and into the future. As a result, in 2018 ASCE decided to curtail efforts to change licensure requirements and started evaluating other avenues to ensure that future civil engineers are fully prepared to address societal demands and advance civil engineering to protect public health, safety, and welfare.

The recently completed third edition of The Civil Engineering Body of Knowledge (CE-BOK3) makes clear – even more than previous versions – the need for civil engineers to pursue post-graduate education along with structured mentorship and life-long self-development to acquire and maintain the necessary knowledge, skills, and attitudes to prepare them for responsible charge of civil engineering services. In many respects, the newest version of the CE-BOK places higher expectations on civil engineers than earlier versions. It is also clear that licensure does not ensure fulfillment of the CE-BOK. To address the gap that remains after licensure and before a civil engineer is truly ready to assume responsible charge of civil engineering services, ASCE has created the Engineer Tomorrow initiative.

While threats to engineering licensure affect licensed engineers of all disciplines, this paper focuses specifically on civil engineers, who are disproportionately impacted. According to graduation statistics published in Engineering by the Numbers (1) 14,370 baccalaureate degrees in civil, structural, and environmental engineering were awarded in the U.S. in 2018 out of a total of 136,233 baccalaureate degrees awarded across all engineering disciplines. Despite the small proportion of engineering graduates, NCEES Squared – 2018 (2) reports that 23,000 out of 33,000 PE exams administered in 2018 were in civil disciplines (including structural and environmental). 70% of all PE exams were administered in civil engineering even though civil engineers only represent 10% of all engineering graduates. Further, only 25% of engineering graduates across all disciplines pursue licensure.

Why is there such a disparity? Civil engineers disproportionately pursue careers in the "built environment", where professional licensure is required for their practice and career advancement. Many graduates of other engineering disciplines seek careers in industry, manufacturing, or other career paths that do not require professional licensure. Generally, engineers in industry, and manufacturing fall under the "industrial exemption". A PE license is not required to work in these sectors, ostensibly because the work is covered under the federal Uniform Commercial Code which sets minimum standards for corporate conduct and liability to protect the public. These engineers work under the corporate umbrella of their employer and typically are not held individually liable for their actions.

The purpose of this paper is to answer the following research questions:

- What are the ongoing threats to licensure as a professional engineer and why are they happening?
- Why do future civil engineers need to fulfill the CE-BOK to meet ever-changing societal needs and expectations?
- How can ASCE's Engineer Tomorrow initiative shape the civil engineer of the future to meet these needs?

The Role of Engineering Licensure

The existence of laws dealing with the practice of engineering goes back to ancient times; the famous code of the Babylonian ruler Hammurabi (c. 1800 BC) applies the "eye for an eye" policy toward engineering. “If a builder erects a house for a man and does not make its construction firm, and the house which he built collapses and causes the death of the owner of the house, that builder shall be put to death.” Hammurabi’s code, harsh as it was, did not punish unlicensed practitioners – provided their work did not kill anyone. The concept of legislation restricting a profession to licensed professionals can be traced back through historical records to a decree made by King Roger of Normandy in AD 1140 requiring doctors to present proof of competency before being allowed to practice on the public. (3)

In the U.S., the individual states bear the responsibility for regulating professions, as outlined in the Tenth Amendment of the Constitution, and reinforced by the Supreme Court in Watson v. Maryland (1910). Wyoming enacted the first engineering licensing law in 1907, soon followed by Louisiana, Florida, and Illinois. In 1947, Montana became the last state to enact an engineering licensing law. Licensure in the U.S. differs from other forms of professional certification in that it is mandated by each state jurisdiction as a prerequisite for certain activities.

What separates a licensed PE from other practicing engineers? In short, the PE has completed several steps (post-bachelor’s degree) that indicate a high level of commitment to professional knowledge and competency. These steps typically include passing an 8-hour fundamentals exam, completing four years of progressive engineering experience in a particular field of engineering (under the supervision of a PE), and then passing an 8-hour exam testing knowledge gained during the candidate’s period of apprenticeship. Once obtained, the engineer is obligated to meet both a professional standard of care and code of professional ethics to maintain the license.

When is a PE license required? Each state has a definition of the practice of professional engineering (where a PE license is required), but they all generally conform to the definition included in the National Council of Examiners for Engineering and Surveying (NCEES) Model Law (4) as follows: “The term “Practice of Engineering”, as used in this Act, shall mean any service or creative work requiring engineering education, training and experience in the application of engineering principles and the interpretation of engineering data to engineering activities that potentially impact the health, safety, and welfare of the public. The services may include, but are not limited to, providing planning, studies, design, design coordination, drawings, specifications, and other technical submissions…”

As the world gets more complex, so will the demand for more complex engineering solutions. Engineering licensure is a legal standard that sets the minimum competency for practice however, this standard has not kept pace with reductions in credit hours in baccalaureate engineering programs, rapid advances in technology, and societal changes/expectations. This is puzzling as each of the other “learned professions” (medicine, law, architecture, and accounting) as well as several other licensed occupations have each increased minimum formal education requirements for licensure to a master’s degree or other advanced professional degree.

Engineering licensure is still critically important, but alone is no longer adequate to demonstrate a civil engineer is prepared to assume responsible charge – as demonstrated in CE-BOK3. Other mechanisms (post-licensure) are also needed to promote, monitor, and document the competence of those who practice in the various fields of civil engineering.

Several states have moved in the opposite direction making obtaining a license easier – which, one could argue lowers the standard for licensure. These include:

- Twenty states accept an ABET/ETAC degree in Engineering Technology as equivalent to an ABET/EAC degree in Engineering. Twenty more states (and the District of Columbia) accept Engineering Technology degrees with additional years of experience prior to licensure. (5) Engineering Technology graduates are an important contributor to engineering teams, however the content of their degree does not meet the rigor of the typical baccalaureate degree in Engineering and should not be considered comparable, without (at a minimum) additional educational requirements to fill the gap.
- The Principles and Practices (PE) exam is intended to test the competency of engineers upon completing their apprenticeship – typically four years of progressive engineering experience under the supervision of a PE. Traditionally, licensure candidates could only take the PE exam after they had completed the requisite number of years of progressive engineering experience and had that experience reviewed and approved by a state licensing board. In 2005, Nevada became the first state to allow early taking of the PE exam. Candidates can take the PE exam as soon as they have passed the Fundamentals of Engineering (FE) exam and completed their baccalaureate degree. As of July 2018, fifteen states now allow early taking of the PE exam. (6) Early exam taking does not test progressive experience in an engineer's career. Opponents to early exam taking also fear that a court challenge of the experience requirement is inevitable. It's easy to imagine that a judge – who became a lawyer as soon as he or she passed the bar exam – would conclude that an engineer should be granted a license in a similar manner – as soon as they successfully pass the PE exam.

Ongoing Threats to Licensure

Is there a continued (ongoing) need for engineering licensure? Fortunately, society is not faced with catastrophic engineering failures on an every-day basis. However, some recent high-profile catastrophes where poor engineering judgment and/or oversight resulted in harm to public health, safety, and welfare include the following:

- The Deep-Water Horizon oil spill where eleven workers died, and untold environmental damage occurred due to a prolonged oil spill. The United States District Court (7) found that British Petroleum (BP) was grossly negligent in one case for misinterpretation of a pressure test on the blow-out safety system by their site engineer.
- The catastrophic failure of a natural gas system in Massachusetts that damaged 131 structures, including destruction of five homes in the city of Lawrence, and towns of Andover and North Andover. One person was killed and at least 21 individuals, including two fire fighters were injured. The National Transportation Safety Board (NTSB) (8) determined that omissions in the engineering work plan package and construction documentation for the project by the utility engineer did not include consideration of the existence of regulator sensing lines within the scope of the work. When one gas main was abandoned in-place, a pressure-drop in the connected regulator sensing line occurred.

This caused gas regulators to open and ultimately over-pressurize the system causing the catastrophe.

In these two examples, the engineers did not have a PE license as the activities fell under the "industrial exemption" clause in that state. In both cases, federal agencies have considered adopting rules to require a PE to oversee critical engineering decisions. To-date, no formal action has been taken.

- The I-35 bridge collapses in Minneapolis, Minnesota, where thirteen people died and another 145 were injured. The National Transportation Safety Board (NTSB) [(9)] cited a design flaw as the likely cause of the collapse, noting that a too-thin gusset plate ripped along the line of the rivets. They further concluded that additional weight of construction material and equipment on the bridge at the time contributed to the catastrophic failure.
- The Florida International University (FIU) pedestrian bridge collapse that killed six and injured ten. The National Transportation Safety Board (NTSB) [(10)] determined that the probable cause of the collapse was load and capacity calculation errors made by the bridge engineers in its design of some of the main span truss members. They further concluded that inadequate peer review failed to detect the calculation errors in the bridge design.

In these two examples, it was the failure of PEs to meet their obligation to a normal standard of care that resulted in harm to the public.

Both licensed and unlicensed engineers make mistakes every day and the public are harmed when they do. Unfortunately engineering failures call into question whether engineering licensure is still relevant, if public health, safety, and welfare are not protected. Other trends that imperil the licensed practice of engineering, include:

- Threats to professional and occupational licensure at both the State and Federal levels, including challenges to the need for licensure at all.
- An ever-expanding body of engineering knowledge required to maintain minimum competency for responsible charge, and the acceleration of this expansion with rapid advances in technology.
- Shrinking undergraduate credit hours in engineering programs at most public institutions that simply cannot teach this ever-expanding body of knowledge in a four-year degree program.
- Commoditization of the engineering profession – the buying and selling of engineering services based on price, not qualifications, along with outsourcing of engineering tasks to project team members from disparate regions with no "local knowledge" of the problem(s) they are working to address.
- Advances in software and modeling that seemingly apply engineering standards and codes to derive solutions that sidestep engineering judgement and infer to some the PE is obsolete or unnecessary.
- State licensing laws that keep educational standards for engineering relatively unchanged over the last 70-100 years, failing to recognize, keep pace with, and address decreasing

credit hours in baccalaureate engineering degree programs, combined with rapid accelerations in technology and societal needs/expectations that demand more from PEs.
- An unwillingness of most licensed engineers to recognize these trends and their impact on future professional practice.

ASCE has been keenly aware of these pressures and has been at the forefront of efforts to defend civil engineering licensure, the jurisdiction of civil engineers, and ensure the public remains protected in our changing world. Until 2018, ASCE's focus has been to increase the formal educational requirements for the licensure of civil engineers, a concern that can be traced as far back as the Mann Report (11) in 1918. At issue is whether the ever-expanding body of engineering knowledge that engineers must understand and employ to practice competently can fit within today's four-year engineering degree program. Since the Mann report there have been numerous other scholarly works addressing this issue, that will not be detailed here. This paper will focus on more current work and recent efforts to increase (without success) the minimum educational requirements for licensure of civil engineers.

In 1995, ASCE convened a Civil Engineering Education Conference (CEEC '95) (12) where it was concluded that "an additional period of study, recognized by a professional degree, is required before entering practice". In 1998, ASCE adopted the original version of Policy Statement 465, which states "ASCE supports the concept of a master's degree as the first professional degree for the practice of civil engineering at a professional level."

In 2004, ASCE published the first edition of the <u>Civil Engineering Body of Knowledge</u> (CE-BOK1) (13) to document the knowledge, skills and attitudes that civil engineers must attain for responsible charge of civil engineering work. This document clearly demonstrated that a baccalaureate degree in civil engineering was no longer adequate formal education for licensure, and that additional formal education was needed – a master's degree or equivalent.

Also, in 2004, the National Academy of Engineering (NAE) published <u>Educating the Engineer of 2020</u> (14) which concluded "it is evident that the exploding body of science and engineering knowledge cannot be accommodated within the context of the conventional four-year baccalaureate degree." Advances in science and engineering knowledge have increased exponentially since then, yet the minimum educational standard for licensure is still a bachelor's degree in engineering.

In 2008, NCEES – the organization that represents all licensing jurisdictions – adopted language in their Model Law and Model Rules to provide states with guidance on how to implement the change to a master's degree as the first professional degree for licensure. This was not without controversy and debate within NCEES continued. In 2015 the language was relegated to a Position Statement (15) after no state jurisdiction had adopted the changes.

Technical societies representing some of the other engineering disciplines – led by the American Society of Mechanical Engineers (ASME) opposed this change to the NCEES Model Law. Their position is best summarized in the publication <u>Mandatory Educational Requirements for Engineering Licensure</u> (16) which states: "ASME believes that the typical scope of an ABET accredited bachelor's degree can be and has been demonstrated to accommodate technical breadth and flexibility and the intellectual skills necessary for engineering graduates to qualify for employment in an engineering position. In addition, it is the appropriate qualification to attain licensure as a Professional Engineer." They go on to state that "…increasing educational requirements for licensure should not be used as a tool to offset the nominal decrease in graduation requirements for the first professional degree."

Ironically, ASME has not adopted a body of knowledge for their professional domain to support their position. Further, many of their members work in careers that do not require a professional license, so they may have limited understanding of the importance of licensure to protect public health, safety, and welfare. That said, with no ME-BOK to compare to the CE-BOK, it is difficult to refute whether mechanical engineers and other non-civil disciplines indeed need post-baccalaureate engineering education for licensure.

Most states do not license engineers by discipline. Engineers are granted a license and are expected to practice only within their area of competence. Because of this, initiatives to increase educational standards for licensure were inclusive of all disciplines, not just civil engineers. While increasing educational requirements for civil engineers was contentious within the ranks of civil engineers, the other disciplines were resoundingly opposed.

Since professional and occupational (trade) licensure is regulated at the state level, there are ongoing organized efforts around the country to undermine both professional and occupational licensure, including:

- "Consumer Choice" bills that would allow for practice without a license if disclosed to the public.
- Elimination of specific occupational licenses.
- Elimination of licensing boards – including P.E. Boards (or cuts in funding to diminish their role).
- Legislative and/or executive orders requiring review and analysis of licensure requirements with recommendations to remove any "unnecessary" requirements leading to the "lowest common denominator" for licensure standards.
- Increased state oversight of regulatory boards.

Between 2015 and 2020 proposals in as many as 25 states directly affected licensure of professional engineers, including:

- In Louisiana – Louisiana bill H.B. 748 [(17)] would prohibit the use of most professional certifications and accreditations within the state and includes a provision that presumes that market competition is enough to protect consumers.
- In Ohio – Ohio bill S.B. 255 [(18)] would undermine and potentially eliminate engineering licensure in the state. The legislation sets forth a new policy allowing the state to use the least restrictive regulation to protect consumers from present, significant, and substantiated harms that threaten public health and safety. The policy of employing the least restrictive regulation shall "presume that market competition and private remedies are sufficient to protect consumers."

- In Oregon – Oregon bill H.B. 2153 [19] would have permitted commercial interior designers to practice engineering if they have completed a voluntary certification program.
- In Arizona – Arizona bill S.B. 1142 [20] seeks to establish the least restrictive means of regulating an occupation and proposes the elimination of licensure requirements for certain professions. Professional engineers are not specifically targeted but are included in the bill language.
- In Tennessee – Tennessee bill H.B. 1945/S.B. 1914 [21] would allow any person to practice any occupation without a license, if the person discloses that he/she is unlicensed before entering into an agreement with the consumer.

Several national organizations are leading the charge for fundamental changes in professional and occupational licensing. The American Legislative Exchange Council (ALEC), identifies itself as "America's largest nonpartisan, voluntary membership organization of state legislators dedicated to the principles of limited government, free markets and federalism." In 2015, ALEC promulgated a "model law" entitled The Occupational Licensing Consumer Choice Act [22] which they recommend all states adopt. The model law makes it legal to perform any occupation without a license provided the consumer is informed. The term "lawful occupation" is defined as "… a service, profession, or line of work in the sale of goods or services that is not otherwise illegal irrespective of whether the occupation requires an occupational license in order to operate."

The Institute for Justice (IJ), also advocates for the elimination of "pointless, overreaching and unnecessary government regulation" which constrains economic freedom and creates barriers for persons to join a profession or line of work. In the November 2018 article The Cost of Occupational Licensing [23] they conclude: "Licensing laws grant a monopoly to licensed workers in an occupation and empower captured boards to guard entry into the occupation and otherwise enforce the monopoly. Licensing proponents argue that such monopolies are justified because they raise quality of services and protect the public from unsafe, incompetent or unscrupulous providers…Unfortunately for licensing proponents, few studies support their theory…Some studies have found that licensing has little effect on quality, as well as dampens innovation necessary to increase quality in the future. Similarly, studies on the public safety benefit are scarce and provide limited support for the idea that licensing provides added protection."

The lack of distinction between a trade and a profession is a significant concern. All licensed occupations have four similarities: (1) specialist knowledge; (2) credentials that determine admission to the profession; (3) regulated activities; (4) a common set of values. However, there is an important distinction between complex, technical professions (engineering, medicine, law, architecture, accounting, etc.) and vocational occupations (barbers, cosmetologists, florists, interior designers, naturopaths, manicurists, etc.). Professionals such as engineers, doctors, lawyers, architects, and certified public accountants are granted a high level of public trust, and directly impact public health, safety, and welfare. The services provided by these professions require advanced technical knowledge, critical thinking and judgement, to solve complex problems. Trade practices do not typically require complex analysis, and judgment, and do not operate under a similar malpractice standard. Unfortunately, many advocates for de-licensing do not make this obvious and logical distinction.

Even though professional and occupational (trade) licensure is set at the state level, the federal government has also engaged in this discussion. A July 2015 White House Report, Occupational Licensing: A Framework for Policymakers [(24)] includes recommendations for "Licensing Best Practices". The recommendations include: "In cases where public health and safety concerns are mild (no definition), consider using alternative systems that are less restrictive than licensing … Minimize procedural burdens of acquiring a license … Where licensing is deemed appropriate, allow all licensed professionals to provide services to the full extent of their current competency, even if this means that multiple professions provide overlapping services".

In a 2018 report titled, Policy Perspectives – Options to Enhance Occupational License Portability [(25)] the Federal Trade Commission (FTC) concluded "Although some professional licensing can serve a beneficial role in protecting the health and safety of the public, it generally limits the number of workers who can provide certain services. This reduction in the labor supply erects barriers in labor markets, which can restrain competition, potentially resulting in higher prices and reduced access to services. Moreover, while licensing may increase the wages of licensees at the expense of higher prices paid by consumers, studies show that it does not improve quality."

In 2018, the U.S. Department of Labor awarded $7M in grants to twelve states to support occupational licensing reform. "These investments support selected states' analysis of relevant licensing criteria, potential portability issues, and whether licensing requirements are overly broad or burdensome." U.S. Secretary of Labor Alexander Acosta [(26)] stated, "excessive licensing can create economic barriers to Americans seeking a job…and hinder competitiveness for businesses".

Each of these viewpoints, support movement toward de-licensing, or at least narrowing the scope of services that only professional engineers can perform.

The Alliance for Responsible Professional Licensure (ARPL) [(27)] was formed in 2019 to respond to these challenges, with the following stated purpose: "The Alliance promotes a responsible, balanced approach to professional licensing. We aim to educate policymakers and the public on the importance of high standards, rigorous education, and extensive experience within complex, technical professions that are relied upon to protect public safety and enhance public trust. We also look to offer best practices and solutions drawn from our experience to serve as models that work for the public and members of a given profession. The Alliance advocates for licensing practices within professions that deliver uniform qualifications, standards, safety, and consistency, while also providing individuals with a clear career path and fair opportunities to pursue and maintain that career."

ARPL members include ASCE, the National Society of Professional Engineers (NSPE), American Institute of Architects (AIA), the American Institute of Certified Public Accountants (AICPA), National Council of Examiners for Engineering and Surveying (NCEES), Council of

Landscape Architect Registration Boards (CLARB), National Council of Architectural Registration Boards (NCARB), and the National Association of State Boards of Accountancy (NASBA). To achieve their stated objectives, each member organization will need to diligently monitor legislation, and educate legislatures, federal agencies, and the public, on the critical and essential role professional licensure plays in protecting public health, safety, and welfare.

The Need for Engineering Licensure

The need for engineering licensure grows more important each day (not less) as problems and their accompanying solutions become more complex in this rapidly changing world. To understand how quickly society is evolving and how critical it is for civil engineers to stay current with these changes, it is important to understand the dynamic advances in technology – and their influence on other aspects of society – that affect how engineers' practice, and what society expects today and into the future.

Pulitzer prize winning author, Thomas L. Friedman, has written extensively on foreign affairs, global trade, globalization, the environment, and the influence of technology on society. In his most recent book, Thank You for Being Late (28) Freidman refers to what global society is undergoing as the "Age of Accelerations". According to Friedman, to understand the 21st century, you need to understand that the planet's three largest forces – Moore's Law (rapid exponential advances in technology), the Market (globalization), and Mother Nature (climate change and diversity loss) – are accelerating all at once. These accelerations are transforming five key realms: the workplace, politics, geopolitics, ethics, and community – and are reshaping the world.

Friedman cites 2007 as a major inflection point, with the release of the iPhone (the birth of the "smart" phone), together with advances in silicon chips, software, storage, sensors and networking, creating a new technology platform that is reshaping how we interact in society. How pervasive are these changes? According to the Pew Research Center (29) an estimated five billion people have mobile devices and half of these devices are smart phones. In little more than a dozen years, nearly one-third of the world population uses a device that did not exist before 2007, giving them instant mobile access to the internet in the palm of their hand.

There is probably no better example of the convergence of these forces and their influence on society than the ongoing COVID-19 pandemic. The pandemic has turned the world economy upside down as we all strive to contain and protect ourselves from the coronavirus. Among other things, this has forced us to learn how to work, meet, and coordinate with others through web-based virtual meeting sites. When the pandemic passes, and face-to-face contact is no longer a serious concern, we will still embrace virtual meetings for a wide range of purposes to cut down on transportation, improve time management, work-life balance, and efficiency. Virtual meeting platforms have been available for several years but have not been as widely used as they are today. We will not go back to "the way it was" when the pandemic is over. This is just one example of a likely "new normal" practice that will evolve from this convergence of forces. The pandemic will create many more "new normal" practices as well.

To predict the impacts of advances in technology on professions, Richard and Daniel Susskind, authors of The Future of Professions: How Technology will Transform the Work of Human Experts [30] conclude "that increasingly capable machines, operating on their own or with non-specific users, will take on many of the tasks that have been the historic preserve of the professions." These fundamental changes, "will lead eventually to the dismantling of the traditional professions." They conclude that, to maintain relevance as technology and societal expectations evolve, professions must evaluate the following:

- Is there an entirely new way to organize work?
- Must all current licensed work continue to be done only by licensed professionals?
- Can licensed professionals be trusted to admit if services could be delivered by non-licensees?
- Is the traditional arrangement still fit for the purpose and serving society well?

These questions underly the debate over de-regulating licensed professions. Given all this, is there still a need for engineering licensure?

The licensed practice of engineering is a creative art, not simply the appropriate application of mathematical and scientific principles. A PE, faced with a problem, evaluates the situation, identifies multiple alternative solutions, analyzes each against stated outcomes, and selects the best (optimal) solution to address the client's needs. The PE must consider sustainability, resiliency, economics, aesthetics, regulations and many other factors when completing their analysis – none of which are simple math or science problems. Complex calculations are routinely performed by computer software, but the software program does not provide the necessary inputs, nor consider whether the outputs makes sense. Software programs cannot apply the creative understanding and innovation that a PE with the proper background, experience, and training, employs to solve a problem.

Because the licensed practice of engineering is a creative art, the PE license establishes an essential malpractice standard under which the PE must operate. The PE is obligated to perform their duties to a normal standard of care – the level at which an ordinary, prudent professional with similar training and experience in good standing in a same or similar community would practice under the same or similar circumstances. Further, PEs must perform in conformance with a professional code of ethics, with a fundamental requirement to hold public health, safety, and welfare paramount above all other considerations. PEs can be held individually liable for their actions (as well as their employer) if they fail to meet these standards.

The PE license establishes these standards and obligations for all engineers who choose to perform engineering services where a PE license is required. These standards provide PEs with the boundaries they must operate within to meet their obligations to their client and the public, as well as the consequences for failure to fulfill their duties. This was the basis for the creation of engineering licensure and is needed now and into the future more than ever.

The Need to Fulfill the Civil Engineering Body of Knowledge (CE-BOK3)

The conclusions in ASCE's third edition of the Civil Engineering Body of Knowledge (CE-BOK3) are the foundation that this paper's recommendations are based on. But what is a Body of Knowledge and what role does it serve the profession?

In Society of Professions: Applications to the Civil Engineering 'Raise the Bar' Initiative (31) Ressler defines a profession as having "a professional domain defined by a body of knowledge that describes the complete set of concepts, terms, and activities that make up a professional domain, and is typically defined by the relevant learned society or professional association." Recognized as the relevant learned society for civil engineering, in 2004 ASCE published the first edition of the Civil Engineering Body of Knowledge (CE-BOK1) to define the knowledge, skills, and attitudes necessary for responsible charge of civil engineering services, to protect public health, safety, and welfare. ASCE has updated the CE-BOK twice since then. ASCE is the first professional engineering organization to develop the scholarly work defining its Body of Knowledge and civil engineering is the only major engineering discipline to have one.

ASCE has used each edition of the CE-BOK to influence the ABET criteria for accreditation of civil engineering baccalaureate degree programs that most institutions follow, and most licensing standards recognize. This influence helps to ensure that the civil engineering baccalaureate degree is robust but does not change the fact that all necessary formal education for fulfillment of the CE-BOK cannot fit within the traditional four-year civil engineering degree curriculum.

As noted in The Evolution of the Civil Engineering Body of Knowledge: From the First Edition to the Third Edition (32) the definition of the CE-BOK evolved since the CE-BOK1 was published. In both the first and second editions, the CE-BOK defined the knowledge, skills, and attitudes necessary for entry into the practice of civil engineering at the professional level, where "entry into the practice of civil engineering at the professional level" was defined as becoming licensed as a professional engineer (PE). Although CE-BOK3 supports licensure and recognizes licensure as an important aspect of the civil engineering profession, fulfillment of CE-BOK3 is separate and distinct from licensure. As such, CE-BOK3 removes the direct link to licensure and recognizes that CE-BOK3 applies to all civil engineers regardless of career path or area of practice.

This change can be attributed to several factors that licensure requirements are not addressing:

- The unwillingness of licensing boards to address the gaps between the baccalaureate degree in civil engineering (the typical educational requirements for licensure) and the formal education required to practice in responsible charge of civil engineering (as defined in CEBOK3).
- Recognition that a more formal and structured process is needed for individuals to receive mentored experience.
- Recognition that life-long learning is essential to maintain competency and stay current with rapid advances in technology and engineering understanding to serve in responsible charge.

- Trends to further erode licensing requirements of all professions making it obvious that influencing licensing laws to address gaps between licensure and fulfillment of the CEBOK will not be successful.

According to Ressler and Lynch, in The Civil Engineering Body of Knowledge and Accreditation Criteria: A Plan for Long-Term Management of Change [33] sociological theory supports the idea that continuous change is an inherent characteristic in any professional BOK, and that the CE-BOK must continue to evolve. Citing Andrew Abbott, a sociologist and social theorist in The System of Professions: An Essay of the Division of Expert Labor [34] Ressler and Lynch conclude that a strong profession must be able to adapt its body of knowledge in response to emerging needs, opportunities, and threats. Ressler and Lynch specifically cite the following as influences that will necessitate the continuous evolution of the CEBOK:

- New engineering challenges (e.g. climate change, emphasis on sustainability, energy).
- Shortages, terrorism, increase in the frequency and severity of natural disasters.
- New technologies (e.g. building information management, high-performance materials, smart buildings, and sensing technologies).
- Changes in international business environment (e.g. limited financial capital, low-cost engineering services delivered via the internet, increased market consolidation).
- Changes in law and regulatory environment (e.g. licensure laws, environmental regulation).
- Changes in relationships between and within engineering disciplines (e.g. evolving role of paraprofessionals).
- Engineering failures (e.g. Hurricane Katrina, the Gulf oil spill, the Minneapolis I-35 bridge collapse).

Recognizing that a profession's Body of Knowledge is not static – that it must evolve as advances in math, science, technology and societal needs dictate, ASCE continues to monitor these changes and periodically updates the CE-BOK (currently on an eight-year cycle).

Published in 2019, the third edition of ASCE's Civil Engineering Body of Knowledge – Preparing the Future Civil Engineer (CE-BOK3) [35] builds upon the work of the previous editions, but also draws heavily on two internationally recognized engineering competency models – the Engineering Competency Model[36] and the Graduate Attributes and Professional Competencies Profiles.[37]

CE-BOK3 is described by 21 outcomes in four categories – Foundational, Engineering Fundamentals, Technical, and Professional. Each of the 21 outcomes is described in a rubric, which includes the level of achievement required to prepare a civil engineer for responsible charge. The outcomes rubrics are based on Bloom's Taxonomy for the Cognitive Domain [38] as well as Bloom's Taxonomy for the Affective Domain.[39] With the addition of the affective domain, CE-BOK3 is the first version that explicitly recognizes the need for civil engineers to internalize and have a value system that supports responsible charge of civil engineering services. The following is a summary table of outcomes for each **cognitive domain** and typical pathway to achievement. [35]

Outcome	Cognitive Domain Level of Achievement				
	Level 1 Remember	Level 2 Comprehend	Level 3 Apply	Level 4 Analyze	Level 5 Synthesize
Foundational Outcomes (4)					
Mathematics	**UG**	**UG**	**UG**		
Natural Sciences	**UG**	**UG**	**UG**		
Social Sciences	**UG**	**UG**	**UG**		
Humanities	**UG**	**UG**	**UG**		
Engineering Fundamentals Outcomes (4)					
Materials Science	**UG**	**UG**	**UG**		
Engineering Mechanics	**UG**	**UG**	**UG**		
Experimental Methods and Data Analysis	**UG**	**UG**	**UG**	**PG**	
Critical Thinking and Problem Solving	**UG**	**UG**	**UG**	**ME**	**ME**
Technical Outcomes (7)					
Project Management	**UG**	**UG**	**ME**		
Engineering Economics	**UG**	**UG**	**ME**		
Risk and Uncertainty	**UG**	**UG**	**UG**	**ME**	
Breadth of Civil Engineering Areas	**UG**	**UG**	**UG**	**ME**	
Design	**UG**	**UG**	**UG**	**ME**	**ME**
Depth in a Civil Engineering Area	**UG**	**UG**		**PG**	**ME**
Sustainability	**UG**	**UG**	**UG**	**ME**	
Professional Outcomes (6)					
Communications	**UG**	**UG**	**UG**	**ME**	**ME**
Teamwork and Leadership	**UG**	**UG**	**UG**	**ME**	**ME**
Lifelong Learning	**UG**	**UG**	**UG**	**ME**	**ME**
Professional Attitudes	**UG**	**UG**	**ME**	**ME**	
Professional Responsibilities	**UG**	**UG**	**ME**	**ME**	**ME**
Ethical Responsibilities	**UG**	**UG**	**ME**	**ME**	**ME**

UG – Undergraduate Education **PG** – Post-Graduate Education **ME** – Mentored Experience

The following is a summary table of outcomes for each **affective domain** and typical pathway to achievement. [35]

	Affective Domain Level of Achievement				
Outcome	**Level 1 Receive**	**Level 2 Respond**	**Level 3 Value**	**Level 4 Organize**	**Level 5 Characterize**
Technical Outcomes (1)					
Sustainability	**UG**	**UG**	**ME**	**SD**	
Professional Outcomes (6)					
Communication	**UG**	**UG**	**ME**	**SD**	
Teamwork and Leadership	**UG**	**UG**	**ME**	**SD**	
Lifelong Learning	**UG**	**UG**	**ME**	**SD**	
Professional Attitudes	**UG**	**UG**	**ME**	**SD**	
Professional Responsibilities	**UG**	**UG**	**ME**	**SD**	
Ethical Responsibilities	**UG**	**UG**	**ME**	**ME**	**SD**

UG – Undergraduate Education **PG** – Post-Graduate Education

ME – Mentored Experience **SD** – Self Development

Achievement of the CE-BOK is traditionally achieved through a combination of four components:

- Undergraduate education leading to a bachelor's degree in civil engineering or a closely related engineering discipline.
- Post graduate education equivalent to or leading to a master's degree in civil engineering or a closely related engineering discipline.
- Mentored early career experience under one or more civil engineers in responsible charge of civil engineering services, which progresses in both complexity and level of responsibility.
- Self-development through formal and informal activities, and personal observation and reflection, that continues throughout the individual's professional career.

To emphasize the critical importance of achievement of the CE-BOK, ASCE updated Policy Statement 465 [40] in 2019 stating, "The American Society of Civil Engineers (ASCE) supports the attainment of the Civil Engineering Body of Knowledge (CE-BOK) as a requirement for exercising responsible charge in the practice of civil engineering. The CE-BOK is defined as the knowledge, skills, and attitudes necessary to exercise responsible charge in the practice of civil engineering and is attained through undergraduate and post-graduate engineering education, mentored experience, and self-development. Licensure constitutes a legal authority to practice engineering, however, the requirements for licensure do not ensure attainment of the CE-

BOK….". This last sentence is significant. "Licensure constitutes a legal authority to practice engineering, however, the requirements for licensure do not ensure attainment of the CE-BOK….". Said another way, licensure alone no longer demonstrates that the civil engineer has obtained the depth of formal education, and mentored experience necessary to exercise responsible charge in the practice of engineering.

The Role of the Engineer Tomorrow Initiative in Shaping the Civil Engineer of the Future

For decades, ASCE has been a leader in examining and shaping civil engineering education. Through its three versions of Civil Engineering Body of Knowledge for the 21st Century, ASCE has defined the evolution of knowledge, skills, and attitudes that civil engineers need for responsible charge of civil engineering services. ASCE formed the Engineer Tomorrow initiative in 2019 with a focus on ensuring that today's civil engineers gain the necessary knowledge, skills, and experience to meet these obligations and sustain the profession in the future. The Engineer Tomorrow initiative (41) defines the "need" as follows:

> The complex challenges facing 21st century society will require professional civil engineers to advance their technical excellence and professional leadership to continue to protect the public. Future civil engineers will need to master many newer fields, such as sustainability, computer applications, advanced materials, nanotechnology, and the like.
>
> **A need for expanded knowledge** – Civil engineers require greater breadth and depth of knowledge, but that has become increasingly difficult as that body of engineering knowledge continues to explode. Civil engineers must deal with an ever-growing number of technical, environmental, and social factors to address infrastructure challenges.
>
> **Society expects more** – Every other learned profession has recognized the need to require education beyond the bachelor's degree as their body of knowledge expanded. The time has come for engineering – with its broad impact on public health and safety – to recognize that need as well.
>
> **Formal education hours are shrinking** – The credit hours required to earn the traditional four-year undergraduate engineering degree have decreased significantly, from more than 145 in 1950 to about 128 today. The expanding technical and professional knowledge required by engineers will no longer fit in this shrinking curriculum.
>
> **Enhanced leadership skills** – Civil engineers with enhanced technical, leadership, communications, and business skills will give the profession more effective project teams, generating improved operations and service. That becomes particularly important to a civil engineering employer.

Requirements for a PE license have always been considered the minimum standard of achievement to document that a civil engineer is prepared for responsible charge. That is no longer the case. Consequently, the goal of ASCE's Engineer Tomorrow initiative should be to make fulfillment of the current version of the CE-BOK the standard that all civil engineers must fulfill for responsible charge.

CE-BOK3 portrays a profession that aspires to a “higher calling” to serve society and meet its ever-expanding needs and challenges and should be used to recruit individuals to pursue civil engineering as a career. Civil engineering can and should attract “the best and the brightest” as few professions have such a direct and lasting impact on society.

ASCE’s Engineer Tomorrow initiative must strive to communicate, promote, facilitate and register fulfillment of the CE-BOK by civil engineers as they advance in their career. To do so, ASCE must reach students, educators, engineering graduates, employers, clients, and the general public to be successful. Engineer Tomorrow should focus specific efforts on all four pillars of the CE-BOK: (1) undergraduate education; (2) post-graduate education; (3) progressive mentored experience; and (4) life-long professional development.

The goals of Engineer Tomorrow will only be realized if there is some means to recognize fulfillment of CE-BOK3. Hence, Engineer Tomorrow is currently exploring credentialing and creation of a certification to demonstrate this achievement. Certification is an effective way to acknowledge advancement beyond licensure during one’s career path. Certification can:

- Demonstrate different levels of competency and specialty expertise in a specific field of civil engineering. For example, board certification might include a specialty designation (e.g. water resources, structural, transportation, geotechnical).
- Provide an opportunity to help the public/clients/employers better identify qualified engineers and differentiate between engineers with varied skill sets to select the most qualified engineer to address a specific need.
- Support reciprocity throughout the U.S. and globally.
- Enhance or replace the PE license if it is otherwise diminished or eliminated.

A successful credentialing program must be based on a well-defined set of metrics and outcomes, in this case, fulfillment of CE-BOK3, and should be specific to a specialty area of civil engineering. There are several facets of a successful credentialing program that ASCE’s Engineer Tomorrow would need to implement.

At the undergraduate level, a goal of Engineer Tomorrow should be to introduce the CE-BOK to every freshman civil engineering student and integrate it throughout their four-year curriculum, so students can track their path and immerse themselves in their individual CE-BOK program. There is no better document to show students the “road map” of their professional career path.

Another goal at the undergraduate level, should be to assist educators in teaching students what they don’t yet know – and how they will need post-graduate education to gain and maintain the depth and breadth of engineering knowledge required for their area of practice. With the rapid acceleration of technological advances and societal needs, civil engineers must understand that their formal education is not static. Their formal education needs to continue throughout their career to ensure that they stay current with the ever-expanding body of knowledge that they must know to meet their professional obligations to protect health, safety and welfare of the public.

Another goal of Engineer Tomorrow should be to improve the structure and documentation of mentored engineering experience. Progressive mentored experience is one of the cornerstones for preparation of civil engineers for responsible charge – as some engineering skills are best taught in the workplace through guided experience. Today, civil engineers have varied opportunities and experiences with mentoring. Some companies have structured progressive mentoring programs for their young engineering staff, to help them learn the requisite skills to become professional engineers. Other companies simply do not have the time, resources, or knowledge to fulfill their responsibility to mentor their young engineering staff to the depth and breadth described in CE-BOK3.

CE-BOK3 describes specific outcomes achieved through mentored experience that should be the foundation for a detailed and user-friendly program to document the individual's progress in fulfillment of each metric, with acknowledgement of the achievement. Adding structure – and supporting guidance – to mentored experience will assist both employers and early-career engineers to fulfill the outcomes that are best learned through progressive engineering experience.

Post-graduate education is likely to take on different forms for each civil engineer. Some engineering graduates will move directly on to a master's program upon completion of their bachelor's degree. Others will pursue a master's degree (part-time) while in the work force. Others will find alternate methods to fulfill the post-graduate outcomes defined in CE-BOK3. Engineer Tomorrow should devise methods to document fulfillment of post-graduate outcomes for those who choose alternate methods.

It is likely that the typical pathway to fulfillment of CE-BOK3 will take a minimum of 6-8 years post-baccalaureate degree. Fulfillment of CE-BOK3 demonstrates an individual is prepared to act in responsible charge of civil engineering. However, the credential cannot stop there as a civil engineer's learning cannot be static, it must evolve with the ever-expanding body of knowledge necessary to meet society's needs and expectations. Consequently, the credential must also include guidelines, standards, and methods to document life-long learning that engineers must complete to maintain their competency and their credential. A credential will have less value if life-long learning is not a requirement to maintain the credential.

ASCE currently offers board certification in each of the following specialties:

- Coastal Engineering
- Geotechnical Engineering
- Navigational Engineering
- Ocean Engineering
- Ports Engineering
- Water Resources Engineering

Except for geotechnical and water resources engineering the specialty areas are quite narrow and specialized in scope. The perception of each of these certifications is that they distinguish eminence in the specialty area, not simply competence to practice in responsible charge. Further ASCE has struggled to attract civil engineers to pursue these certifications on a broad scale.

Engineer Tomorrow should expand and augment these certifications to establish a credential that signifies fulfillment of CE-BOK3 in each of the following civil engineering specialties (at a minimum):

- Construction
- Environmental
- Geotechnical
- Structural
- Transportation
- Water Resources

The certification program should also include a certification in general civil engineering practice for those who do not focus on one specialty area of civil engineering. Since this certification is documentation of fulfillment of the CE-BOK, and not eminence in the field, it should easily complement ASCE's current board certifications.

Some other professions already effectively leverage more than one credential in a well-defined system. The medical profession's model is one such example. In this model, licensure and certification co-exist in an integrated system – legal permission is granted by states (licensure); higher standards of practice (certification) are set by the profession. This gives the profession, rather than state licensing boards, the ability to set the appropriate standards of practice within different specialty areas of medicine. It reflects a well-organized system of many certifications where education, experience, and examination requirements are rigorous, universal, and consistently applied. In 2011, nearly 90% of all licensed physicians were Board Certified [42] – evidence that this system serves the medical community well.

To succeed, credentialing of civil engineers must achieve similar results, where engineers embrace the need for credentialing to demonstrate necessary expertise and achievement in their specific areas of practice, and where clients of engineering services look to credentials, like consumers of medical services, to ensure that only those qualified through credentialing are retained to deliver the services sought.

If successful, ASCE's Engineer Tomorrow initiative should:

- Prepare the professional – civil engineers need advanced knowledge to stay current with technological advances to meet the challenges of a changing world.
- Advance the profession – prepare the profession for what is next.
- Further protect the public – build the civil engineer of the future, whether licensure keeps up or not.

Discussion and Recommendations

The expansion of science and engineering knowledge, combined with advances in technology, software, and machine learning, are providing both challenges and opportunities in all aspects of engineering. Changes are happening at such an accelerated rate that they are rapidly changing civil engineering practice. The time is now to act. Civil engineers must embrace and stay current with advances in technology and adapt engineering practices to meet current and future societal needs, or they will fail to meet their professional obligations. This not only places public health, safety and welfare at risk, it also puts the continued professional practice of civil engineering in peril.

Earlier initiatives by ASCE and others to address these concerns chiefly centered around increasing the educational requirements for licensure. That might have been an acceptable solution ten years ago, but efforts to influence licensing boards were unsuccessful, and with today's political environment trending towards de-regulation, are unlikely to succeed in the future. CE-BOK3 concludes that a combination of post-baccalaureate engineering education, structured mentoring of a progressive nature, and life-long learning are all required to prepare civil engineers to address society's evolving needs and expectations. Simply obtaining a PE license is no longer adequate preparation for those in responsible charge of civil engineering.

ASCE's CE-BOK3 presents in detail the requirements to address the increasing demands on civil engineers today and into the future. These changes will evolve and ASCE must continue to assess, evaluate, and update the CE-BOK, to stay current. Since attempts to address prior concerns through changes in licensure requirements have failed, the next logical path to action is fulfillment of CE-BOK3 as a personal professional obligation of each civil engineer. This can best be achieved through a credentialing program for all civil engineers, similar in character and scope to the medical model.

Unfortunately, CE-BOK3 is unfamiliar, or at best an abstract notion to most civil engineers. This needs to change. Through attainment of CE-BOK3, civil engineers will evolve in their professional knowledge and practice, to meet their obligations to society. ASCE's Engineer Tomorrow initiative should strive to create programs and mechanisms to help civil engineers understand and pursue fulfillment of CE-BOK3. To achieve this goal are the following recommendations:

1. Develop a campaign to integrate CE-BOK3 in all undergraduate civil engineering programs, and format CE-BOK3 such that it is a user-friendly and effective learning tool.
2. Develop a program to engage civil engineering graduates to promote the need for post-graduate education as part of their early career development.
3. Develop a structured and progressive mentoring program to assist early career civil engineers and their employers fulfill the experiential outcomes of the CE-BOK, along with user-friendly tools to guide and document fulfillment of each specific rubric.
4. Develop a program to promote the need for life-long learning to keep pace with the rapid advances in technology and the related evolution of societal needs. Create courses and other opportunities for civil engineers to fulfill those obligations.
5. Develop a credentialing program to track a civil engineer's progress toward and fulfillment of the outcomes of CE-BOK3 (like the medical model). Credentialing must include standards for life-long learning to maintain the credential throughout a civil engineer's career. Like the medical model, the credential should be specific to a specialty area of civil engineering (e.g. structural, transportation, geotechnical, water resources).

6. Promote credentialing to early career civil engineers, and their employers as an essential obligation of the civil engineer in responsible charge.
7. Promote credentialing to clients, and society at-large as a demonstration that the individual is qualified in their area of specialization (like the medical model).
8. Continue to monitor and evaluate the evolving external factors that drive the need for change in the civil engineering domain and update the CE-BOK on a periodic basis as warranted. Update and revise the above recommendations as appropriate to ensure that civil engineering evolves as society does to meet their professional obligations.
9. Continue to monitor threats and changes to licensure laws, to ensure that engineering licensure standards remain rigorous. While not adequate to qualify civil engineers for responsible charge, licensure is still an important benchmark in each civil engineer's career and a minimum safeguard for protection of public health, safety, and welfare.