AC 2011-619: TWENTY-FIRST CENTURY CIVIL ENGINEERING: AN OVERVIEW OF WHO, WHAT, AND WHERE

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Twenty-First Century Civil Engineering: An Overview of Who, What, and Where

Abstract

From the erection of the Ġgantija temples and development of the Roman aqueducts to the design and construction of One World Trade Center and the expansion of the Panama Canal, civil engineers have played a crucial role in improving people's quality of life. The civil engineer of the past operated in a less complex world and relied more on ingenuity and trial and error. As societal needs have evolved and the world has become more complicated, the materials, methods, and technology used by engineers have had to become more sophisticated and specialized. The civil engineering profession has evolved to meet these needs developing several sub-disciplines over the years, with individuals in each of these specialization areas increasingly being tasked with new and broader responsibilities to meet the ever growing challenges in today's society.

The primary objective of this paper is to analyze the recent past and current demographics of the civil engineering work force and its sub-disciplines and use the information to draw conclusions on future trends and needs. First, the paper compares demographic data from the past decade, focusing on the Civil Engineering discipline as a whole. Subsequent sections discuss changes, advances, and the future direction of some of the sub-disciplines, including Construction Management, Environmental, Structural, Geotechnical, Transportation, and Water Resources. The paper concludes with predictions into the next decade on the outlook for civil engineering as a function of location, type of industry, and comparison to other engineering disciplines.

Reflections on the First Decade of the Twenty-First Century

According to the Bureau of Labor Statistics (BLS) the number of civil engineers has increased steadily over the last 35 years, from a total of 118,400 (considering civil, architecture and environmental engineers) in 1972 to 332,700 (counting civil and environmental engineers) in 2008.[1,2] Projections of employment numbers into 2018 show civil and environmental engineering possessing anticipated growth rates of twenty-four and thirty-one percent respectively.[1] These rates are considered to be much faster than the average for all occupations and lag behind only biomedical in the engineering field which suggests that the civil engineering workforce will continue to be critical for society both now and into the future.

In terms of percent of the overall engineering workforce, civil engineering has proven itself to be a steady to slightly increasing occupation since the final quarter of the last century. In 1972, civil and architectural engineers accounted for 16% of all engineering occupations, with this number increasing to 21.2% in 2008.[1,2] Figure 1 illustrates the relative percentages of various engineering disciplines as a percent of the total engineering workforce in 2008.

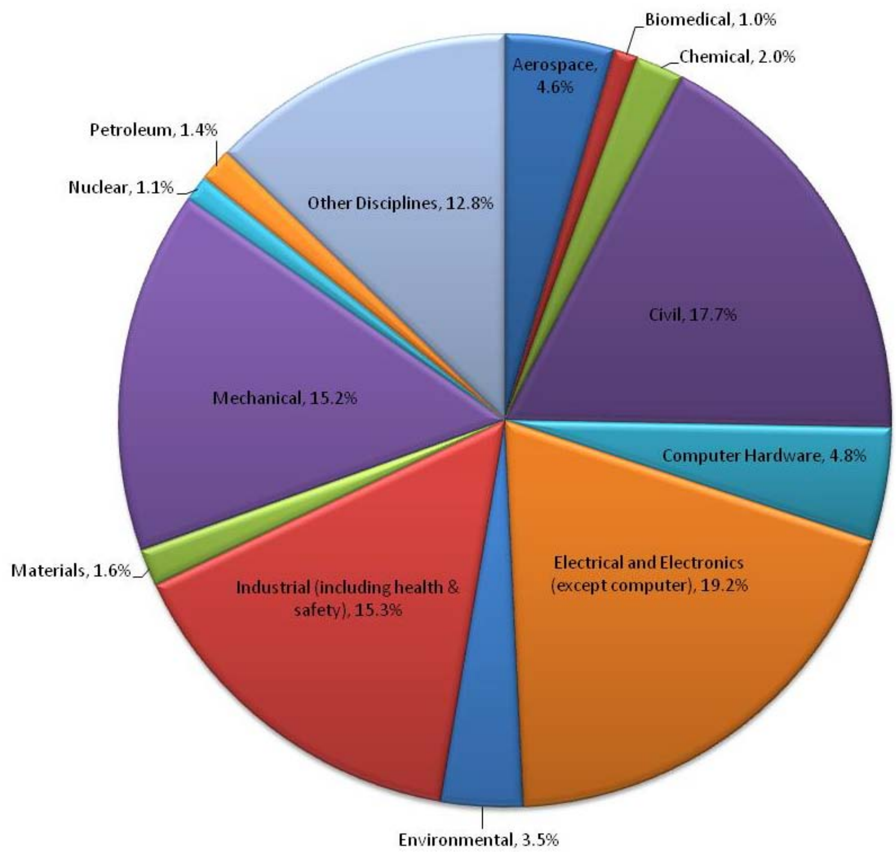

Figure 1: Relative Distribution of Various Disciplines of Engineering as a Percent of the Total Engineering Workforce in 2008[1]

Based on the disciplines presented, Civil Engineering represents the second largest group, and if combined with Environmental Engineering accounts for the largest percentage of engineers in the US workforce.

Educational Experience and Licensing

According to a report in *CE News,* only 36% of practitioners believe that entry-level civil engineers are well prepared for the workforce, compared to 70% of academics[3]. This disconnect may be attributed to a variety of factors, the largest of which may be a lack of communication between practitioners and academics. The increase in advisory committees, in response to ABET criteria requiring input from constituents, should help to improve communication between these two groups. Despite this disconnect, education remains a significant component of most Civil Engineers' preparation for entering the workforce.

According to 1999 data from the National Science Foundation Division of Science Resources Statistics, the highest degree held by a majority (~71%) of Civil Engineers is a Bachelor's, while roughly a quarter hold Master's and only 2% have obtained a Doctorate.[2] Of those working in civil/architectural engineering, an overwhelming majority (94%) hold degrees in engineering with 84% of those holding civil engineering degrees. Those who hold engineering degrees outside of civil most commonly hold environmental, mechanical, agricultural, chemical or general degrees, while the 6% who do not hold engineering degrees most commonly have a degree in Geology.[2] In addition to education, licensure or certification is also a common asset possessed by Civil and Environmental Engineers. Data from 1997 shows that while only a quarter of engineers in all of the disciplines have a license or certification, over two-thirds of civil engineers and almost half of environmental engineers hold a license or certificate, the two highest percentages of all disciplines in engineering.[2]

Gender, Age, and Ethnic Diversity

As one of the older and more well established engineering disciplines, Civil Engineering tends to follow general engineering trends with respect to gender, age and ethnic diversity. Table 1 summarizes the gender distribution for all of architecture and engineering compared to civil engineering for both 2003 and 2009.[4,5] While Civil Engineering in general has a smaller proportion of females than all disciplines, the slight downward trend from 2003 to 2009 in this percentage was similar to the trend for all disciplines.

Table 1: Gender Distribution of All Architecture and Engineering and Civil Engineering Workforce in 2003 versus 2009[4,5]

Gender	Architecture and Engineering		Civil Engineering	
	2003	2009	2003	2009
Male	85.9%	86.2%	91.3%	92.9%
Female	14.1%	13.8%	8.7%	7.1%

One important note with regard to the data is the fact that Environmental Engineering was considered a part of Civil Engineering in the 2003 data, but a separate sub-discipline in 2009. Gender distribution for Environmental was not included in the report, however; because occupations with an employment base less than 50,000 did not have data shown (Environmental had a base of 31,000).

Table 2 summarizes minority involvement in all engineering, as well as Civil Engineering, over the same time period. In contrast to the increase in Black or African American and Asian percents realized in all of Architecture and Engineering, Civil Engineering experienced slight decreases in both of these populations. The Hispanic or Latino population percentages, however, were comparable between Civil and engineering in general.[4,5]

Table 2: Percent of Minorities in Architecture and Engineering and Civil Engineering Workforce in 2003 versus 2009[4,5]

Race or Ethnicity	Architecture and Engineering		Civil Engineering	
	2003	2009	2003	2009
Black or African American	4.4%	5.5%	4.6%	4.1%
Asian	8.7%	9.9%	11.7%	10.6%
Hispanic or Latino	5.2%	7.2%	5.3%	7.3%

The median age for engineers in all disciplines ranges from 35 – 46 with an overall value of 41, based on 1999 data. Civil Engineering is slightly on the high side of this range with a median age of 42, while Environmental Engineering matches the overall at 41.[2] Table 3 summarizes the percent of individuals in each age range for all of engineering as well as Civil and Environmental Engineering. As with the median values, the Civil distribution is slightly greater in the higher age groups, while Environmental follows general trends.

Table 3: Distribution by Age of Total, Civil, and Environmental Engineering Population as of 1999[2]

Discipline	**Age**				
	< 30	**30 – 39**	**40 – 49**	**50 – 59**	**>60**
All Engineering	14%	32%	29%	18%	7%
Civil	15%	26%	29%	21%	10%
Environmental	12%	32%	32%	18%	6%

Geographic and Industry Distribution and Earnings

Based on 2009 Bureau of Labor Statistics, Table 4 summarizes the states employing the highest number (and correspondingly highest percent) of Civil Engineers. Unsurprisingly, the list includes the top four states by population. It is also possible to consider the number of Civil Engineers as a function of total number of employed individuals in the state. Table 5 lists the top five states with the highest concentration of Civil Engineers in their workforce. Washington is the only state to appear on both lists, with a high number of employed civil engineers and a lower overall state population.

Table 4: States Employing the Largest Percent of Civil Engineers as of May 2009[6]

State	Percent of all Civil Engineers	Number of Civil Engineers Employed
California	14.7%	38,430
Texas	10.1%	26,390
Florida	5.6%	14,750
New York	4.9%	12,890
Washington	4.8%	12,590

Table 5: States with the Largest Concentration of Civil Engineers as of May 2009[6]

State	Employment per Thousand	Number of Civil Engineers Employed
Alaska	4.579	1,410
Washington	4.515	12,590
Colorado	3.542	7,910
Hawaii	2.993	1,760
Maryland	2.733	6,840

When considering where Civil Engineers are working in terms of industry, over half can be found in the professional, scientific, and technical services area, while federal, state, and local government is the next largest concentration area. Figure 2 presents the 2009 relative percentages of Civil Engineers in various industrial categories as divided by the Bureau of Labor Statistics.[7]

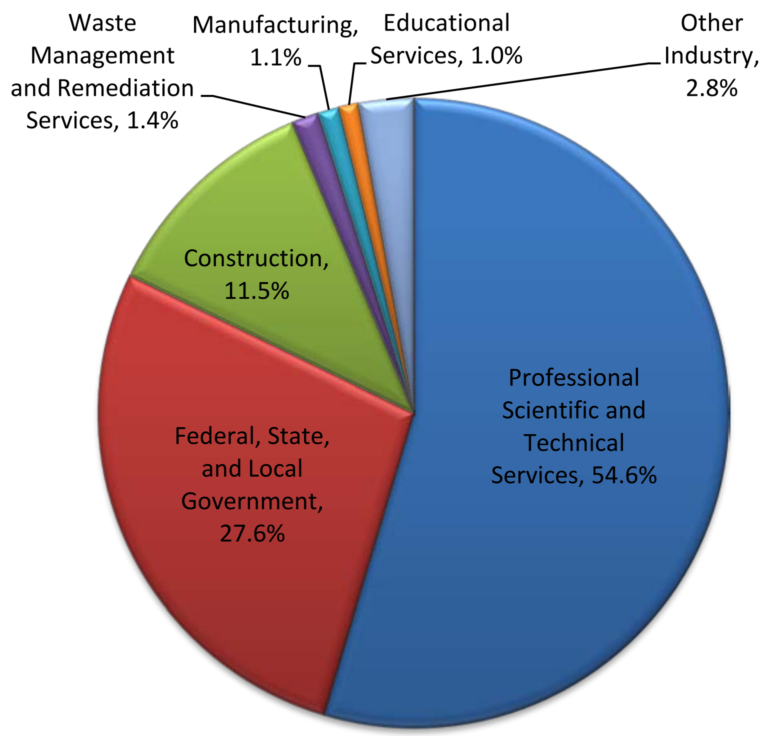

Figure 2: Distribution of Civil Engineers by Industry in 2009[7]

Based on 2009 data, the mean annual wage for all Civil Engineers was $81,180.[6] This value varies by both location and years of experience. The areas with the highest annual mean wage in the United States are listed in Table 6. This table does not adjust for differences in cost of living in the various areas.

Table 6: Top Five Areas with Highest Civil Engineering Annual Mean Wages as of May 2009[6]

State	Annual Mean Wage
District of Columbia	$93,790
California	$91,910
Texas	$87,950
New Jersey	$87,090
Louisiana	$86,790

From a historical and discipline comparison perspective, wages for civil engineers trend on the higher side of the engineering disciplines and have increased from 2003 – 2009. Median weekly earnings for all Architecture and Engineering individuals in 2003 was $1,053, compared to the $1,150 in Civil Engineering, while in 2009 median weekly earnings were $1,266 and $1,326, respectively.[4,5]

Consideration of Sub-Disciplines in Civil Engineering

F.A. Hayek said in his Nobel Prize lecture[8] "I prefer true but imperfect knowledge, even if it leaves much indetermined and unpredictable, to pretence of exact knowledge that is likely to be false." With this guiding principle, many types of data, including anecdotal evidence, were used to develop the sub-discipline sections and make predictions about the future of the sub-disciplines of civil engineering. Each of the following sections provides an overview of the profession in general including background information, professional societies, education and certification expectations and trends and the future direction of the sub-discipline. The sub-disciplines discussed include construction management, environmental, geotechnical, structural, transportation, and water resources.

Construction Management Engineering

The primary sectors that employ civil engineers in construction management are the Nonresidential Building Construction and Heavy and Civil Engineering Construction sectors of the construction markets. The residential construction market is not considered as a sector of employment for the civil engineer from a construction standpoint; rather, civil engineers' work in the residential sector is related to design.

In May of 2009, non-residential construction jobs numbered 17,470, a relatively small sector of the civil engineering workforce. These engineers are specifically working for construction companies; municipal, state and federal positions (at 28,400, 32,780, and 10,130 respectively) not included in this number.[1] Per the BLS data, Heavy and Civil Engineering Construction accounts for an unknown number of employed civil engineers. This does not include those working as construction managers, of which 50,560 were employed in the sector in May of 2009. The construction manager is described by the BLS as one who:

> *Plan, direct, coordinate, or budget, usually through subordinate supervisory personnel, activities concerned with the construction and maintenance of structures, facilities, and systems. Participate in the conceptual development of a construction project and oversee its organization, scheduling, and implementation. Include specialized construction fields, such as carpentry or plumbing. Include general superintendents, project managers, and constructors who manage, coordinate, and supervise the construction process.*[1]

The number of civil engineers who have transitioned into this field is unknown as there is considerable overlap from employee's transitioning into construction manager positions, not necessarily with a civil engineering background.

The future of the Nonresidential Building Construction and Heavy and Civil Engineering Construction sectors of the construction markets depends to a great extent on the US government continuing to fund the federal Highway Trust Fund, which enables state Departments of Transportation to continue design and implementation of construction projects. The primary focus of Heavy and Civil Engineering Construction as deemed by the BLS will include construction and expansion of transportation, water supply, pollution control systems; and repair or replacement of roads and bridges. Nonresidential Building Construction includes the expansion, construction, repair, or renovation of public structures, buildings, and building complexes.[1] A recent focus on restoration and efficiency of existing structures owned by the public was stipulated in the American Recovery and Reinvestment Act of 2009 (ARRA). One recipient of the funding ARRA, The Corps of Engineers, solicited design-build working relationships with construction firms for their projects. This type of construction delivery is forecasted for greater use in the future due to expedited project completion.

Construction Societies

Professional organizations that cater to the construction industry and parallel the professionalism of the National Society of Professional Engineers, and the American Society of Civil Engineers include the *American Institute of Constructors*, (AIC)[9], and the *Construction Management Association of America* (CMAA)[10]. The AIC works in tandem with the Constructor Certification Commission to provide certification for Associate Constructors (AC), graduates in ABET and ACCE accredited college programs or those with four years of qualifying construction experience. It also provides Certified Professional Constructor certification for those who have already attained their AC or who have worked in the construction industry for over eight years of qualifying education and qualifying construction experience with a minimum of two years in upper management positions.[9]

Education and Certification

The Professional Constructor is an individual who commits to serve the construction industry in a professional and ethical manner and engages in the continued development of his/her skills and education to meet increasing industry challenges and changes. The profession of Constructor includes job titles such as, but not limited to, Project Manager, General Superintendent, Project Executive, Operations Manager, Construction Manager, Chief Executive Officer, etc.[11]
The CMAA program provides testing to become a Certified Construction Manager through their testing agency, Construction Manager Certification Institute. The basis of sitting for the CCM exam designation is meeting the requirements of graduation from an accredited university and 48 months of Responsible-in-Charge project experience or no degree but 12 years of general design/construction experience. Both organizations require member's adherence to their code of ethics and both organizations require continuing education of their members to maintain their certifications. Having either designation provides ample proof of the constructor's commitment to the industry and their integrity as a construction professional.

The civil engineering constructor will be expected to lead construction teams and in many cases perform the tasks of the above mentioned construction manager. This requires the understanding of construction processes along with the ability to work in diverse teams. Construction is a dynamic field with multiple players from the owner, financier, the designer, consultants, the constructor, the subcontractors, suppliers, and craftspeople to the end user. An understanding of these parties can be developed through the additional education of BSCE's via a Master of Construction Engineering Management, Master of Construction Engineering, Master of Construction Management, or similarly developed program.

Environmental Engineering

The environmental engineering profession, the branch of engineering related to the design and planning of engineering work related to prevention, control and remediation of wastes and environmental health hazards, is predicted by the Bureau of Labor Statistics to grow 31 percent between the years 2008-2018, which is an increase in 5 percent from the 2006 estimates.[1]

Most environmental engineers are employed by engineering and consulting services, with remaining fractions in industry and government as shown in Figure 3.[1]

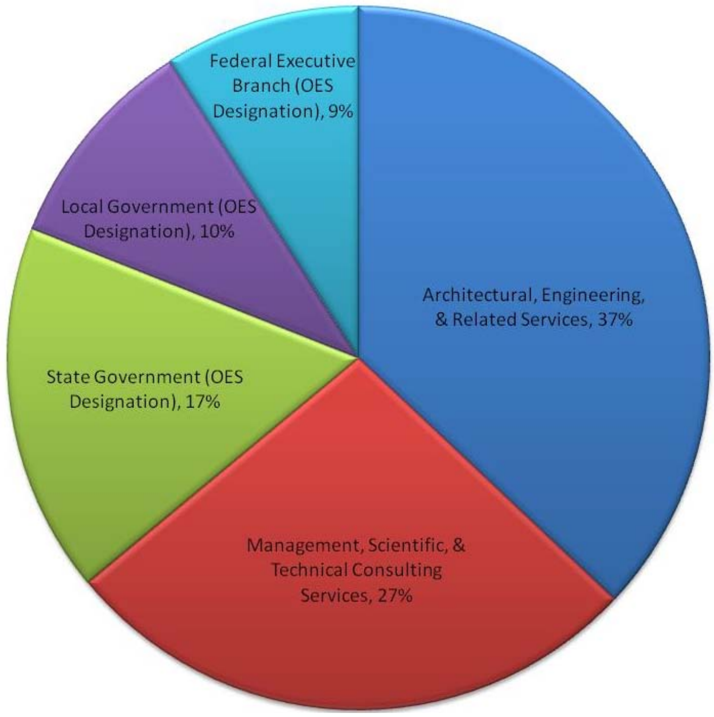

Figure 3: Percent by Industry of Environmental Engineering Employers[1]

Environmental engineers typically make in a year between $47,660 to $115,750, with the median wage at $77,040 per year. These figures work out to be $22.92 to $55.65 per hour with a median hourly wage of $37.04 per hour.[10] The states employing the highest concentration of these environmental engineers are Wyoming, Alaska, Massachusetts, New Mexico and Vermont, whereas states with the highest salaries for environmental engineers are New Mexico, District of Columbia, Maryland, Hawaii and California.[12]

Environmental Societies

Environmental engineering societies are just as diverse as the discipline itself and organizations exist to represent the interests of each of the sub-disciplines. Societies addressing educational and technical expertise for the sub-disciplines of environmental engineering include:

- *Water and Wastewater*. The American Water Works Association (AWWA) promotes advocacy, education, training and advancement of treatment technologies related to water works and the Water Environment Federation (WEF) represents water quality professionals. The WateReuse Association's focus is to improve and increase local water supplies via high quality, locally produced, sustainable water supplies. ASCE offers an opportunity to exchange technical material through Environmental and Water Resources Institute (EWRI).

- *Solid Waste.* The National Solid Waste Management Association (NSWMA) mission is to promote the management of waste in a manner that is environmentally responsible and sustainable while protecting the public and the employees of solid waste management firms. The Solid Waste Management Association of North America (SWANA) provides education and services to members of the solid waste field.
- *Air.* The Air and Waste Management Association (AWMA) assists their members by providing technical and educational information related to air quality, air permitting, climate change, and waste incineration and combustion.
- *Hazardous Waste.* The North American Hazardous Materials Management Association (NAHMMA) is dedicated to pollution prevent and reducing hazardous wastes from entering municipal solid waste streams by fostering and promoting education, development of policies, and providing professional development opportunities.
- *Education.* The Association of Environmental Engineering and Science Professors (AEESP) consists of and serves students and faculty in environmental engineering academic programs. ASEE also addresses environmental engineering educational issues.

Due to the diverse background and interdisciplinary nature of environmental engineering professionals, environmental engineers may join organizations associated with other engineering disciplines. For example, the *American Institute of Chemical Engineers* (AIChE) and the *American Chemical Society* (ACS) may be appropriate memberships for environmental engineers working in industries with a focus on chemical, oil and petrochemical manufacturing.

<u>Education and Certification</u>

The *American Academy of Environmental Engineers* (AAEE) is dedicated to the practice of environmental engineering through activities supporting research, education and outreach of technical material. AAEE oversees the process to become a Board Certified Environmental Engineer (BCEE) or a Board Certified Environmental Engineer Member (BCEEM). Both require eight years of practice and completion of written and oral exams or sixteen years of experience to waive the exam. To be a BCEE or BCEEM, the candidate shall posses a degree in environmental engineering or other engineering field acceptable to the Board of Trustees. Additionally, the BCEE must hold a valid professional engineers license, whereas BCEEM is not a registered professional engineer. Another pathway to attain membership is to be an AAEE Member. AAEE possesses an environmental engineering degree or other acceptable engineering degree and is currently practicing in the field teaching. Students studying environmental engineering may also become AAEE Student Members.

Geotechnical Engineering

Because geotechnical engineers interact with and provide support for the other civil engineering disciplines, it is anticipated that this sub-discipline will grow at the same rate as civil engineering (24% into 2018).[1] Geotechnical engineers rarely work in isolation, and they are involved in a variety of projects in both the public and private sector. For example, if one considers three representative projects, a clear pattern of the need for the use of geotechnical engineering expertise in conjunction with other civil engineering (at the least) knowledge can be seen:

- *Foundation design for a high rise research facility in a major metropolitan area with limited site access*: At a minimum, a geotechnical engineer would be required to work with structural and transportation engineers and architects.
- *Reconstruction and improvements to US 95 through the Philadelphia area*:[13] Geotechnical engineers are required to work with structural, water resource, environmental, and transportation engineers as well as community representatives and archaeologists.
- *Repair of the Jefferson Memorial Seawall*:[14] Geotechnical engineers were required to work with structural engineers, historians, and archaeologists.

In addition to data collected from the Bureau of Labor Statistics, general web searches, and the American Society of Civil Engineers, interviews with practicing geotechnical engineers were incorporated into this section. The demographics of the 14 practitioners interviewed for this section are summarized below:

- The number of years with employer varied greatly (2 to 20) as did the rank of the interviewee (field engineer to principal)
- Ten were men (71%) and four were women (29%)
- One was from the public sector and 13 from private sector (all consulting firms)
- 12 were Professional Engineers in at least one state and two were Engineers in Training

Somewhat in contrast to earlier data presented indicating practitioners do not feel graduates are prepared for their engineering positions, the engineers interviewed for this article were happy with their more recent hires. When asked of their expectations of new hires some general themes were apparent:

- A master's degree or the willingness to obtain a master's degree in a timely manner
- A solid understanding of the fundamentals and the ability to use those fundamentals to obtain practical solutions
- Solid communication skills
- In a word, a professional. One practitioner summed this up by saying "We don't want technicians, but people who are smart technically, can be active professionally, can build relationships, and advance in our organization."
- Work experience through co-ops, internships, or summer employment.

Geotechnical Societies

Geotechnical engineers, because of their interdisciplinary nature, are members of many professional societies. A web search and interviews revealed the following societies claiming geotechnical engineers as members. The most prominent include:

- *American Society of Civil Engineers and the GeoInstitute*: In 1996, the GeoInstitute was formed as a professional society within ASCE. Interestingly, while non-engineers (e.g. geologists) may be members of the GeoInstitute, they may not be members of ASCE. Since 1996, some of the geotechnical sections of local ASCE chapters have converted to GeoInstitute chapters. At the time of writing there were 19 GeoInstitute chapters and 58 geotechnical sections of local ASCE chapters.[15]

- *The International Society of Soil Mechanics and Geotechnical Engineering*: the GeoInstitute is a US member society of ISSMGE. Membership to ISSMGE is complimentary for non-engineers that belong to the GeoInstitute, but engineers that belong to the GeoInstitute (and thus are members of ASCE) must pay an additional fee to join ISSMGE. The organization claims 18,000 members.[16]
- *ADSC: The International Association of Foundation Drilling*: this organization brings together contractors, equipment manufacturers, foundation design professionals, and academics.[17]

Other discipline specific organizations to which geotechnical engineers belong include:

- *American Geophysical Union*
- *American Institute of Professional Geologists*
- *American Society of Highway Engineers*
- *Association of Environmental and Engineering Geologists*
- *ASFE: The Geoprofessional Business Association*
- *Association of State Dam Safety Officials*
- *Association of Women Geoscientists*
- *United States Society on Dams*

Most of the engineers interviewed for this paper were active in one or more professional societies and many of the senior engineers (15+ years of experience) either currently held or previously held leadership positions in a professional society. This indicates that geotechnical engineers are engaged professionally and have ample networking opportunities. Several of the interviewees pointed out that the role of professional societies is likely to increase in importance as more states adopt continuing education requirements.

Education and Certification

The engineers interviewed all viewed the attainment of a professional engineer's license as a critical part of their and their co-worker's professional development. This is buttressed by the fact that all of those interviewed were either already professional engineers or were engineers-in-training. Furthermore, all of the engineers interviewed supported continuing education requirements to maintain licensure.

The practitioners interviewed, however, did not feel as strongly about the desirability of specialty certification. Generally, most were in favor, but even those in favor expressed some misgivings. The engineers that did not support specialty certification did so because they saw it contributing to the fragmentation of the civil engineering field. For example, one engineer that did not support specialty certification said "it will be a bit harder to get a cohesive project team together when everyone will be a specialist, but no one will be that jack of all trades." In addition, one engineer that admitted to having "mixed feelings" about specialty certification noted that "we essentially already have this in place through the (ASCE code of) ethics up holding our PE certification which stipulates we will only seal work we have directly over seen and in areas in which you have expertise…as long as we up hold our ethical obligations to our PE seal, there is no true need."

Most of the geotechnical engineers interviewed (10 out of 14) support ASCE Policy Statement 465. Some representative responses were "all for it," "a step in the right direction," and "worthless." One of the engineers stated that he supports it because "in my opinion, the learning curve in practice is shorter when folks have the additional education." Several noted that support of this policy will require a monetary commitment from employers to help defray the costs of obtaining additional formal education. Lastly, three of the practitioners pointed out that more emphasis needs to be placed on the "experience" requirement of Policy Statement 465.[18] One of them highlighted the importance of "…mentorship and apprenticeship under experienced professionals (on the job training)."

Students considering a career in geotechnical engineering should expect the field to grow at the same pace as the general civil engineering field. To improve their employability upon graduation, they should obtain internships (either during the summer or through a school-sponsored for-credit program) or co-op positions. Students should also be prepared to obtain a master's degree and their professional engineer's license if they would like to advance in the field.

Structural Engineering

Two recent surveys of structural engineering professionals provide a glimpse at the profession in its current state. The first is a 2009 survey by the Structural Engineering Institute (SEI) and the Council of American Structural Engineers (CASE) Joint Committee on Building Information Modeling (BIM) in cooperation with the Structural Engineers Association of Texas (SEAoT) and focused on the demographics of the Structural Engineering profession.

25,000 SEI members were emailed the survey with 1,400 responding. The majority of the structural engineering offices have less than 20 people, while the average office has from 2 to 10 people. Most respondents are upper management, between 30 and 40 years of age and have a master's degree. Most offices use Autodesk AutoCAD. Respondents used a wide variety of computer analysis software and emphasized that there needed to be interoperability between structural analysis software and BIM. Of the building types reported, commercial buildings were the most common. [19]

The second survey focuses on the state of the industry in 2010 from *Structural Engineering &* Design and found that in 2010, 83 percent of respondents said they were happy to be an engineer, while 89 percent said the same in 2009. It would seem with a positive response rate of greater than 80 percent, those who participated in the survey are positive about their profession. Contrast that with only 41 percent in 2010 responding that now is a good time to be an engineer, while 59 percent said the same in 2009. In 2010, 48 percent of respondents said they felt the economy is improving in the United States which is an improvement from the 2009 survey when only 23 percent of the respondents felt the economy was getting better. 53 percent of respondents in 2010 agreed or strongly agreed that they felt their jobs were secure from potential downsizing in the current year. In 2009, only 47 percent responded the same. The number one challenge for

2010 was to keep a backlog of work (64 percent), then maintaining clients (12 percent), maintaining salaries (7 percent) and then maintaining staff (6 percent). Government and office buildings (at 61%) represent the highest areas of activity for structural engineering firms. Other significant areas of work include industrial (52 percent), educational (49 percent), medical (43 percent) and residential (42 percent). Respondents felt the public sector had the highest potential growth for 2010. These growth areas included government (60 percent), transportation infrastructure (49 percent), medical (40 percent), bridges (34 percent) and educational (32 percent).[20] An overall survey summary indicates the following:

> *Based on responses to the survey, we can conclude that although 2009 was a very tough year for the profession, structural engineers as a whole are optimistic that 2010 and even 2011 will show improvements in growth and earnings and that the country, and the industry itself, will soon bounce back. BIM technology is also finding a place in more firms than ever before and the firms who use it are using it on more projects than they have in the past. Structural engineers are beginning 2010 with hope for the future of the industry and their careers and are making the best of the slowly recovering economy.*[20]

Structural Societies

There are three principle structural engineering professional associations which include:

- SEI, the *Structural Engineering Institute* of the American Society of Civil Engineers, ASCE. Its mission is to advance and serve the structural engineering profession.[21]
- NCSEA, *National Council of Structural Engineering Associations*. NCSEA was formed to constantly improve the level of standard of practice of the structural engineering profession throughout the United States, and to provide an identifiable resource for those needing communication with the profession.[22]
- CASE, *Council of American Structural Engineers*. Their mission is to improve the practice of structural engineering by reducing the frequency and severity of claims and their vision is to be the leading provider of risk management education and technology for use in the practice of structural engineering.[23]

Other professional societies that have specific interests within structural engineering include:

- *ACI, American Concrete Institute*
- *AISC, American Institute of Steel Construction*
- *AWC, American Wood Council*
- *AISI, America Iron and Steel Institute*

Education and Certification

One of NCSEA's Strategic Initiatives is to provide leadership and assistance to the State Member Organizations such that they can facilitate legislation leading to SE licensing. ACEC's CASE and ASCE's SEI, both agree with NCSEA that separate licensure is recommended. SEI's policy reads as follows:

The Structural Engineering Institute (SEI) of the American Society of Civil Engineers (ASCE) supports structural engineering licensure, encourages all qualified and licensed engineers practicing structural engineering to obtain a structural engineering license, and encourages jurisdictions to license structural engineering as a specialty.[24]

As of June 2010, eleven states have incorporated the SE license into their legislation. Seven of these states (Illinois, Hawaii, California, Nevada, Oregon, Utah and Washington) have a full or partial practice act while the remaining (Arizona, Idaho, Nebraska and New Mexico) have a title act.[25]

A practice act limits the actual practice of structural engineering to those who hold an SE license while a partial practice act limits the practice of structural engineering by type of structure that requires an SE to design. A title act limits who can use the title of Structural Engineer. In both cases, the engineer must take one or more structural engineering licensing exams offered by the National Council of Examiners in Engineering and Surveying (NCEES) and/or the state in which the engineer is seeking license. In 2004, NCEES published specific qualifications for a Model Law Structural Engineer (MLSE), which can be found at NCEES.org. This document is intended to provide typical requirements for education, experience, and examination that could be adopted by a state licensing board to establish a structural engineering practice or title restriction in that state.[26]

To qualify for this MLSE, a candidate must meet specific educational (Obtain a degree from an EAC/ABET-accredited program that includes 18 semester hours of structural analysis and design, nine of which are structural design) and experience (Complete four years of structural engineering work) requirements and pass 16 hours of structural engineering exams. In support of this model law, beginning in April 2011, NCEES now offers a 16-hour exam in two components on successive days. The 8-hour Vertical Forces (Gravity /Other) and Incidental Lateral component will be offered on Friday and the 8-hour Lateral Forces (Wind/Earthquake) component will be offered on Saturday. The morning sessions will consist of 40 multiple-choice questions covering a comprehensive range of structural engineering topics. The afternoon sessions will have four one-hour essay questions and focus more closely on a single area of practice in structural engineering.[27]

There is an additional educational requirement in the MLSE beyond the BSCE. Few if any BSCE degrees allow students to take 18 hours of structural analysis and design. This then is consistent with the survey information discussed previously that most respondents had obtained a master's degree.

Transportation Engineering

Transportation projects involve a workforce with backgrounds in many disciplines, both within and outside of engineering. Broadly, transportation involves planning, design, construction, and operation and management of complex systems of facilities and vehicles to move both goods and people. The transportation enterprise can involve engineers of many types, including traffic engineers, structural engineers, geotechnical engineers, environmental engineers, hydraulic engineers, and electrical engineers; as well as those with backgrounds in fields such as planning, biology, accounting and finance, and logistics. The evolution of transportation systems and changes in technology is also leading to changes in the skills and training required. For example, expertise in geographic information systems (GIS) is now critical for many transportation-related jobs.

Many large transportation projects are public projects, and the public agencies make extensive use of private sector consultants in the work. This creates substantial competition between the public and private sectors for talented professionals in the transportation field. While the federal government provides considerable amounts of money for transportation projects, it hires a relatively small percentage of the transportation workforce. The larger shares are found in state and local governments (largely through state departments of transportation) and the private sector.

Toole and Martin summarized the status of the transportation workforce in a 2004 *ITE Journal* article. At that time, state departments of transportation employed more than 250,000 people (not all engineers). More than 38,000 local agencies also employ engineers and others either directly or as consultants to further transportation projects at the local level.

Concern about transportation workforce developments led the U.S. Department of Transportation to host a National Workforce Summit in 2002[28]; this has been followed by a more recent series of regional workforce development summits across the United States.[29] Transportation agencies are in the midst of large-scale retirements and limited budgets that make training and retaining a qualified workforce exceptionally difficult. Specifically, a 2003 Transportation Research Board Special Report found that almost half of the transportation workforce would be eligible to retire in the ensuing 5 to 15 years.

Transportation projects are increasingly focusing on renewal rather than new construction. Further, even large public projects can be at risk from tight public budgets, as evidenced by the recent cancellation of the NJ Transit ARC tunnel project by New Jersey Governor Chris Christie.[30]

Transportation Societies

Transportation professionals can be involved in a variety of professional organizations, including:

- *The Transportation and Development Institute* (T&DI), which is affiliated with the American Society of Civil Engineers (ASCE) and accepts members who work in the transportation field who may or may not be civil engineers. As of September 30, 2010 T&DI membership was 17,636,[31]
- *The Institute of Transportation Engineers* (ITE), which comprises transportation professionals including engineers, has approximately 17,000 members.[32] Approximately 10,750 of these members participate in one or more of 12 “special interest councils” based on employer type or technical interest;[33] and
- *The Transportation Research Board* (TRB), which promotes research in all areas of transportation. The TRB, an arm of the National Research Council, oversees more then

200 standing committees and task forces that involve more than 4,000 volunteers who work on transportation-related projects or issues.[34]

The latter two have internal groups that focus on education and workforce issues.

Education and Certification

Transportation practitioners who were educated as civil engineers are likely to be licensed, professional engineers. Additional certifications available include:

- Professional Traffic Operations Engineer (PTOE), which supplements a PE license. There were 2,361 PTOEs as of September 21, 2010;[35]
- Traffic Signal Operations Specialist (TSOS), for practitioners who are not licensed professional engineers but have significant experience with traffic signals. As of September 21, 2010, 83 people had obtained the TSOS certification;[36]
- Professional Transportation Planner (PTP), for transportation planners who may or may not be licensed professional engineers. The 4-year-old program had granted 271 PTP certifications as of September 21, 2010;[37,38] and
- Certified Transportation Planner (CTP), an advanced credential for those who are certified by the American Institute of Certified Planners (AICP).

The first three of these are administered by the Transportation Professional Certification Board, Inc. (TPCB), which was founded by the Institute of Transportation Engineers but is now an independent organization. The TPCB had also implemented a Traffic Operations Practitioner Specialist certification, available to those without a PE license, which it discontinued due to lack of interest on the part of applicants; only 63 were granted.[39]

A significant portion of the projected job growth in civil engineering is due to transportation projects. For example, the Bureau of Labor Statistics states that "Spurred by general population growth and the related need to improve the Nation's infrastructure, more civil engineers will be needed to design and construct or expand transportation…. They also will be needed to repair or replace existing roads, bridges, and other public structures".[1]

Water Resources Engineering

Historically, water resources engineers plan, design, operate, and manage projects to prevent floods, supply water, collect storm water and wastewater, generate hydropower, manage waterways, and much more. At the forefront of infrastructure design and construction for millennia, water engineers have constructed dams, aqueducts, canals, and other large water infrastructure. Indeed many ancient civilizations can be identified as 'hydraulic civilizations' because of their reliance on the human control of water.

During the past decade the demand on water resources engineers has increased as challenges have intensified and diversified and become more complex with metropolitan populations growing, infrastructure aging, climate changing, and policy becoming more complex. This has led to a broadened view of water resources engineers as stewards of the world's water with their responsibilities extending well beyond design to include planning, management, and operation of sustainable water resources systems.

As is well known, the future is difficult to predict. It is estimated that by 2030 the world will be using 30 percent more fresh water[40]. Recent trends in the United States' population distribution suggest people will continue to move into areas of high hydrologic hazard including floodplains, coastal zones, steep slope areas, and further from metropolitan centers. Moreover, scientists project climate variability and change will have significant impacts on water resources leading to a need for innovative water storage, efficient water transmission and distribution, and coastal area and riparian protection. Together, these challenges lead to the expectation for growth of water resources engineering jobs. Logically, since the profession of water resources engineering is expected to continue to broaden, one would predict this sub-discipline will grow at a rate greater than civil engineering (>24% by 2018).

Water Resources Societies

ASCE was founded in 1852, one of the first professional societies serving the water resources engineering community. Perusal of the early Transactions of the American Society of Civil Engineers indicates the members focused on storing and conveying water for supply, drainage, and navigation purposes. More specialized professional societies focused on water infrastructure emerged when the *American Water Works Association* (AWWA) was formed in 1881 and the *American Public Works Association* (APWA) was formed in 1937. As the water resources engineering profession has broadened, the societies that serve the profession have expanded. Consequently, an exhaustive listing of societies is not possible. Two additional societies that commonly serve water resources engineers in the United States include:

- *Water Environment Federation* (WEF) - formed in 1928 serving water quality professionals with specializations in wastewater treatment
- *American Water Resources Association* (AWRA) - formed in 1964 with the goal to advance water resources education, management, and research

Water resources engineers are also served by numerous societies with a link to water including:

- *American Geophysical Union (AGU)*
- *American Meteorological Society (AMS)*
- *Association of State Floodplain Managers (ASFPM)*
- *National Water Resources Association (NWRA)*
- *National Association of Flood and Stormwater Management Agencies (NAFSMA)*
- *Association of State Dam Safety Officials (ASDSO)*
- *National Ground Water Association (NGWA)*
- *Association of Metropolitan Water Agencies (AMWA)*

Existing societies have also expanded to create sub-units for the specialized areas. For example, slightly more than a decade ago ASCE created several new institutes, one of which was the *Environment and Water Resources Institute* (EWRI). EWRI is focused on environmental and water resources issues and provides a forum for water resources engineers to gain more specialized attention to their discipline as well as cross-exposure to the inter-related environmental topics.

It is unclear how the future of water resources engineering will respond to or dictate changes to serving professional societies. Clearly, the profession will continue to change as water resources issues become more complex. Societies will need to evolve to respond to the need to raise awareness of sustainability and increase creativity and innovation.

Education and Certification

Water resources engineers have the skills and technologies to develop solutions to most of the problems that currently surround water. A major limitation now and in the future is effectively implementing the solutions by engaging policy makers, economists, government agencies, and the public. In addition, in the future the increasing complexity of projects will require a greater depth of specialization, broader awareness and knowledge of sustainability and multidisciplinary objectives, and a heightened sense of creativity and innovation. The reasoning for the need of greater depth in an area of specialization has been well documented in the discussion of the American Society of Civil Engineers (ASCE) Policy Statement 465, *Academic Prerequisites for Licensure and Professional Practice*.[18] Collectively; the civil engineering profession has been addressing the need for greater academic preparation with the development of M/30 programs.

Being able to effectively engage policy makers, the public and others in multidisciplinary projects with multiple objectives is an area of need. Educators are seeking to address the need for multidisciplinary education through the use of the Capstone Design courses. Selecting design projects that require the water resources, structural, geotechnical, transportation, environmental, and other areas collaborate and integrate their efforts is essential for successful capstone projects that can address the widest range of ABET criteria. Professional societies are providing greater opportunities to interact with other disciplines within their own profession. For example, the *American Society for Engineering Education* (ASEE) introduced a multidisciplinary engineering division to foster interaction among the engineering disciplines.

Another area that is important for students and young engineers is to better understand the political process enveloping a project. A way to become fully aware and engaged in the political process is to become involved in advocacy. ASCE is helping to support this effort through highlighting important political issues related to the profession and sponsoring engineers to become involved in the political process through the ASCE Congressional Fellowships. Educators need to continue to follow the lead of ASCE and provide greater integration of the political process and policy analysis techniques into the civil engineering curriculum as outlined in the ASCE Body of Knowledge (BOK).

Incorporating sustainability concepts into water resources education has advanced the last decade. Civil engineering educators have moved forward with different approaches to integrate sustainability into the civil engineering curriculum.[41,42] From a professional society perspective ASCE has introduced the need for incorporating sustainability in the ASCE Body of Knowledge, "Analyze systems of engineered works, whether traditional or emergent, for sustainable performance." The need in the future links with the first point – greater cooperation with other disciplines and non-professionals to develop broader sustainability elements and goals for projects. This is especially critical with the emerging Sustainable Infrastructure Rating System from ASCE.

With water issues becoming more complex, creativity and innovation are critical elements to produce and implement effective designs. The question from an education standpoint is how to help students exercise and improve their ability to be creative, innovative and successfully work with a wide range of stakeholders to solve trans-disciplinary problems. One approach is to broaden education with greater emphasis on liberal arts, which is being achieved in a number of ways. One way professional societies are addressing this issue is with elements for humanities and social sciences in the ASCE BOK. But how to professionally engage these areas of knowledge and incorporate them into practice is not well defined and few examples exist. Existing societies including ASCE-EWRI and AWRA are seeking to provide knowledge and activities to help professionals build trans-disciplinary foundations, but more effort is needed.

New professional certifications have emerged in response to the increased specialization in the water resources engineering profession. One organization, the *American Academy of Water Resources Engineers* (AAWRE) was formed in 2004, as a sub-unit of the ASCE-EWRI with the goal of improving the practice of water resources engineering, elevating the standards, and in general advancing the water resources profession. It is the first academy created under guidance from the Civil Engineering Certification, Inc. (CEC) and it provides voluntary, post-license credential (Diplomate, Water Resource Engineer (D.WRE)).

To meet future project challenges, water resources engineers must seek educational opportunities and professional activities that can provide greater specialization, an ability to work across disciplines and with policy makers and the public, an understanding of sustainability concepts and how to incorporate them into projects, and finally, how to be creative and innovative.

Looking Forward – The Next Decade

On October 11, 2010, *Money* magazine listed environmental and civil engineering as the 5th and 6th best job in America, respectively[43]. Projections indicate that civil engineering will continue to exhibit strong trends in growth and increases in the demand for employment at rates that are considered faster than the average.[1] Table 7 lists the five engineering disciplines predicted to experience the greatest percentage of growth from 2008 – 2018, while Table 8 ranks the top engineering disciplines by the total number of job opportunities expected from 2008 – 2018 due to both growth and replacement needs.

Table 7: Predicted Top Engineering Disciplines with Largest Percent Employment Growth from 2008 – 2018[7]

Engineering Discipline	Predicted Percent Employment Growth
Biomedical	72%
Environmental	31%
Civil	24%
Petroleum	18%
Industrial (including health & safety)	14%

Table 8: Predicted Top Engineering Disciplines with Largest Number of Job Opportunities from Growth and Replacement Needs from 2008 – 2018[7]

Engineering Discipline	Total Job Opportunities
Civil	114,600
Industrial (including health & safety)	94,600
Mechanical	75,700
Electrical and Electronics (except computer)	72,300
Environmental	27,900

Considering all engineering disciplines, civil engineering is third in percent growth and first in the total number of job opportunities due to growth and replacement needs. It is important to note for both of these tables that the US Department of Labor lists Environmental Engineering separate from Civil Engineering. Separately, Environmental Engineering ranks second with respect to the largest percent of predicted employment growth and fifth for largest number of job opportunities from growth and replacement needs. Combining both Civil and Environmental would place them second overall in percent growth and first in job opportunities.

When considering geographic location, Table 9 summarizes the five states with the greatest predicted growth in employment opportunities for civil engineers in the United States when comparing 2006 levels to predicted 2016 levels.

Table 9: Predicted States with Highest Percent Increases in Civil Engineering Employment Opportunities from 2006 – 2016[44]

State	Percent Employment Change	Numeric Employment Change
Utah	36%	900
Nevada	32%	930
Florida	30%	4,300
Wyoming	29%	220
Arkansas	25%	370

Although this indicates high levels of growth relative to 2006 levels, it is important to recognize that these states may not necessarily be hiring the greatest number of civil engineers in the future. From the list presented, only Florida is in the top five (ranked third) based on the number of civil engineers employed in the state. Considering only numeric employment increases, states that rank the highest are Texas (5,360), California (5,100), Florida (4,300), Washington (2,910), and Virginia (1,940).

Civil Engineering employment by industry is forecasted to have sectors with both high increases in demand, as well as significant decreases in demand. While the industries that employ the overall greatest number of civil engineers are not predicted to fluctuate from 2008 – 2018, several smaller areas are expected to see noticeable changes. The greatest increases are listed in Table 10, while those industries with the largest reductions are presented in Table 11.

Table 10: Predicted Industries with the Greatest Increase in Percent Demand for Civil Engineers from 2008 – 2018[45]

Industry	Percent Increase
Management, Scientific, & Technical Consulting Services	85.5%
Computer Systems Design & Related Services	37.3%
Electrical Contractors & Other Wiring Installation Contractors	35.7%
Waste Treatment & Disposal	32.9%
Facilities Support Services	30.5%

Table 11: Predicted Industries with the Most Significant Decrease in Percent Demand for Civil Engineers from 2008 – 2018[45]

Industry	Percent Increase
Basic Chemical Manufacturing	36.8%
Semiconductor & Other Electronic Components Manufacturing	35.6%
Petroleum & Coal Products Manufacturing	27.7%
Oil & Gas Extraction	20.6%
Electric Power Generation, Transmission, & Distribution	20.3%

With regards to the data in Table 11, it is important to recognize that although these decreases appear to be significant percentages, the overall percent of civil engineers employed in all five industrial areas of Table 11 combined sums to less than 1% of the total number of civil engineers employed in all industrial areas.

Conclusions

For centuries, civil engineering has been a critical component of the advancement of society and the improvement of the quality of life. Requirements associated with these positions have evolved over the years, and the individuals engaged in the profession of civil engineering have continued to rise to the challenges presented. Civil Engineering is, and is predicted to remain, a growing discipline that comprises a significant total of the overall engineering workforce in the United States. While Civil Engineering sub-disciplines have developed to include specialized societies and certifications in several of these specialty areas, interaction between sub-disciplines, as well as with other engineering and non-engineering disciplines is a vital component of any engineering project. As discussed in this paper, interdisciplinary collaboration is becoming more and more essential to the success of civil engineering projects, the goal of which is to improve people's lives. Although some states and industries are predicted to see decreases in the demand for civil engineers over the next decade, the overall outlook for the civil engineering workforce is a positive one.

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