The Engineer of 2020 as of 2020

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Has the Engineer of 2020 materialized as expected? Has the education of that engineer met the predictions established fifteen years ago? If so, how and what lessons can be learned moving forward? This paper will present a critical review of the current realities of the state of engineering practice in the year 2020, based on where we expected to be when the National Academies published *The Engineer of 2020* in 2004.

How well did this visionary report predict the future? What aspects of the document are in fact reality, which continue to show potential, and which did not materialize as envisioned? At the time of publication, the document was prepared by an impressive collection of educators and practitioners. It was widely cited and deemed inspirational, aspirational, and paradigm-changing. *The Engineer of 2020* focused on envisioning the future and predicting the roles engineers would play in that future. It included a list of attributes that were expected to be desired in the engineers as of the year 2020. This paper presents an evaluation through the lens of civil engineering practice and civil engineering education. In addition to the National Academies' report, this paper considers more recent profession-shaping publications to include the American Society of Civil Engineer's (ASCE's) *Body of Knowledge, 3rd Edition*.

This paper only presents the views, opinions, and experiences of the authors, a practitioner and an educator. Formal assessment is not incorporated as part of this exploratory analysis methodology. It is anticipated that this paper will be of interest to both civil engineering practitioners and educators as they consider the state of the practice.

Introduction

It is April 1984 and Winston Smith toils away at his job with the Records Department of the Ministry of Truth where his responsibilities include rewriting historical records to better align with the totalitarian super-state's version of history. As a "thoughtcriminal," Winston dreams about a possible future rebellion against the Thought Police and the government's leader, "Big Brother." This frightening post-global war glimpse of the future was written in 1949 by George Orwell. *Nineteen Eighty-Four* [1], as a novel, was widely acclaimed as a forewarning, but very little from the book proved to be a reality in 1984, other than the potential for world-wide nuclear war.

It is now October 26, 1985 as Marty McFly is surprised by his friend and eccentric scientist Dr. (Doc) Emmett Brown's sudden arrival in his DeLorean, which also happens to double as a successful time machine. 1.21 gigawatts later, Marty McFly and Doc have now arrived at October 21st, 2015. This scenario comes from the movie *Back to the Future II* [2] starring Michael J. Fox as Marty McFly. As people crowded into theatres for the movie's release the day prior to Thanksgiving 1989, they were treated to the unique opportunity to see an interpretation of the future per the film's director Robert Zemeckis. While flying cars, self-tying shoes, and hoverboards featured in the movie were not a reality in 2015, the film did correctly predict several technological and sociological changes. Some of those predictions include the extensive use of cameras, fingerprint scanners, hands-free video games, flat-panel TVs, and tablet computers.

It is now 2001. In route to the planet Jupiter aboard Discovery One, Dr. David Bowman is fighting for control of the spacecraft; fighting with HAL 9000, a computer with an incredibly human-like personality. *2001: A Space Odyssey* was published as a novel [3] by Arthur C. Clarke in 1968. That same year, it was released as a movie [4] directed by Stanley Kubrick. When the novel and book were released, the space race was in full effect, but humans had yet to leave Earth's orbit. While space travel had advanced significantly by the year 2001, we were not in fact conducting archeological work on the surface of the moon as was predicted in the novel and movie. However, it could be argued that HAL's statement "I'm sorry Dave, I'm afraid I can't do that" was in fact an accurate prediction of computer error messages that were a common part of our technological lives in the year 2001 and continue today.

What do these contributions to literature and entertainment share in common? They each showed a willingness to envision how the future would look. Not an easy or enviable task. In truth, when each of these items were released nobody could argue against the creative license used to describe the future. It is only once we have reached those milestone years of 1984, 2001, and 2015 that we have the ability and perhaps sense of obligation to take a critical look at what predictions were correct and what prediction were not.

While it may not have received a world premier opening night, *The Engineer of 2020:Visions of Engineering in the New Century* [5] also made predictions of the future. *The Engineer of 2020* was published in 2004 and attempted to predict the roles that engineers would play in the year 2020. A companion text titled *Educating the Engineer of 2020: Adapting Engineering Education to the New Century* [6] was published in 2005 and focuses on changes necessary in engineering education to prepare engineers to practice in the year 2020.

As we are now in the year 2020, it is interesting to consider the predictions these texts made. What aspects of each document are in fact reality? Which continue to show potential? Which did not materialize as the authors envisioned? This study will be limited to evaluating only *The Engineer of 2020* report. Evaluation of the *Educating the Engineer of 2020* report will be part of this study only as it relates to education's role in achieving the vision set by *The Engineer of 2020* report. A full review of the *Educating the Engineer of 2020* report will be part of a subsequent study. An exploratory analysis methodology is used to evaluate *The Engineer of 2020* in the context of the year 2020. The intent is to learn from those predictions. This paper is meant to provide an introspective look at the current state of the industry; in no way is this paper intended to be a disparaging critique of the publications.

The Engineer of 2020

The Engineer of 2020 is a product of the National Academy of Engineering. It was prepared by a committee of 18 hand-selected individuals. Among those committee members, 12 had affiliations identified as academic institutions, 4 were affiliated with technology-based companies (IBM, HP, Telcordia, and Reliant Energy), 1 was affiliated with a national laboratory (Sandia), and 1 was affiliated with National Public Radio. Biographical sketches for each member of the committee are included in an appendix to the report and indicate extremely impressive credentials.

The document's preface identifies that the report's intent: "centers on an effort to envision the future and to use that knowledge to attempt to predict the roles that engineers will play in the future [5]." The report was stated to "provide a framework that will be used in subsequent work to position engineering education in the United States [5]." The proactive nature of the report is summarized in "what lies ahead, rather than waiting for time to pass and then trying to respond."

The committee's effort was broad in the sense that it was considering all sub-disciplines of engineering, but at the same time narrow in that it was focusing on the geographical limits of the United States. While the United States was the primary focus, the report does clearly acknowledge the global interconnectivity of the practice of engineering.

The committee's effort was chartered by the National Academy of Engineering's Committee on Engineering Education. The charge to the committee reads as follows:

> *"1. Development of a vision for engineering and the work of the engineer in 2020.*
>
> *2. Examine engineering education and ask 'what it needs to do to prepare engineers for the future.'* [5]*"*

Item 1 from the committee's charge resulted in *The Engineer of 2020* report. That report was then used as the basis for framing the discussion around Item 2, which in-turn resulted in the *Educating the Engineer of 2020* report.

The committee hosted a workshop during the fall of 2002 with 35 participants. A strategic planning consultant moderated the workshop and guided participants through four specific scenarios. The intent of using the scenario-based discussion was to "help participants think broadly about events and issues that could shape the future [5]." The scenarios themselves were not intended to be directly representative of conditions in the year 2020. The four scenarios considered were: 1) the next scientific revolution, 2) the biotechnology revolution in a society context, 3) the natural world interrupts the technology cycle, and 4) global conflict or globalization. The story form of each scenario will not be repeated in this paper as they are readily available in the report.

After the workshop, members of the committee used workshop keynote presentations, workshop discussions, workshop scenarios, and the committee's consensus about new technologies to collectively prepare the report. The 101-page report (including appendices) begins with an executive summary followed by two chapters focused on 1) the technological context of engineering practice and 2) the societal, global, and professional contexts of engineering practice. The first two chapters consider trends in engineering as a means of considering what the future may hold. The report's third chapter presents aspirations for the individual engineer in the year 2020. The final chapter defines the attributes that the engineer of 2020 will need to be successful. The report concludes with appendices that present the previously mentioned four scenarios (Appendix A), a list of workshop attendees (Appendix B), and biographical sketches of the committee members (Appendix C).

The executive summary makes the case that it is not acceptable for the engineering profession and engineering education to lag behind technology and society. This is especially true as the rate of technological change occurs at a faster and faster pace. Accordingly, the committee's overarching research question appears to be "What will or should engineering be like in 2020?"

Predictions: What Became Reality, What Still Shows Potential, and What Did Not Materialize?

The final chapter of *The Engineer of 2020* report contains specific predictions regarding the engineering profession in the year 2020. Those predictions are as follows:

- The pace of technological innovation will continue to be rapid (most likely accelerating).
- The world in which technology will be deployed will be intensely globally interconnected.
- The population of individuals who are involved with or affected by technology (e.g. designers, manufacturers, distributors, users) will be increasingly diverse and multidisciplinary.
- Social, cultural, political, and economic forces will continue to shape and affect the success of technological innovation.
- The presence of technology in our everyday lives will be seamless, transparent, and more significant than ever.

In the following paragraphs, the authors will evaluate each of the predictions. Consideration will be given to predictions that became a reality, still show potential, or did not materialize.

Pace of Technology

The pace of technological innovation has indeed continued to accelerate. For example, the processing power of a CPU can be measured in Floating Operations Per Second (FLOPS). FLOPS continue to increase exponentially, gaining an order of magnitude every 5 years [7],[8]. Artificial Intelligence is currently being tested in many areas, including the ability to debate humans on complex topics (IBM Project Debater) [9]. Cloud computing is now commonplace, and did not exist a few years ago. Artificial intelligence is currently being used to pilot LIDAR-equipped motorcrafts in civilian commercial applications; this technology is expected to change industries as vast as shipping [10].

Innovations are developing at a global scale. For example, China, Japan, and South Korea receive the majority of patents for unique inventions [11]. Engineering-related inventions make up more than half of all those reported globally in 2018 [11]. Additionally, international collaborations in science and engineering publications has continued to rise since 2000, with U.S. authors most frequently collaborating with authors from China [11].

Adamuthe and Thampi [12] looked at the rate of technology change over the period of time between 1970 and 2018 and then used statistical trend analysis to forecast future growth through the year 2040. They specifically looked at technology in the form of mainframes, minicomputers, cluster computing, grid computing, autonomic computing, and cloud computing. They utilized a large dataset to validate the growth pattern of technology and concluded that the technologies evaluated demonstrated non-linear growth and most technologies exhibited a nearly polynomial trend [12].

The National Academy of Engineering committee correctly predicted that the pace of technological innovation would continue to be rapid and even correctly predicted that the pace would be accelerating.

Global Interconnections

The world in which technology is deployed continues to become more globally connected. In 2005, only 5% of U.S. adults used social media platforms. Today, 72% use social media [13]. Globally, more than 360 million people came online for the first time in 2018, at an average rate of more than 1 million new users per day [14].

While the technology exists and has become more readily available for world populations to demonstrate better interconnectedness, it is questionable if technology has resulted in better understanding between cultures, countries, and populations. More global-level connectivity has not definitely resulted from having both access to technology and the knowledge that it can better enable nearly instantaneous world-wide communication. It could be argued that technology has done more to highlight cultural differences than it has to bridge those differences. The great promise of 5G technology is that the "daily lives of people across the planet will be more closely intertwined than ever [15]." It is unclear if that will serve to promote more understanding and positive connections.

It is the authors' assessment that *The Engineer of 2020* report prediction that technology will result in a more globally connected planet still shows potential.

Increasing Diversity and Multidisciplinary

The next prediction was that "The population of individuals who are involved with or affected by technology (e.g. designers, manufacturers, distributors, users) will be increasingly diverse and multidisciplinary." In the National Science Foundation's *State of the U.S. Science and Engineering 2020* report [16], science and technology sectors include not only engineering, computer sciences, mathematics, and physical and life sciences, but also psychology and social sciences. Seventeen million U.S. workers are considered part of the skilled technical workforce [16]. For engineers alone, this value has risen from 2.11% of the U.S. population in 2005 to 2.71% in 2018 [17]. Additionally, the number of people connected to technology continues to increase, as previously cited herein. It is therefore the authors' assessment that the size of the population of those involved with or affected by technology has both increased and become more multidisciplinary.

A study of the diversity portion of this prediction indicates that diversity has increased slightly among the U.S. science and engineering (S&E) workforce, although women and certain racial and ethnic groups are still under-represented. Women accounted for 29% of all S&E employment in 2017, up from 26% in 2003 [16]. The increase was concentrated in life sciences and psychology, as opposed to engineering. The proportion of individuals in under-represented minority groups rose from 9% in 2003 to 13% in 2017 [16].

Thus, it is the authors' assessment that we have seen improvement in diversity, but there is a long way to go. This prediction in *The Engineer of 2020* report still shows potential.

Forces Shaping Innovation

It is the authors' assessment that *The Engineer of 2020* report prediction that "social, cultural, political, and economic forces will continue to shape and affect the success of technological innovation" has become a reality.

In 2019, leading-edge engineering innovations according to the National Engineering Academy include: (a) advanced manufacturing, (b) engineering the genome, (c) self-driving cars: technology and ethics, and (d) block chain technology [18]. Each of these areas occurs at the intersection of engineering disciplines and these forces. For example, advanced manufacturing research is related to using robotics in manufacturing applications to boost efficiency. This advancement is in response to the economic forces around labor and globalization [18]. The recent focus on safety and ethics related to the development of self-driving cars and the technologies that support them is partially a result of the public outcry related to two recent deaths involving vehicles using driverless systems [19].

Politically, federal tax credits have accelerated the deployment of clean, renewable energy and played an important role in the rapid growth of the U.S. renewable energy industry. Between 2005 and 2015, wind electricity generation increased 7-fold to 191 terawatt-hours (TWh) in 2015 [20]. Photovoltaic (PV) electricity generation rose from near-zero to 36 TWh in 2015 [20].

The implementation of new technologies will continue to be shaped by social forces and public opinion which can result in political will to enact new regulations. 91% of adults in a 2014 Pew Research Center Study "agreed" or "strongly agreed" that consumers have lost control over how personal information is collected and used by companies [21]. The Cambridge Analytica data breach resulted in national news and congressional inquiries into social media giant Facebook's use of consumer data [22]. It is yet to be seen how or when regulations will be put in place as technologies mature, but it can be expected that increased public awareness will result in political forces further shaping technology implementation.

Specific to civil engineering, we have seen recent climate change protests resulting from activists like 17-year-old Greta Thunberg. As society becomes more vocal about engineering issues that impact future generations, political will for change also increases. The American Society of Civil Engineers has given the United States a grade of D+ in the most recent Infrastructure Report Card. The report notes that there is a $2.0 trillion, 10-year investment gap in the United States. Innovative funding will be needed to bridge this gap and fix America's deteriorating infrastructure [23]. These economic forces have already resulted in innovations such as a recent rise in public-private partnerships, also known as P3 models. These models have a significantly higher likelihood of meeting cost and schedule objectives compared with traditional public sector project delivery where a project is owned, managed, and financed by government [24].

Seamless, Transparent, and Significant Technology

Technology is indeed becoming more seamless. Self-driving cars are starting to be produced on scale. Convenience apps such as grocery ordering, transportation services, and other delivery services are integrated seamlessly into many consumers' lives, as well as smart-home technology such as programmable thermostats.

As indicated previously in this report, transparency in technology is showing potential but has a long way to go. Specific areas of concern include how consumer data is stored and the ethics of decision-making by artificial intelligence. Cybersecurity is a growing concern; according to the U.S. Department of Homeland Security's Cyber Security division: "As information technology becomes increasingly integrated with physical infrastructure operations, there is increased risk for wide scale or high-consequence events that could cause harm or disrupt services upon which our economy and the daily lives of millions of Americans depend [25]."

It is the authors' assessment that this prediction shows potential. Technology continues to improve rapidly, but is not integrated seamlessly in all parts of our lives. For example, although BIM use in the architecture, engineering, and construction industries (of which civil engineering is a subset) is increasing, and has many potential applications and benefits, it has yet to be adopted as the industry-wide standard in the U.S.[26]. Additionally, transparency is a concern that is currently being addressed mostly from a public policy standpoint, but varies dramatically by geographic location. Transparency of technology has a long way to go before this prediction is fulfilled.

What the Engineer of 2020 Missed

As we have illustrated, the *Engineer of 2020* hit the mark with some predictions and came close with others. While the primary intent of this study was to evaluate the specific predictions made in the report, it is also interesting to consider the nature of certain realities currently faced by engineers in the year 2020 that were not directly considered or predicted in the report. Three significant items to highlight are:

- Climate change
- Cyber Security
- Pandemic spread of diseases

Climate change was mentioned very briefly in the report, but was arguably overlooked to a level that would be justified based on both the information available at the time of publication and the current level of modern impact.

For example, the rate of sea level rise between 1900 and 1990 was between 1.2 millimeters and 1.7 millimeters per year on average. By 2000, the rate had risen to 3.2 millimeters per year [27]. In 2016, this rate was estimated at 3.4 millimeters [28]. Much of the East Coast and Gulf Coast of the United States are at or only slightly above sea level, and notable flooding is already occurring. According to Climate Central, a non-profit coalition of independent leading scientists and researchers: "roughly three-quarters of the tidal flood days now occurring in towns along the East Coast would not be happening in the absence of the rise in the sea level caused by human emissions."

Cyber security or cyberterrorism was only mentioned once in the *Engineer of 2020*. From the view of a civil engineer, the infrastructure necessary to support cyber demands and cyber security is substantial. In 2020, outside pressure for civil engineering firms in professional practice to better address cybersecurity concerns in order to win projects is increasing. For example, programs such as the relatively new Cybersecurity Maturity Model Certification (CMMC) Program is currently standard for the department of defense supply chain. This program or a future variation is predicted to eventually become the standard for the federal supply chain, which includes federal infrastructure projects [29].

The pandemic spread of disease is the final item deserving to be highlighted as missing from the *Engineer of 2020* report. The concept of a global pandemic is only mentioned once. However, infectious disease is mentioned in 13 locations throughout the *Engineer of 2020.* Although the Engineer of 2020 did not specifically predict events such as the global pandemic of 2020, we have witnessed a rapid change in terms of how civil engineers work. That rapid change was predicted in the report.

From a professional practice standpoint, civil engineering is more regionally-based than many other engineering disciplines, which has led to an in-person based approach, and arguably a loss of engineering talent to other engineering disciplines known for more flexible work schedules. Civil engineering has lagged other engineering fields when it comes to work from home policies and practices. Within a matter of weeks in March 2020, outside forces caused the profession to substantially adjust previous work flows to enable remote work. While the long-term impacts of this shift are yet to be seen and the specific events leading to this change were not predicted, the *Engineer of 2020* was on point in noting the imperative need for the profession to quickly adapt to societal changes.

Additionally, although the 2020 COVID-19 pandemic is making history as we speak, we are also seeing the positive impact leaders with backgrounds in STEM and engineering in global crisis, such as scientist and German chancellor Angela Merkel. As will be discussed in the next section, this leadership highlights many of the attributes predicted to be needed in the *Engineer of 2020* report.

Each of these items has significant social, economic, and political implications and underscore the need for the collaboration and multidisciplinary understanding of fields beyond engineering, as will be also discussed in the next section.

Attributes of the Engineer of 2020

The *Engineer of 2020* report culminates in the presentation and description of a series of attributes. It is these key attributes that the report suggests will "support the success and relevance of the engineering profession in 2020 and beyond [5]." The report acknowledges that those future attributes are similar to what makes an engineer successful at the time the report was published (2004), but technology has resulted in making those attributes more complex. Following is a list of the attributes and a paraphrased description of each:

- **Strong analytical skills.** These core skills include principals of science, mathematics, and areas of design and research for a practical application, which can include complex biological systems. They also include knowledge of the engineering design process, including planning, establishing processes, evaluating, and a focus on pragmatic outcomes. The report notes that even though the subject matter will evolve and technology will change, these core skills will remain.
- **Practical ingenuity**. Engineers identify problems and find solutions, with skills in planning, iterating, and adapting for a practical application.
- **Creativity.** Innovation and invention are indispensable engineering skills, often requiring interdisciplinary knowledge.
- **Communication.** These skills include effective listening in conjunction with oral, visual, and written communication, across increasingly interdisciplinary and global platforms. Communication includes the ability to effectively engage multiple stakeholders, from team members to the public, with varying levels of education and engineering process understanding.
- **Business and management.** These skills include the ability to make business decisions with an understanding of the strengths and limitations of science and technology. The report notes: "…engineers who mastered principals of business and management were promoted into leadership roles. This will be no different in the future [5]."
- **Leadership.** Leadership skills are not defined in the report. Rather, they are presented as necessary to be developed as an engineer's career advances in the context of bridging the gap between technology and policy. It's also noted that participating, understanding, and bridging the gap between public policy and technology goes "well beyond the roles accepted in the past [5]."
- **High ethical standards** and a strong sense of **Professionalism.** These are skills in recognizing the nature of balancing social, economic, environmental, and military factors. Effective and wise use of resources and technology is integral to engineering work. The ability to make appropriate decisions within the context of how technologies impact on the world is also included in these attributes.
- **Dynamism, Agility, Resilience,** and **Flexibility.** These skills are defined together as the ability to learn and quickly adapt to new things and to apply knowledge to new problems and contexts.
- **Lifelong learners.** This attribute is noted to encompass all previous attributes. The expanding bodies of knowledge and technologies require that engineers continuously learn new things, not only in engineering and technology, but also about interdisciplinary areas, including business, history, and politics.

While *The Engineer of 2020* report was written to be broadly applicable to all forms of engineering, it is interesting to compare this list of attributes to those that the civil engineering profession has deemed to be important. The American Society of Civil Engineers (ASCE) published the 3rd Edition of the Civil Engineering Body of Knowledge (CEBOK) in 2019 [30]. The CEBOK "defines the knowledge, skills, and attitudes necessary for entry into the practice of civil engineering [30]." The history of the CEBOK, as well as the process and considerations made during the preparation of the 3rd Edition are well documented [31],[32],[33],[34]. The 3rd Edition consists of 21 outcomes in four separate categories. Each outcome is thoroughly defined within the document. The authors used those outcomes and definitions to compare them with *The Engineer of 2020* attributes. The matrix provided in Table 1 identifies where overlaps exist between the two documents.

As Table 1 illustrates, every attribute and every knowledge, skill, and attitude have at least one match between the two reports. If, in fact, the *Engineer of 2020* report's attributes are critical to success, then it would suggest that ASCE's CEBOK provides guidance that is well-aligned. Things that were perceived in 2004 as going to be important to the engineering profession 2020 are also viewed as import by ASCE as of 2019.

It should also be noted that the prior versions of ASCE's CEBOK significantly influenced the process of defining the civil engineering outcomes required for ABET accreditation. It is reasonable to anticipate that the 3rd Edition of the CEBOK will have a similar impact on future ABET accreditation criteria. To that end, those attributes defined by the Engineer of 2020 report and common with the CEBOK outcomes will impact the content covered in civil engineering programs of study and will ultimately be embodied in the civil engineers entering the workforce.

That could be argued as good foresight on the part of National Academy of Engineering. Alternatively it could be argued that these items are commonly perceived as good attributes, regardless of the year.

State of the Attributes in 2020

Several attributes stand out as core knowledge expertise areas in today's engineers. The most obvious of these are **strong analytical skills** and **practical ingenuity.** Per job search websites, like *engineering.com*, technical skills are the most desired attribute by employers of engineers [35], and the skill on which ABET-accredited university curriculums are most focused.

The **lifelong learning** attribute is also true and is further supported by public policy, especially in civil engineering. Forty out of the fifty U.S. states require continuing education for engineers [36]. 70% of structural engineers surveyed in a 2015 survey indicated that their firms provide continuing education training [37].

Areas that are showing potential, due to an increase in training and awareness, are **communication**, **business and management leadership**, and **high ethical standards/professionalism**. Some states require ethics training as part of continuing education requirements for licensure [36]. However, there is still work to be done in each of these areas. For example, in a study by the American Society of Mechanical Engineers [38], academics were asked if they thought their school provided adequate communication training for engineers. 52% of mechanical engineering department heads thought their graduates were strong in this area. In the same study, industry leaders were asked the same question. Industry responded that only 9% thought the hired graduates had strong communication skills.

ASCE *Civil Engineering Body of Knowledge, 3rd Edition* **Knowledge, Skills, and Attitudes**	**NAE *The Engineer of 2020* Attributes**								
	Strong Analytical Skills	Practical Ingenuity	Creativity	Communication	Business and Management	Leadership	High Ethical Standards and Professionalism	Dynamism, Agility, Resilience, and Flexibility	Lifelong Learners
Mathematics	■								
Natural Sciences	■								
Social Sciences			■	■				■	
Humanities			■	■			■		
Materials Science	■								
Engineering Mechanics	■								
Experimental Methods and Data Analsys	■								
Critical Thinking and Problem Solving	■	■	■						
Project Management					■	■	■		
Engineering Economics					■		■		
Risk and Uncertainty					■	■			
Breadth in Civil Engineering Areas	■								
Design	■	■	■	■			■		
Depth in Civil Engineering Areas	■								
Sustainability							■		
Communication				■		■			
Teamwork and Leadership				■	■	■			
Lifelong Learning								■	■
Professional Attitudes								■	
Professional Responsibilities							■		
Ethical Responsibilities							■		

Table 1. Cross-Walk of Attributes vs. Knowledge, Skills, and Attitudes

There are a few areas that have not materialized as expected. These are **creativity** and **dynamism, agility, resilience, and flexibility**. Engineers as a whole have low tolerances for risk, and civil engineering in particular spends less than many other engineering industries in research and development, especially in private practice. Structural engineers, which are often considered a subset of civil engineering, are one of the most sued of any type of engineer. As a result, civil engineering as a whole tends to reward tried and true techniques based on years of experience more than innovative solutions. This is also true of some clients, especially government transportation organizations (example: DOT's) and contractors. This is also reflected in the overall industry productivity. According to the U.S. Department of Labor and Research, the productivity of the construction industry has been declining since the 1970s, even as the hours worked have risen [39].

There are certainly pockets of innovation. Bright spots in the industry include research in materials science, smarter traffic management systems, virtual construction and 3D modeling technologies, the use of point cloud data to quickly and efficiently survey existing conditions, and the use of drones for construction inspections. However, it remains the authors' opinions that civil engineers in particular generally lack the tools/skillsets needed to quickly adapt to new problems and contexts, especially those that occur at the intersections of civil engineering and other disciplines.

Closing Thoughts

The *Engineer of 2020* report states, "life has a habit of reminding us that our predictions are rarely accurate [5]." In truth, many of the predictions made by the committee have become a reality or still show potential. Further, the report's anticipated attributes needed by engineers in the year 2020 align well with ASCE's current suggested knowledge, skills, and attitudes.

The *Engineer of 2020* includes two statements that were true at the time the report was published (2004) and remain true today. The engineering profession must "continue to prepare ourselves for an uncertain future [5]." Due to the "steady growth of the influence of technology in our lives" the engineering profession must be proactive to prepare for the future.

We cannot afford to be reactionary to changes that impact our profession. Discussion of what that means to our engineering work cultures and educational systems is beyond the scope of this analysis. However, in the authors' opinions, the civil engineering industry in particular is at a crossroads. By embracing the changing technological landscape, there is limited-time for civil engineers to seize the opportunity to expand their traditional engineering roles to become global leaders before these technological advances reach maturity. The industry and product lifecycles shows that innovators and early adopters benefit the most from technology adoption (both financially and as leaders), which has been true since the first introduction of this concept in 1965 [40].

While supported by citations, the content of this paper is limited to the opinions of the authors (a civil engineering practitioner and civil engineering educator). The authors have plans to continue this line of investigation to include a deeper dive into the *Educating the Engineer of 2020* document.

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