

ETHICS IN CIVIL AND STRUCTURAL ENGINEERING

PROFESSIONAL RESPONSIBILITY
AND STANDARD OF CARE

- Ideal for use in ethics courses within civil/structural engineering departments
- Covers the ethical codes of practice from ASCE, NSPE, WFEO, and others
- Includes review and discussion problems at the end of each chapter

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**Professional Responsibility
and Standard of Care**

Dave K. Adams



New York Chicago San Francisco
Athens London Madrid
Mexico City Milan New Delhi
Singapore Sydney Toronto

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**For my wife Michele, whose honorable character
inspires and delights me every day.**

About the Author

Dave K. Adams is a licensed civil and structural engineer in the state of California, currently serving as a Principal Associate at BWE, Inc. in San Diego, CA. Upon graduation in 1990 from the University of California, San Diego, with a Bachelor of Science degree in Structural Engineering, Dave moved to the Central Valley in California to work for Lane Engineers, Inc. in Tulare, where he learned design concepts and diverse team dynamics while working with a multitude of city and county agencies, as well as clients with a wide range of backgrounds. He moved back to San Diego in 2012 and continues to design, detail, and investigate structures of all types. Dave also serves as a subject matter expert (structural) for the California engineer's licensing board and presents webinars throughout the year for various engineering organizations. He enjoys scuba diving with his daughter, studying stocks and finance with his oldest son, and discussing politics with his youngest son. He also enjoys just spending time with his wife doing whatever the schedule requires or the mood desires.

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Preface

My first experiences with ethical theory and the concept of human morality came at a very young age. As an infant, my path through life was built around those who made choices for me due to my extremely limited capacity to make choices on my own, whether good or bad. Choice was mostly a matter of survival: food, shelter, clothing, and instruction. I was taught very simple principles of the ethical theory to which my parents ascribed, most often in the form of commands like “play nicely,” “don’t put your finger in that,” and “eat all of your peaches.”

As I got older, others still made choices for me, but the types of decisions expanded into entertainment, fashion, culture, and taste. It did not always depend on whether I accepted the choice that was made for me, but sometimes I could exert my influence by crying, pouting, pleading, or destroying things. I considered a choice *good* if it served me well: food should be tasty, shelter should make me feel safe, clothing should be comfortable, and instruction should be fun. When my family experienced times of financial hardship, however, these goals were not always met. Another lesson taught by my parents: be satisfied with what you have. The concept of *good* took on a more unselfish

meaning, and I was beginning to develop a deeper sense of compassion for others.

The study of ethics is ultimately a study of human behavior in making choices. As professional engineers, our choices directly affect other people and society as a whole. The decision-making process is a direct reflection of education, training, experience, intuition, courage, and determination, but it is also a reflection of the inner voice that beckons all human beings: “Why should I choose to make a particular decision?” For a licensed professional, the decision is not only a matter of ethics, but also a matter of competence. Not that a perfect choice will be made (or that one is required), but a choice will be made within the bounds of a properly justified *standard of care*. Choices may be good or bad, with negligible or significant consequences, but society trusts that a professional will do their best to make good choices with acceptable outcomes and that engineers will recognize the level of risk that is acceptable to the public.

My goal in writing this book is to provide tools for practicing civil and structural engineers that can be useful in improving the ability to make good, professional choices on matters of ethics and to be able to defend those choices to others and to oneself. Choices that will have a lasting effect on one’s career and ultimately on one’s personal fulfillment. We bring a core set of personal values to the profession but then are introduced to another system of values, or an ethical philosophy, which those licensed within that profession are strongly encouraged to adopt and implement in the decision-making process. As you study this book, you will also develop an understanding of legal requirements for professional civil and structural engineers and how those may be different from ethical codes of conduct published by engineering societies all over the world.

I should also point out that the material in this book is for informational purposes only and should not be regarded as a substitute for applicable legal or technical advice. I am not an attorney, but as a licensed civil and structural engineer (close to 30 years), I have become well acquainted with aspects of practice dealing with a legal standard of care and common ethical issues. I truly hope you will find the information in this book helpful, enlightening, and encouraging.

Self-Study or Coursework

At the end of each chapter, there is a set of review questions with answers taken directly from the text. These are intended to stimulate thought and to remind you of what you read. Appendix A includes answers to some of the questions to facilitate self-study. Each chapter also includes a section of discussion questions that are based directly on the content, but the answers require more thought and research. These can be completed alone or in groups, depending on class size and format. They are best graded using a convenient rubric of your choice, and most universities publish instructions on how to develop suitable rubrics. Much of the content for developing answers to the discussion questions can be found in this book, but other resources may need to be consulted as directed by the questions or as needed to fully develop a response. An instructor's manual that contains answers to the remaining end of chapter review questions is available online at **www.mhprofessional.com/EthicsInCivil&StructuralEngineering**. Part II of the instructor's manual includes sample responses to some of the discussion questions and also includes information on finding or developing a suitable rubric that can be used for scoring student responses.

There is enough content in this book to create a suitable course in engineering ethics, but there are numerous variables that may warrant the incorporation of other freely available materials. In fact, there is a great deal of content available from many different resources that can be combined to create a truly dynamic experience. As a minimum, I would recommend incorporating materials from your region's licensing board—these regulatory agencies usually publish codes of ethical conduct that can be studied in detail and are particularly relevant to issues important to that region. Those precepts can be compared with materials published by engineering societies, such as the National Society of Professional Engineers (NSPE) or the World Federation of Engineering Organizations (WFEO). You will discover many others scattered throughout this book.

Following are simple suggestions for the content of a 10-week course (for universities using the quarter system) or a 15-week course (for universities using the semester system) in engineering ethics using this book as the main text. Part III of the instructor's manual that is available through the publisher offers more detail with additional texts or resources to supplement student learning and instructional material. The manual also offers suggestions on how the content can be incorporated into courses that focus primarily on other engineering subjects.

A Suggested Ten-Week Curriculum

Week 1: Introduction (see [Chap. 1](#))

Week 2: Depth of Ethical Theory, Part 1 (see Chaps. 1, 5, and 7)

Week 3: Depth of Ethical Theory, Part 2 (see Chaps. 1, 5, and 7)

Week 4: Professional Responsibility (see Chaps. 2, 3, and 7)

Week 5: Standard of Care, Part 1 (see Chaps. 2, 4, and parts of 8)
Week 6: Standard of Care, Part 2 (see Chaps. 2, 4, and parts of 8)
Week 7: Codes of Engineering Ethics (see [Chaps. 2](#) and [6](#))
Week 8: Case Studies (see [Chap. 8](#))
Week 9: Ethics and Sustainability, Part 1 (see [Chaps. 2](#) and [9](#))
Week 10: Ethics and Sustainability, Part 2 (see [Chaps. 2](#) and [9](#))

A Suggested 15-Week Curriculum

Week 1: Introduction (see [Chap. 1](#))
Week 2: Depth of Ethical Theory, Part 1 (see [Chaps. 1, 5,](#) and [7](#))
Week 3: Depth of Ethical Theory, Part 2 (see [Chaps. 1, 5,](#) and [7](#))
Week 4: Professional Responsibility (see [Chaps. 2](#) and [3](#))
Week 5: Defining and Defending an Ethical Foundation, Part 1 (see [Chaps. 1, 2, 4,](#) and [7](#))
Week 6: Defining and Defending an Ethical Foundation, Part 2 (see Chaps. [1, 2, 4,](#) and [7](#))
Week 7: Standard of Care, Part 1 (see Chaps. [2, 4,](#) and parts of [8](#))
Week 8: Standard of Care, Part 2 (see Chaps. [2, 4,](#) and parts of [8](#))
Week 9: Codes of Engineering Ethics, Part 1 (see [Chaps. 2](#) and [6](#))
Week 10: Codes of Engineering Ethics, Part 2 (see [Chaps. 2](#) and [6](#))
Week 11: Case Studies, Part 1 (see [Chap. 8](#))
Week 12: Case Studies, Part 2 (see [Chap. 8](#))

Week 13: Ethics and Sustainability, Part 1 (see [Chaps. 2](#) and [9](#))

Week 14: Ethics and Sustainability, Part 2 (see [Chaps. 2](#) and [9](#))

Week 15: Community Service

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CHAPTER 1

Introduction to Ethics and Morality

In the course of studying the subject of engineering ethics, one of the first discoveries one makes is that the definition of terms is crucial to understanding concepts, defending positions, and validating decisions. Engineering involves the manipulation of natural elements and systems to create something new, usually for the benefit of humanity but the outcomes of engineering work affect other organisms, ecosystems, and future generations of living entities as well. The term *engineering* traditionally means the application of scientific principles and subjects to solve problems and create new things. Engineers are different from scientists, in that scientists make discoveries whereas engineers turn those discoveries into usable things. A concise definition of *engineering ethics* is presented in [Fig. 1.1](#).

Engineering ethics is a set of moral rules and guidelines to assist professional engineers in making decisions that affect society, the environment, and future generations during the execution of their duties. This system of ethics is based on a professional engineer's primary obligation to protect the health, safety, and welfare of the public.

Figure 1.1 A concise definition for “Engineering Ethics.”

Ethics involves the study of behavior—how human beings ought to interact with one another. It is considered a branch of philosophy, where a particular set of rules and standards are assembled based on some overarching theme or concept. The study of ethics consists of three main branches: metaethics, normative ethics, and applied ethics. *Metaethics* covers subjects like the origin or nature of ethical concepts and terms, usually including analysis of conclusions based on religious, evolutionary, and historical development. *Normative ethics* identifies criteria necessary to develop specific rules of moral conduct with direct implications on how human beings and institutions should behave, evaluating how these basic standards and rules are arrived at and defended. *Applied ethics* deals with the analysis and activity of specific difficult or controversial moral issues, such as abortion, war, censorship, and euthanasia. These will all be discussed in more detail later in this chapter.

1.1 Life, Liberty, and the Pursuit of Happiness

The American fight for independence from Great Britain provides important stories and lessons related to citizenship, government, law, freedom, and human ethics. On June 6, 1776, a committee of five individuals, including Thomas Jefferson (Virginia), John Adams (Massachusetts), Roger Sherman (Connecticut), Benjamin Franklin (Pennsylvania), and Robert Livingston (New York), were tasked with writing a formal statement to justify sovereignty from Great Britain. That statement became the *Declaration of Independence*, which is one of three founding documents of the United States of America, along with the *Constitution* and the *Bill of Rights*. It was officially adopted by Congress on July 4, 1776 (although many historians believe the

document wasn't signed until August 2, 1776) and is memorialized in a famous painting by John Trumbull that currently hangs in the United States Capitol Rotunda (see [Fig. 1.2](#)).

The Preamble to the *Declaration of Independence* includes some important points that are pertinent to our understanding of ethics for a group of individuals. One could argue that these concepts are only applicable to citizens of the United States, but I believe they can be taken to heart for any group serving under a body of authority. The writers called them *self-evident truths*.



Figure 1.2 Signing the Declaration of Independence, John Trumbull (1819).

Truth No. 1: "All men are created equal."

Truth No. 2: “They are endowed by their Creator with certain unalienable Rights ... among these are Life, Liberty, and the pursuit of Happiness.”

Truth No. 3: “To secure these rights, Governments are instituted among Men, deriving their just powers from the consent of the governed.”

Truth No. 4: “Whenever any Form of Government becomes destructive of these ends, it is the Right of the People to alter or to abolish it, and to institute new Government, laying its foundation on such principles and organizing its powers in such form, as to them shall seem most likely to effect their Safety and Happiness.”

All human beings have a self-evident right to life and freedom. These rights can be taken away, however, if one violates the laws adopted by the society in which they live. Society develops rules of conduct through officials that are elected and given power to create laws so that chaos is avoided (as best as practical). Laws and societal conditions change over time, obviously. Many of the Founding Fathers of the United States had real, personal problems with the institution of slavery but failed to make corrections to the law for a variety of reasons. Liberty and equality were sacrificed for the sake of a deeply entrenched system of economics, eventually leading to a civil war that changed laws but failed to change hearts. People and cultures around the world still struggle with issues of unequal treatment based on race; however, each individual will always have the freedom and power to *choose for themselves* that all persons should be considered equal simply by virtue of being human and live their lives according to this truth.

1.1.1 Differences of Opinion

When something is thought to be self-evident, that idea or principle is known to be true without a need for proof or justification—only by ordinary human reason. The concept of truth has been studied and discussed throughout history and continues to be a source of contentious debate. How can a person be fully convinced of what is true, especially when it comes to ethics? Generally, each one of us makes a choice. That choice could be religion (“my ethics come from God”), King and Country, another membership-based group within society, a family unit, or even just from oneself. There are often many reasons for choosing an ethical system to follow including genuine loyalty, fear of punishment, hope for reward, or what one honestly believes works for them or for most human beings collectively.

Most people are members of several entities that dictate ethical principles and sometimes those principles can be in conflict across different groups. A church body, for example, claims an ethical code delivered from God as their primary source, having been instituted by an agency outside of this world—indeed, the Creator of the universe, who would have the ultimate independent authority. Members of that church body are likely citizens of a particular country as well and would be bound to obey the laws of that country in addition to God’s Laws. Where there is conflict, church members state that God’s Law governs, but the choice might not always be clear-cut: the tenets of many religious groups exhort their members to also obey authorities that have been placed over them.

1.1.2 The Universal Declaration of Human Rights

In 1946, a group of countries began work on a document that would help them set aside differences over what could be viewed as self-evident truths regarding freedoms that all

persons must have, just by virtue of being human beings. Development of the declaration began in response to the discovery of atrocities committed by the Nazis during World War II, where it was agreed that the intent and meaning of human rights had been poorly defined in the past. These rights were defined, explained, and presented as articles formally agreed upon by the nations of the world, and although there certainly has been dissenting opinion and various levels of commitment over the years, these principles should be soberly considered. The final document was officially adopted by the United Nations (see [Fig. 1.3](#)) on December 10, 1948¹ (as a result, Human Rights Day is celebrated every year on December 1).



Figure 1.3 Secretariat Building at the United Nations Headquarters, New York. (UN Stock Photo, Rick Bajornas,

cropped by author.)

The declaration consists of a preamble and 30 articles that are not legally binding in and of themselves but have been referenced in different dealings between countries including various treaties, economic agreements, and local standards. Conditions around the world have improved since the declaration was first drafted: 59% of countries have a national human rights institution, where none existed previously. Women have the right to vote in 198 countries today, but the total was only 91 in 1948. Freedom of information regulations has been adopted by 111 countries. Significantly, more and more countries are ratifying the *International Covenant on Civil and Political Rights*, which declares that every citizen has the right and opportunity to participate in the conduct of public affairs, has the right to vote and to be elected to public office, and has a right to free expression, assembly, and association. More information can be obtained from the website <http://standup4humanrights.org>.

Some of the more powerful statements made through the declaration include the following:

1. "All members of the human family possess equal and inalienable rights, and this forms the foundation of freedom, justice, and peace in the world." (Preamble)
2. "All human beings are endowed with reason and conscience and should act towards one another in a spirit of brotherhood." (Article 1)
3. "Everyone has the right to freedom of opinion and expression; this right includes freedom to hold opinions without interference and to seek, receive, and impart information and ideas through any media and regardless of frontiers." (Article 19)

4. “In the exercise of his rights and freedoms, everyone shall be subject only to such limitations as are determined by law solely for the purpose of securing due recognition and respect for the rights and freedoms of others and of meeting the just requirements of morality, public order, and the general welfare in a democratic society.” (Article 29)

1.1.3 Basic Civility

Oftentimes, when we think of civility, we think of the Golden Rule: “Do unto others as you would have them do unto you.” In fact, this is one of the most common maxims in most of the world’s religions (see [Fig. 1.4](#)). Civility is best understood as a formal politeness in speech and behavior, but it can also be viewed as genuine or fake. A person can be truly civil because she believes in the honor and dignity of all creatures or she can choose to be selectively civil, where only certain humans or other creatures; such as close family members, employers, dogs, or cats; receive politeness or sensitivity. The Institute for Civility in Government defines this in terms of societal responsibility: “Civility is about more than just politeness, although politeness is a necessary first step. It is about disagreeing without disrespect, seeking common ground as a starting point for dialogue about differences, listening past one’s preconceptions, and teaching others to do the same.”²

Baha'i: "He should not wish for others what he does not wish for himself." (Baha'u'llah, Epistle to the Son of the Wolf)

Buddhism: "Hurt not others in ways that you yourself would find hurtful." (Udana-Varga 5:18)

Christianity: "Therefore, however you want people to treat you, so treat them, for this is the Law and the Prophets." (Matthew 7:12, NASB)

Confucianism: "What you do not want done to yourself, do not do to others." (Analects 15:24)

Hinduism: "This is the sum of duty: Do naught unto others which would cause you pain if done to you." (Mahabharata 5:1517)

Islam: "Do unto all men as you would wish to have done unto you; and reject for others what you would reject for yourself" (Hadith)

Judaism: "What is hateful to you, do not to your fellow neighbor. This is the whole of the Law, all the rest is commentary." (The Talmud, Shabbat 31a)

Shinto: "The heart of the person before you is a mirror. See there your own form." (Munetada Kurozumi)

Taoism: "Regard your neighbor's gain as your gain, and your neighbor's loss as your own loss." (Tai Shing Kan Yin P'ien)

Zoroastrianism: "Whatever is disagreeable to yourself do not do unto others." (Shayast-na-Shayast 13:29)

Figure 1.4 The Golden Rule, as expressed in many of the world's religions.

The Institute goes on to say, "Civility is the hard work of staying present even with those with whom we have deep-rooted and fierce disagreements. It is political in the sense that it is a necessary prerequisite for civic action. But it is political, too, in the sense that it is about negotiating interpersonal power such that everyone's voice is heard, and

nobody's is ignored." Dr. Martin Luther King, Jr. was a fierce proponent of civility as an important characteristic of meaningful, life-changing protest. In a speech³ to the Young Men's Christian Association (YMCA) and Young Women's Christian Association (YWCA) at the University of Berkeley on June 4, 1957, he explained the purpose of nonviolent and civil protest: "Another thing that we [those who led the African-American community through the Montgomery Bus Boycott from December 5, 1955 to December 20, 1956] had to get over was the fact that the nonviolent resister does

not seek to humiliate or defeat the opponent, but to win his friendship and understanding. This was always a cry that we had to set before people that our aim is not to defeat the white community, not to humiliate the white community, but to win the friendship of all of the persons who had perpetuated this system in the past.”

He goes on to say, “The end of violence or the aftermath of violence is bitterness. The aftermath of nonviolence is reconciliation and the creation of a beloved community. A boycott is never an end within itself. It is merely a means to awaken a sense of shame within the oppressor, but the end is reconciliation, the end is redemption.” This is an important message: civility begins with each individual person, regardless of how the rest of the world is behaving, for the purpose of friendship and understanding. This philosophy of a *beloved community* applies to the whole of humanity, but it is practiced on a smaller scale—individuals, families, neighborhoods, organizations, governments, societies, and clubs—so that the collective effort stimulates the unity of all persons around the globe.

A helpful passage from the Bible (Galatians 5:22-23) identifies *Fruits of the Spirit*, which are character traits that most people would agree are good to work on expressing and living, regardless of religious affiliation (or none at all). These include love, joy, peace, patience, kindness, goodness, faithfulness, gentleness, and self-control. The feeling and expression of love is usually directed toward a person, or a group of persons, out of an inner, heartfelt conviction, which arises in response to admiration or mere position. Love is the mechanism by which a person delightfully chooses to seek the best for another before their own without expecting to be rewarded. In fact, love is a defining characteristic of the depth to which the other “fruits” are demonstrated. I can choose to have patience with another person for equally valid (and good) reasons,

but the intensity of quality and commitment will likely be different. Civility requires a dose of patience so that we can listen to others and communicate without losing perspective, and the goal is simply to create a comfortable environment. I could do this just for the sake of my own comfort, which could be viewed positively or negatively, but the benefit would still extend to others. If the motive of my patience is love, however, I genuinely desire for the recipient to feel comfortable and special regardless of what I receive in return.

An appropriate expansion of the Golden Rule could be: “Treat others as *they* would like to be treated.” No one wants to be lied to, but sometimes a person would rather receive a tiptoeing around the absolute truth, such as with questions about their appearance. But, generally, no one wants to be lied to ... and, generally, treat others as you would like to be treated if you have no idea what the other person prefers. Humans are social creatures, and benevolence is a natural part of making personal and professional interactions work. Benevolence can be expressed in different ways, to a variety of degrees, but it typically includes practical acts of compassion, affection, and at least a small dose of selflessness. This simple suggestion comes with obvious caveats: if a person chooses to break the law or to mistreat others, and that person would like for us to treat them as though they committed no wrong, then we cannot comply. They must be tried and punished by the law in order for society to function properly—but they should still be treated fairly and decently.

1.2 Why Study Ethics as an Engineer?

Basic elements of morality naturally exist within each person, and these rules could even form some coherent ethical system on their own. That system could simply be a

matter of self-preservation, or perhaps one that includes a very basic sense of respect for the needs and desires of others. These natural inclinations can only be a starting point for a professional who is linked to a more extensive code of ethics that demands a greater understanding of principles so that the rules can be consistently applied in a practical setting (as consistent as human nature allows). In fact, that is one of the things that separates a profession from just another job—a cohesive code of conduct that all members are typically required to acknowledge and to live by. Such a code provides a familiar setting across different professional societies and cuts through excuses. Most of the precepts are simple enough to understand and they are almost always accompanied by tools or further examples of how they are applied to one's practice. Many engineering ethical codes around the world are noted throughout this book, and [Chap. 6](#) digs more deeply into the details.

An engineering education is heavily loaded with technical subjects and is usually light on humanities like history, literature, and philosophy. Ethics is considered a branch of philosophy, but it is a natural part of sociology and psychological studies as well. Perhaps the most important reason to study ethics is that a professional engineer is required to honor an ethical code and the more deeply she understands that code, the easier it will be to remember why the rules exist and how they apply in practice. Human beings do not function in a vacuum—our decisions affect the lives of others, regardless of intention. Engineers generally take a mechanical approach to learning subjects, but the study of ethics requires a more personal commitment. Our profession requires interaction with others and our moral position on matters can result in suffering or happiness for ourselves, for others, and even for society as a whole.

A proper study of ethics is also important to create a bridge from feelings and emotions to rational appraisal and

judgment in the interest of truth. Decisions inevitably require sifting through ethical issues to detect hidden biases and working through barriers that may prevent the resolution of conflicting moral obligations. Biases can be difficult to judge on the basis of emotion alone, but recognition of *intent* can help a person decide whether a bias will deliver good or bad consequences when put into action. Study is necessary to give meaning to terms like justice, right, wrong, dignity, and respect, and skill must be developed to make use of ethical tools (concepts, rules, principles) for making rational decisions.

1.3 Branches of Ethical Theory

Suitable conclusions about how we ought to live our lives depend on some understanding of theories and terms (metaethics), what people have thought or done in the past (normative ethics), and real-world examples (applied ethics). Fields of anthropology, religion, sociology, economics, psychology, political science, medicine, law, and a host of others are analyzed to arrive at and defend positions on how human beings should respond to issues that may have a variety of different moral conclusions. A purely scientific approach to ethics will result in disappointment, since ethics cannot be discovered in a materials lab or found among the bones of a prehistoric race, unearthed for examination. More than anything else, moral truths are matters of *reason* that can be pondered, debated, carefully examined, and formally declared.

1.3.1 Metaethics

The branch of ethics called “metaethics” does not tell us how to act, but rather seeks to tell us about the nature of morality and ethical statements or precepts. It does not

require belief in or acceptance of codes or rules, but it unavoidably involves reflection on the presuppositions and commitments of those engaged in the study or discussion of moral thoughts and practices. It involves the study of evidence used to support moral ideas, whether morality is culture-based and fluid and if it is more than just a matter of taste or preference (as opposed to definable truth). Work in this area seeks to understand and answer many questions: Are there moral truths, or only opinions? If they exist, can they be ultimately justified and proven? Can we prove that any moral opinion is superior to another? To what extent does the definition of terms apply and why does it matter? As a result, metaethics is often thought of as high-level, abstract philosophy where persons may strongly disagree about a particular moral position (abortion, for example) but find agreement on the origin, status, intent, and meaning of alternative arguments.

Foundations of ethics generally include evidence from nature, administrations of human beings, and the laws of religion. Although much of philosophical history has been written with an acceptance of God, or divine beings, rounded discussions have also included more secular sources. The writings of Plato (c. 428–347 BCE), Ancient Greek philosopher who founded an academy of philosophy just outside the walls of Athens (see [Fig. 1.5](#)), include the sentiment that the ethical definition of justice is created by those who have the greatest strength. In a world of political opinion and power, this is not a difficult conclusion to accept. The concept and reality of personal liberty, for example, vary between cultures and governments. On the one hand, freedom is thought to be simply a matter of nature or a gift from God that exists and should be upheld to the best degree that society can sustain. On the other hand, however, freedom is described as a product of human government that can be granted liberally or severely

restricted, depending on the conscience and objectives of those in power.



Figure 1.5 Mosaic of Plato's Academy from Pompeii.

One of the principal debates within metaethics is about the legitimate, or illegitimate, basis of moral standards. Cognitivism or naturalism is the view that ethical statements are based on observable, measurable facts or well-founded belief, including facts about nature, what

makes people happy, feelings, and human capabilities to reason and discern. Nonnaturalism promotes the thought that ethical statements are not based on empirically verifiable facts, and the noncognitivist adds that the truth of those statements cannot be known at all. These positions further exhibit differences between realism and relativism. Realists propose that moral facts exist independent of any beliefs or evidence about them, whereas relativists believe that moral values are instead created by individuals or cultures in radically different ways. Realists argue the independence of moral values in several ways, including dictation by God, existence as some form of abstract properties that are objective (similar to common physical properties), or even reducible to one of the scientific characteristics of the universe. One of the arguments of a relativist, on the other hand, is that cultures can differ significantly on the categorization of morals as good or bad, and this fact makes it impossible to justify the existence of truly independent values.

1.3.2 Normative Ethics

The field of normative ethics is often defined by two parts: normative and descriptive. The normative component analyzes how people should act and develop criteria for determining right and wrong moral standards. Descriptive ethics (also called comparative ethics) is the study of a person's views about moral beliefs, or what a person thinks is the right or wrong thing to do. There are currently three major approaches to the study of normative ethics. These include *virtue ethics*, which emphasizes moral character; *deontology*, which emphasizes duty or rules; and *consequentialism*, which emphasizes the consequences of one's actions.

The main questions explored through normative ethics are, “What is right?” and “What is good?” The first question leads us to demonstrable action (what a person should do). In Utilitarianism, for example, right actions are simply those that maximize the amount of happiness in a given situation to the individual, community, or even the world. Immanuel Kant (1724–1804 CE) introduced the concept of a *categorical imperative*, which identifies right actions as moral duties or responsibilities. Society generally recognizes right behavior as following the law, treating others with a basic sense of civility, and oftentimes just doing what everyone else is doing for whatever reason—there are both strengths and weaknesses in each of these positions. Commonly accepted norms within individual cultures help people to feel comfortable in their surroundings and these norms are perceived as right behavior, even though they could be morally reprehensible to a different culture.

The second question lies in the realm of character traits or the perceived quality of a person, which moves us into the study of virtue ethics. A *virtue* is a morally desirable state of character that is assigned value based on a set of predefined principles. For example, one working principle may be that it is good to help others. The trait of empathy could be defined as a virtue because it allows one person to help another bear an emotional burden. Apathy, on the other hand, leads a person to keep to himself. However, both of these traits could play opposite roles as well. If an empathetic person was only concerned about helping others, they may continually choose to sacrifice their own rights and health, which would not be a good exercise of that virtue. Apathy toward someone or something may be necessary to help a person focus on a more important or necessary task without the influence of emotion. These observations are similar to how Aristotle perceived of virtues, where they commonly lie between two extremes.

1.3.3 Applied Ethics

Studying ethics would be of no value if we did not learn how to apply precepts to real-life situations or dilemmas. Knowledge just for the sake of knowledge is not helpful. It must be applied through the exercise of wisdom—experience, judgment, contemplation, and understanding. Engineering itself is based on the application of scientific knowledge for the purpose of creating something useful. If an engineer does not create, then the knowledge that she has is not helpful. In the field of philosophy, applied ethics examines moral problems faced by real people rather than theories that have imaginary applications and consequences. Just as with engineering, real-world ethical issues require careful thought and an unbiased willingness to reconsider your views or conclusions in light of reasonable alternatives or evidence.

The subject matter in applied ethics is, obviously, quite broad. Subjects include anything from business-related ethics to capital punishment, and most people will experience several opportunities to make decisions on these types of subjects over the course of their lives. Subjects are normally very specific, as opposed to the other branches of ethics that may be more ethereal in scope. Arguing in support of a position on a real-life ethical issue can be influenced by two things: a belief that absolutes of morality do exist, or simply a strong belief that some answers are preferred to others. The pursuit and discussion of different positions involves an exercise of applied ethics, but it is also easy to see how the other branches of ethics will be employed as well in this pursuit to fully construct and understand any premises offered or conclusions made.

Pursuit of answers may simply be a matter of responding to the question, “What would a duly-licensed, competent civil (or structural) engineer do?” A primary resource, of course, lies in the ethical codes published by licensing

boards and technical societies. These documents provide specific instructions related to how an engineer must respond to different ethical challenges. For example, in the realm of corporate and professional responsibility, the Engineering Council in Sri Lanka states that engineers shall “not attempt to damage/criticize, maliciously or falsely, directly or indirectly, the professional reputation, prospects, practice, or employment of other engineering professionals.”⁴ There can still be legitimate debate and extensive discussion on different views, including the subject matter that may be up for discussion in this case, but essentially the right thing to do has been prescribed: avoid purposely damaging this person’s standing as an engineer. One of the remaining questions that applied ethics can help us explore is whether the situation conflicts with other precepts within the code of ethics, such as to hold paramount the safety, health, and welfare of the public.

1.4 Morality and Virtue

The term *morality* typically refers to a set of rules by which we live to help us interact with other people and to make decisions. They usually take the form of commands so that they can be clear and (generally) easy to understand regarding implementation, and they are often thought to be relevant to all persons, cultures, and regions. That being said, most people recognize that there can be legitimate exceptions depending on the situation and the persons involved. They are different from laws adopted by society, though there can be many similarities. People choose to follow moral rules for three main reasons: they want to avoid punishment or pain, they were simply told to do them, or they truly want to observe them because they believe it is the right thing to do.

Nearly every person exists in a community of some sort with other human beings, and all participants want that community to function. Different modes of leadership or government will promote a variety of mechanisms to define how a community should function, such as a basis for raising a family, a system for economic growth, and allowances for recreation. A very basic sense of morality recognizes that all members of a community should be allowed to participate in some way, which requires cooperation and recognition that moral deeds promote positive growth of a community. Although there is an important difference between saying that someone performs moral deeds versus saying that someone is a moral person, society can still function well with each type of person.

Richard Brandt (1910–1997 CE) proposes six features that show a person truly has adopted some type of moral code for themselves⁵:

1. The person has intrinsic desires or aversions (motivations) for acting, or failing to act, in certain ways.
2. When the person acts contrary to these intrinsic desires or aversions, he feels uncomfortable and guilty.
3. These desires or aversions are thought to be important enough to justify some degree of coercion (even if just by that person's conscience) to induce a form of behavior.
4. Anyone else who exhibits these same acts and also believes them to be important is held in high esteem by this person.
5. An ability to understand and communicate the basis of these motivations using specific terminology.

6. Such a person also thinks that her motivation, associated feelings, attitude of approval, admiration, and beliefs of importance are not arbitrary, but justified.

When we think of *ethics*, on the other hand, we are actually considering and establishing a foundation upon which moral rules are built—ethics is not concerned with the specific rules, but it rather focuses on understanding how and why they exist in the first place. It defines general principles that are used to set the foundation, and these principles help one to evaluate and judge between different sets of moral rules. Ethics causes us to consider whether to take the interests and desires of others into account when deciding what we should do for ourselves. Exploration of ethics also leads us to evaluate our motivation for following moral rules, and motivation is almost always mindful of consequences. In terms of our behavior, there are three main consequences:

Consequence 1: How we come across to others. No one truly wants to be known as the “bad seed,” or a person from whom everyone else scatters. People naturally want to be treated well, and our negative habits (treating others unkindly) can alienate us from joys we might otherwise experience through human interaction.

Consequence 2: My own quality of life. Moral rules help us to become better persons with a structured quality control system that alerts us to problems that may get us into trouble or reduce our chances of happiness or success. Frequent interaction with others can give us a hint as to how people generally want to be treated, but the exercise or discovery of a moral code should not be trial and error.

Consequence 3: Legal penalties. Moral rules include legal rules, such as “Do not steal,” which can impose

certain punishments to the perpetrator and can stain one's reputation for a lifetime, even if that person finds his way back to the right path.

Since moral values cannot be proven through ironclad, undebatable scientific evidence, some people have difficulty accepting that they can be more relevant than mere opinion or speculation. A person's character, in other words, is a private affair and it does not matter whether their own principles are true for everyone else—if they help the believer to obey the law and respect other persons, then that is good enough (so it has been said). It seems obvious, however, that there do exist at least some moral rules that are more evident and universal than others. If there are good, solid reasons why a person should not kidnap and torture an innocent child, for example, and there are no good reasons on the other side, then we can *objectively* say that kidnapping and torturing an innocent child is wrong. A person's character is formed through belief and adherence to moral values, which can be learned in the family, the church, and even society itself plays an important role.

In his book, *The Case for Character Education*,⁶ David Brooks notes that changes in family, high geographic mobility, the influence of media, and instability of a child's environment lend credibility to the argument that character education should not only take place in the home or church, but within other settings as well. This position in no way reduces the importance of familial and religious influence but emphasizes that society can and should make these teachings available to less fortunate students. There is obvious difficulty in selecting appropriate subject matter for a public setting, but curricula on character development are, for the most part, agreeable by most. Brooks presents the beliefs of Horace Mann (1796–1859 CE), who was one of the prime sources of the creation of public education in the

United States; in universal, nonsectarian, and free education with aims of social efficiency, civic virtue, and character rather than mere learning for the advancement of sectarian goals.

The CHARACTER COUNTS!⁷ training program (<https://charactercounts.org>) includes a comprehensive set of tools to help educators and administrators introduce character education into the lives of students. It was developed in 1992 in the United States by an organization of 17 prominent youth-serving educational organizations to develop and provide strategies, curricular resources, and training that can be used in a public or private school setting as a positive impact on the school system, the community, and individual families. Six pillars are emphasized, each of which would gain nearly universal approval: trustworthiness, respect, responsibility, fairness, caring, and citizenship. Defining elements of the program are the promotion of a positive school experience for every student (and, as a result, every teacher and administrator) that includes decision-making strategies, mindfulness, growth in character, and theories of behavioral change. A sampling of moral instructions within each of the six pillars is shown in [Fig. 1.6](#).

Pillar 1: Trustworthiness

- A. Be honest.
- B. Keep your promises.
- C. Be reliable—do what you say you'll do.
- D. Be loyal—stand by your family, friends, and country.

Pillar 2: Respect

- A. Treat others with respect and follow the Golden Rule.
- B. Be tolerant and accepting of differences.
- C. Don't threaten, hit, or hurt anyone.
- D. Deal peacefully with anger, insults, and disagreements.

Pillar 3: Responsibility

- A. Do what you are supposed to do.
- B. Persevere.
- C. Do your best.
- D. Use self-control.

Pillar 4: Fairness

- A. Play by the rules.
- B. Be open-minded; listen to others.
- C. Don't take advantage of others.
- D. Don't blame others carelessly.

Pillar 5: Caring

- A. Be kind and compassionate.
- B. Express gratitude.
- C. Forgive others and show mercy.
- D. Help people in need.

Pillar 6: Citizenship

- A. Do your share to make your home, school, community, and world better.
- B. Cooperate.
- C. Stay informed; vote.
- D. Be a good neighbor.

Figure 1.6 A few of the moral instructions taught within the Six Pillars of Character in the CHARACTER COUNTS! educational curriculum. (CHARACTER COUNTS! is a registered trademark of the Josephson Institute.

<https://charactercounts.org/character-counts-overview/six-pillars/.>)

1.4.1 Virtue Ethics

The fundamental principle of *virtue ethics* is that a person should act in the same way that a good or virtuous person would act under similar circumstances. A virtuous person has been described by Confucius (551–479 BCE) as a gentleman who keeps his promises, is well-spoken and respectful, and is gentle toward others. Aristotle (384–322 BCE) taught that virtues lie somewhere between the extremes of excess and deficiency and they are to be exercised as habits. The virtue of courage, for example, lies between the excess of foolhardiness and the deficiency of cowardice. Virtues are thought of as character traits that are not superficial but are a solid part of one's being ... compelling that person to consistently act because of a deep commitment. Virtues are known to be *good traits* that lead to *good actions*, contributing to the well-being of both the actor and those who are on the receiving end. Concepts and teachings on virtue ethics are explored in more detail in [Chap. 5](#).

General virtues are commonly known to modern society, as they have been labeled *seven heavenly virtues*. These include purity, temperance, charity, diligence, forgiveness, kindness, and humility. In fact, we could just as easily have listed the Fruits of the Spirit that were presented earlier in this chapter. These are contrasted with *seven deadly sins*: lust, gluttony, greed, sloth/laziness, wrath, envy, and pride. Virtues are relevant for personal life as well as professional activity; and in the sense of engineering, they contribute to competency and the standard of care. Virtues make a person's life more satisfying, as they compel one to become better at what they love (improving confidence in

engineering judgment), they attract others (more loyal clients and a steady stream of new ones), and they focus attention on things that truly matter to a healthy society.

1.5 Review Questions

- 1.1.** Identify and describe the three branches of ethics commonly studied in philosophy.
- 1.2.** What are the five most common sources from which a person may choose their system of ethics?
- 1.3.** Why was the Universal Declaration of Human Rights developed in 1946?
- 1.4.** How does the Institute for Civility in Government define *civility*?
- 1.5.** How does a nonviolent resister approach her enemy, according to Dr. Martin Luther King, Jr.?
- 1.6.** What are the Fruits of the Spirit and why should they matter?
- 1.7.** Why is it important for a professional engineer to study ethics?
- 1.8.** What are the three branches of ethical theory? Provide a brief description.
- 1.9.** Explain moral relativism, considering differences between cultures.
- 1.10.** What is the definition of a virtue?

1.6 Discussion Questions

- 1.1D.** Present and discuss three differences between scientists and engineers.

1.2D. Three sources of where someone may choose their system of ethics are government, family, and religion. Identify two positive and two negative aspects within a system of ethics that may be derived from each of these sources.

1.3D. Review Article 19 from the Declaration of Human Rights (reprinted in this book, see Sec. 1.1.2) and explain how the free exchange of ideas is possible in a group of persons who are vehemently opposed to one another.

1.4D. In Dr. Martin Luther King, Jr.'s speech on civility and resistance, he discusses friendship and understanding. Explain how these two goals can be effective in persuading others to accept your position on an ethical matter.

1.5D. Obtain a copy of NSPE BER Case No. 01-9, *Reference—Quid Pro Quo*, from the NSPE website (<https://www.nspe.org/resources/ethics/ethics-resources/board-ethical-review-cases/reference-quid-pro-quo>). Do you agree or disagree with the Board's opinion (why or why not)? What was the recommended alternative way for Engineer A to find a professional reference? Discuss at least one other way Engineer A could proceed (other than giving up)?

1.6D. Research and identify five characteristics of Dr. Martin Luther King, Jr.'s vision of a beloved community.

1.7D. Identify and discuss three examples of where it *may* be permissible to tell a lie.

1.8D. Do you agree with Plato's sentiment, that the ethical definition of justice is created by those who have the greatest strength? Why or why not? In your answer, provide a definition of justice.

1.9D. Present three separate questions that could be asked to illustrate each one of the three approaches to the study of normative ethics.

1.10D. What would you consider to be five of the most important virtues for the president of an engineering company?

¹UN General Assembly, *Universal Declaration of Human Rights* (New York, NY: United Nations, December 1948).

²“What Is Civility?”, The Institute for Civility in Government, accessed August 3, 2020, <https://www.instituteforcivility.org/who-we-are/what-is-civility/>.

³Martin Luther King, Jr. and James M. Washington, eds, *I Have a Dream—Writings and Speeches That Changed the World* (New York, NY: HarperCollins Publishers, 1992), pp. 30–31.

⁴Engineering Council Sri Lanka, *Ethical Conduct for Engineering Professionals*, accessed February 21, 2021, <https://ecsl.lk/code-of-ethics>.

⁵Richard B. Brandt, *A Theory of the Good and the Right* (Oxford, UK: Clarendon Press, 1979), pp. 165–170.

⁶B. David Brooks and Frank G. Goble, *The Case for Character Education—The Role of the School in Teaching Values and Virtue* (Northridge, CA: Studio 4 Productions, 1997), pp. 60–61.

⁷CHARACTER COUNTS! is a registered trademark of the Josephson Institute.

CHAPTER 2

Defining and Understanding Competence

Almost universally, one of the moral rules included in codes of conduct that are published by engineering societies or licensing boards requires registrants to practice only in areas with which they have competency. This does not mean perfection, or even advanced knowledge, but an ability to understand how something works and what it takes to produce an adequate, functional, and safe design. The measure of one's competence is based on the ability to complete certain tasks, as well as the breadth and depth of knowledge possessed for making engineering judgments. [Figure 2.1](#) presents a list of areas where minimal competency is expected of a licensed professional civil or structural engineer.

1. Ability to apply knowledge of mathematics, physics, and related engineering sciences
2. Understand how individual elements of a civil or structural system function together
3. Capable of blending the requirements of local ordinances with national or state codes
4. Knowledge of basic elements of ethical behavior in a business setting
5. Ability to scrutinize available data and make rational judgments
6. Effectively communicate with clients and colleagues
7. Understand how to use technology and validate data in the design process
8. Research and study appropriate materials to expand knowledge and skill

Figure 2.1 A common list of general competencies for professional engineers.

Competence in completing tasks can (and should) be judged personally, but it is most often assessed by someone else who uses a model of some type to define expectations. One of the first jobs a person inherits is to pick up after themselves. A parent or guardian will demonstrate how it is done (based on knowledge, experience, and preference), supervise the project accordingly—making corrections as needed, explaining why such corrections were necessary—and set up a system for reminding the child when to begin work. As a child grows and is able to take on more responsibility, he may be given more jobs to complete, usually with the benefit of an allowance for competent work. That child may discover a real talent and joy in organization and decide to pursue a career in a related field of work, such as housekeeping, landscaping, or general maintenance.

A person may seek and perform a number of individual, perhaps unrelated, jobs for the simple purpose of earning a living. The worker receives a paycheck and other benefits, and the consumer also receives something: a hamburger, a clean room, a functioning vehicle, an airline ticket, etc. A healthy society includes jobs of every type, where participant and recipient benefit directly (finances or goods that can be used to satisfy a need or desire) and indirectly

(taxes are paid and used by governments for improving infrastructure). Simple jobs do not typically include significant advancements in pay or responsibility, other than for factors unrelated to performance such as increases for inflation or government-mandated minimum wages or benefits.

2.1 Career Readiness

Once a person is offered more responsibility or pay because she has demonstrated more than a basic level of competence in the tasks a job requires, that job begins taking on the elements of a career. Other unrelated jobs may no longer be necessary for meeting basic needs, so an individual can focus more time and effort in refining and developing skills to continue advancing along a single path. A career, therefore, focuses tasks, experiences, knowledge, and training on long-term goals that require a proactive approach at each stage of development. Many people certainly switch careers over time just as they might switch jobs, but the mindset of continual development and growth within a focused area remains a defining quality of whatever career is chosen. If work is meaningful and enjoyable, and a passion is developed for tasks and colleagues, a person's commitment can last a lifetime.

One of the most important things in following through with a decision to enter a career is preparation, which begins with an acknowledgment that careers take commitment. Even if a person chooses a different career later in life, the level of commitment doesn't change—it may be focused in a new direction, but key skills that require development will essentially be the same. The National Association of Colleges and Employers identifies eight key competencies associated with career readiness¹:

1. Critical thinking/problem solving: exercise sound reasoning to analyze issues, make decisions, and overcome problems.
2. Oral/written communication: articulate thoughts and ideas clearly and effectively to persons inside and outside of the organization.
3. Teamwork/collaboration: build collaborative relationships with colleagues and customers representing diverse cultures, races, ages, genders, religions, lifestyles, and viewpoints.
4. Digital technology: leverage existing digital technologies ethically and efficiently to solve problems, complete tasks, and accomplish goals.
5. Leadership: leverage the strengths of others to achieve common goals and use interpersonal skills to coach and develop others.
6. Professionalism/work ethic: demonstrate personal accountability and effective work habits, such as punctuality, working productively with others, and time workload management; and understand the impact of nonverbal communication on professional work image.
7. Career management: identify and articulate one's skills, strengths, knowledge, and experiences relevant to the position desired and career goals, and identify areas necessary for professional growth.
8. Global/intercultural fluency: value, respect, and learn from diverse cultures, races, ages, genders, sexual orientations, and religions.

Selecting a career path as a *professional* typically begins in high school or in the very beginning stages of college. A student may be attracted to the fact that professionals

possess marketable and transferrable skills that can be used in any number of employment centers or geographic parts of the world. This attraction, accompanied by strong desire, will often stimulate more focused research on the types of professions that fit current interests, and consideration will (hopefully) honor future interests as well. Deciding on a career that requires a college education or some other form of training before finding employment takes time and planning. A success-oriented student understands the need for preparation, making appropriate choices, and recognizes important deadlines for commitments and follow-up. These are the beginning stages where professional competence is developed.

2.2 The Profession of Engineering

Simply put, engineering is the application of math and science to solve problems. Engineers figure out how things work and find practical uses for materials and other findings in the world of science to achieve objectives. Those who practice engineering are employed in a variety of environments including government, manufacturing or other industry, agricultural, and private business. As a recognized professional career, engineering is viewed by society (mostly) with respect and honor and engineers must always remember their responsibilities. The relationships that exist between an engineer and members of the profession or the public will be discussed further in [Chap. 3](#).

The Professional Engineers Act in the State of California offers the following definition of a professional engineer: “Professional engineer, within the meaning and intent of this act, refers to a person engaged in the professional practice of rendering service or creative work requiring education, training and experience in engineering sciences and the application of special knowledge of the mathematical,

physical and engineering sciences in such professional or creative work as consultation, investigation, evaluation, planning or design of public or private utilities, structures, machines, processes, circuits, buildings, equipment or projects, and supervision of construction for the purpose of securing compliance with specifications and design for any such work.”²

The Wyoming Surveyors and Engineers Practice Act (see [Fig. 2.2](#)) defines what it means to practice professional engineering within their jurisdiction: “Practice of professional engineering means performing for others or offering to perform for others any professional service or professional creative work requiring engineering education, training and experience and special knowledge of mathematics, physics and engineering sciences. An individual performs a professional service or professional creative work in the practice of professional engineering if he (1) represents himself to be a professional engineer by sign, advertisement, letterhead, card, verbal claim or any other manner; (2) quotes a fee for a professional engineering service; (3) executes a contract or agreement for a professional engineering service; (4) teaches upper division engineering design subjects as a professional engineer at a college or university; (5) performs research investigations as a professional engineer; (6) testifies as an expert in professional engineering; or (7) holds himself out as able to perform or does perform, as a professional engineer, any similar service defined by board rules as the practice of professional engineering.”³

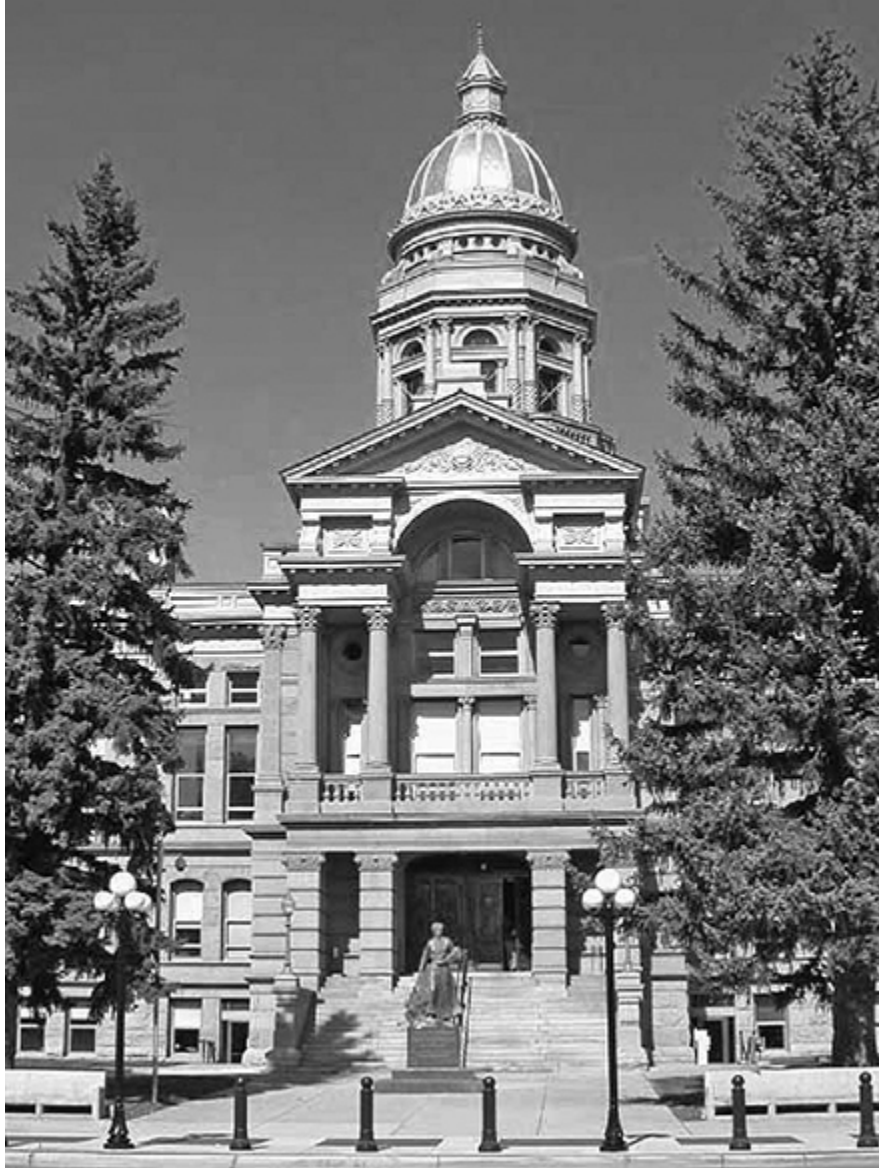


Figure 2.2 The Wyoming State Capitol building. Individual states govern construction within their boundaries and create laws to license professional activity as well. (Photo by Matthew Trump, Creative Commons BY-SA 3.0.)

Worldwide, a professional engineer is defined much the same as what we find in the United States. Technical Academy Scotland, for example, explains that “chartered engineers are characterized by their ability to develop appropriate solutions to engineering problems using new or

existing technologies through innovation, creativity, and change.”⁴ In 2015, the Engineers Service Structure Committee of the Pakistan Engineering Council developed a document⁵ to explain the importance of engineers for the Prime Minister of Pakistan in an effort to improve working conditions and the service structure within government agencies, as well as to bolster recognition of the valuable service provided by engineers. In that document, the committee offered a number of descriptions, including:

1. Engineers are a catalyst of socio-economic advancement as well as defense of the country.
2. Engineers serve humanity and mankind and can perform wonders, provided they are given proper working conditions and a role in decision making.
3. There is a need for engineers to easily move laterally among various organizations on the Federal and Provincial levels, to benefit the nation with their diversified experiences and talents.
4. Engineers are responsible for execution and development of plans, provision and maintenance of essential services, and contribute towards productivity, economic well-being, and defense of the country.
5. Ministries and divisions that are primarily technical in nature need to be manned and managed by engineers with relevant expertise in the respective field.

What exactly is a *profession*, and why does it include engineering? Most resources that attempt to define a profession agree on three primary characteristics: (1) it requires specialized education and training, (2) members must make a personal commitment to a predefined ethical code, and (3) activities are both self-policed within the

profession and judged by members of society. Engineering includes all of these basic characteristics, along with a strong recognition of responsibility and a collective effort to assist the healthy and progressive development of human existence.

The terms *career* and *profession* are interrelated and differences in terminology may not ultimately matter, but understanding the nuances can help students decide an appropriate scope of activity and whether the level of risk associated with an industry is worth managing. A good summary of differences was published in March 2018 on the website of a group called Key Differences with a mission of clarifying doubts by publishing materials to explain differences between key concepts that are frequently misunderstood. The article “Difference Between Profession and Career” offers five key differences⁶:

1. The profession can be understood as a type of occupation which requires formal qualification and prolonged training. Career refers to the sequence of related employments which a person takes on in his life, which includes jobs held, titles earned, projects accomplished, etc.
2. The profession is an occupation. Careers include occupation in the sense that it entails the number of occupations and other roles that a person undertakes in life. In this way, a person makes a career as an entrepreneur, or as a doctor, or can work for an organization.
3. The profession undertaken by a person will be based on his education and the training imparted, but a person's career depends on his ambition in life.
4. The profession is a service-oriented occupation, as rendering service is their primary aim; though they get

a fee for it, they cannot exploit people, for providing their knowledge. A career is growth-oriented, people seek opportunities to excel in their career, to get better pay and a good position.

5. Every profession has some guidelines or code of conduct, which are framed by the regulating body. There is no defined set of guidelines for a career, that is, a person is free to choose his career and pursue it.

2.2.1 What Is Civil Engineering?

Civil engineering is one of the oldest recognized branches of engineering, likely because these projects are critical to the basic needs of any society. It involves the planning, survey, design, supervision, and inspection of infrastructure construction that includes the supply of basic necessities (water supply and treatment facilities, disposal and recycling yards, wastewater collection and treatment systems, dams and power generation plants or fields), transportation (airports, bridges, waterways, roads and highways, tunnels, mass transit systems and routes of travel), and other projects necessary for human habitation (land development, stormwater drainage and collection, buildings for shelter of persons and services). The development of land requires careful master planning and civil engineers lend their expertise for setting both short- and long-term goals, assuring that systems function as intended and people stay connected to one another in the present as well as the future. Elements of infrastructure, such as a highway, are laid out in ways that respect the land around them, such as shown in [Fig. 2.3](#), oftentimes just for the sake of economics—there is no sense in spending the money to remove natural landscape features if there is a simple way to go around them.



Figure 2.3 Civil engineering includes design of infrastructure to provide safe and convenient connections between all types of communities. (Image by Free-Photos from Pixabay.)

Because civil engineering involves numerous related tasks, those who enter the field usually specialize in one or more technical branches. These can include construction management, environmental, transportation (highway, rail, air, nautical), structural, coastal and port engineering, geotechnical and geological, architectural, materials science, utilities, surveying, land development, community and regional planning, water resources (hydrology), and wastewater management.

2.2.1.1 Land Surveying

As an important part of the practice of civil engineering, land surveying has also been recognized by society as a

profession and states issue registrations accordingly, whether part of the duties of a professional engineer, civil engineer, or under its own authority as a professional land surveyor. In fact, there was a recent legal case involving the work of a surveying company in Keith County, Nebraska, which had to answer the question of qualified expert testimony.⁷ The basic work included a boundary survey, where the four corners of the lot were marked with wooden stakes tied with ribbon, driven securely into the ground, clearly visible and in plain sight. After the work was done, the property owner (not a direct client of the surveying company) tripped over one of the stakes, badly injuring his hip. He brought a suit against the surveying company for negligence and loss of consortium.

The property owner's legal team decided not to provide expert testimony to establish a standard of care because they thought the negligent activity was extreme and obvious. The district court, however, determined that the surveyors were, in fact, professionals since they are licensed by the state and that their work is overseen by state agencies and a regulatory board. Because of this, the court determined that any failure to exercise reasonable care must be proved by qualified expert testimony. Since the property owner's legal team did not provide such testimony, they could not prevail as a matter of law. Further, the court found that the surveyor's actions were not negligent. The practice of leaving markers and stakes in place at the completion of the survey was shown to be standard in the industry and generally accepted by the State of Nebraska. The property owner appealed but did not prevail.

Some interesting conclusions were published in the court's decision. In defining a profession, the court added, "We have defined a profession as a calling requiring specialized knowledge and often long and intensive preparation including instruction in skills and methods as

well as in the scientific, historical, or scholarly principles underlying such skills and methods, maintaining by force of organization or concerted opinion high standards of achievement and conduct, and committing its members to continued study and to a kind of work which has for its prime purpose the rendering of a public service.” The practice of surveying is subject to a number of statutes requiring continuing education, adherence to a code of conduct, and submission to an authority that may take disciplinary measures against registrants, which adds to the qualification as a profession.

The court added, “The act of placing survey stakes in the ground as part of the performance of surveying work qualifies as a professional act or service. Although one could argue that the act of driving a stake into the ground was purely a manual skill and was not dependent on professional knowledge or skill, the setting of the stakes was an integral part of the professional service supplied. How high to set the stakes, how to mark the stakes, and how long to leave the stakes in the ground are matters of professional judgment.”

2.2.1.2 Professional Geologists

The American Institute of Professional Geologists (AIPG) was formed in 1963 and is dedicated to training licensed geologists and educating the public on how the profession works to improve the well-being of society. The California Board for Professional Engineers, Land Surveyors, and Geologists defines engineering geology as “the application of geologic data, principles, and interpretation so that geologic factors and processes affecting planning, design, construction, maintenance, and vulnerability of civil engineering works are properly recognized and utilized.”⁸ The Board goes on to define professional work to include

“the application of scientific knowledge, principles, and methods to geologic problems through exercise of individual initiative and judgment in investigating, measuring, interpreting, and reporting on the physical phenomena of the earth.” The profession is recognized as one of the technical specialties within the field of civil engineering.

Ethical principles promoted by AIPG contain similar elements to those published by civil and structural engineering societies, and some of them have special relevance to the practice of geology.⁹ A sample of these principles is noted below.

1. Standard 1.2: Members shall separate facts and observations from interpretations. Members should acknowledge the complexities and uncertainties of Earth systems and state what is unknown in addition to what is known.
2. Rule 3.1.1: A member shall disclose to a prospective employer or client the existence of any owned or controlled mineral or other interest which may, either directly or indirectly, have a pertinent bearing on such employment.
3. Standard 3.5: Members who find that obligations to an employer or client conflict with professional or ethical standards shall have such objectionable conditions corrected or resign.
4. Standard 5.3: Members should work toward the improvement of standards of geological education, research, training, and practice.

2.2.2 What Is Structural Engineering?

Structural engineering is also a specialized branch within the field of civil engineering. The basic task of a structural

engineer is to design buildings, bridges, or other systems that support loads, including their own weight. During the process of design, engineers must determine the magnitude and character of loads, create a mathematical model of individual members or entire structures, analyze how forces are carried by and transferred through those members and systems, determine the resistance capabilities of different materials and connection types, coordinate construction code requirements, and determine compliance with performance objectives. This is oftentimes an iterative process that can be done using a combination of hand calculations, computer programs, or simple matters of judgment based on experience, education, and training. After that process is complete, engineers must communicate the adequacy of the design in order to receive a permit for construction and to relay instructions to contractors who will need to build the structure. This involves the preparation of structural calculations, reports, specifications, and drawings.

A structural engineer is not always involved in the phase of design where artistic form is developed but sometimes that form is displayed in the structure itself, such as the Eiffel Tower in Paris, France (see [Fig. 2.4](#)). This is known as a frame structure, which consists of struts joined together to form a framework. The ability to resist load is a function of the strength of each element and their connections, as well as how they are laid out. One of the most common and stable arrangements takes the form of many triangles joined together, which results in a great deal of redundancy.



Figure 2.4 Structural engineering uses principles of science and art to create new things that improve the well-being of all societies. (Image by Phil Riley from Pixabay.)

Another basic form is a mass structure, where materials are put together to create a solid structure, such as a large gravity dam. Their strength comes from the weight and hardness of the materials and the overall system layout is fairly simple. They are robust and can even sacrifice a small amount of material without a significant loss of strength or reduction in performance. A shell-type structure consists of a thin material shaped to contain a predefined volume, such as a tank or a dome, which remains stable and supports load without added framing. They are lightweight and economical, but the design process is complex and they can be vulnerable to buckling under certain types of loads.

2.2.3 Education

A basic engineering education is intended to prepare a student to enter the workforce, which is where mentorship and personal experience add to the student's base of knowledge and professional growth. In the United States, the practice of engineering is regulated by individual states and educational requirements are specified by governmental licensing agencies, usually based on recommendations provided by engineering societies and organizations. Experience is also required for licensure, and most states have developed formulas that blend different levels of achievement in both categories. For example, the Board of Registration of Professional Engineers and Land Surveyors in the State of Massachusetts¹⁰ prescribes a variety of combinations of education and experience:

1. A bachelor's degree plus a master's degree in engineering from an accredited program with three years of qualifying engineering experience.
2. A bachelor's degree from an accredited program with four years of experience.
3. A foreign degree or non-accredited program in engineering of four years with an equivalency appraisal by the state and four years of experience.
4. A bachelor's degree in engineering technology or any non-accredited program in engineering or related engineering science (physics, chemistry, etc.) with eight years of experience.
5. No specific education requirement with twelve years of experience (including five years of experience in responsible charge), with exam requirements.
6. No specific education requirement with twenty years of experience (including ten years of experience in

responsible charge), with limited fundamentals exam requirements.

2.2.3.1 Engineering Program Accreditation

Accreditation, or some form of nationwide recognition, is an important step in defining matters of knowledge that competence is built upon. In addition to proposing and reviewing subjects deemed necessary for the education of engineers, accreditation agencies require schools to have a clearly defined mission to better educate and serve students, sufficient resources, and evidence to show that mission goals are being achieved. Accreditation is done voluntarily and can be obtained for a college or university as a whole, but it is most often specialized for programs related to certain professions or vocations within an institution. Accrediting organizations in the United States may also be recognized by either the U.S. Department of Education or the Council for Higher Education Accreditation, though this is not mandatory.

The Accreditation Board for Engineering and Technology (ABET) is a nongovernmental agency that establishes standards of quality used to judge the suitability of engineering programs at universities and colleges across the United States and other countries. ABET was founded in New York in 1932 as the Engineer's Council for Professional Development, which was renamed in 1980 and relocated to Baltimore, Maryland in 1996. Program accreditation through ABET carries ISO 9001:2015 quality management certification. Organizations that carry this certification demonstrate the ability to consistently provide products and services that meet or exceed customer and regulatory requirements. A quality management system is set up within the operation of ABET to document processes,

procedures, and responsibilities for achieving quality policies and objectives, which can be used to coordinate activities and improve efficiency and effectiveness.

The accreditation program through ABET is reviewed and updated (as needed) annually and includes criteria for baccalaureate level and master's level programs. Professional societies, institutions, and individuals may propose changes to the criteria at any time, which would be reviewed and considered by the Engineering Area Delegation. Interested groups will find criteria summarized in a document composed by the Engineering Accreditation Commission of ABET.¹¹ Some important definitions considered by reviewers are summarized in [Fig. 2.5](#).

1. "Complex engineering problems" may include wide-ranging or conflicting technical issues, sometimes having no obvious solution, that may also address problems not encompassed by current standards or codes. They may include many divisions and subproblems that involve multiple disciplines and have significant consequences in a range of contexts.
2. "Engineering design" is a process of devising a system, component, or process to meet desired needs and specifications within constraints. It is typically an iterative, creative, decision-making process in which the basic sciences, mathematics, and engineering sciences are applied to convert resources into solutions.
3. "Engineering sciences" are based on mathematics and basic sciences, but carry knowledge further toward creative applications in solution of specific problems.

Figure 2.5 Sample definitions used by ABET in the engineering program accreditation process.

General criteria of an accredited engineering program on the college or university level includes an internal requirement for student and program evaluation. The progress of individual students must be monitored in order to assess the attainment of educational objectives and to identify steps toward a career path upon graduation. An operational process for evaluating, assessing, maintaining, and enhancing the quality of the program must be documented. Furthermore, means of communicating with

students and access to facilities such as laboratories, libraries, and instructional spaces that are instrumental to student success must be adequately provided and advertised. Students and faculty should be able to find resources that explain campus policies and procedures, intended learning outcomes of the program and of individual courses, and established guidelines for resolution of conflicts.

Curriculum for a civil engineering program should train students to apply knowledge of mathematics (through differential equations), calculus-based physics, chemistry, and at least one additional area in the basic sciences to solve real-world problems. Experiments are required in at least two areas, with an emphasis on analyzing and interpreting data, and instruction should also cover project management, business, public policy, and leadership. Students should also learn how to analyze and solve problems with consideration of ethics, sustainability, complexity (components and systems), and responsibility (licensure).

The Bachelor of Science degree in structural engineering offered by the University of California in San Diego (UCSD) has been accredited by ABET since October 1987. The program emphasizes the commonality of engineering structures in materials, mechanics, analysis, and design over the disciplines of aerospace, civil, marine, and mechanical engineering. Objectives include the retention of critical thinking skills, a passion for lifelong learning, possession of a broad set of multidisciplinary skills, the ability to communicate and collaborate in a professional setting, and a clear understanding of ethical issues. Expected student outcomes include an ability to identify and solve complex engineering problems using known factors and results of new discoveries, experiments, or research; an ability to discover and judge solutions that meet a variety of

technical and ethical needs, such as public welfare, global, cultural, societal, environmental, and economic factors; effective communication skills; and an ability to collaborate on an inclusive team and provide leadership, establish goals, plan tasks, and meet objectives.

The National Council of Examiners for Engineering and Surveying (NCEES) publishes an engineering education standard that may be used to judge the equivalency of a nonaccredited engineering program.¹² The standard requires completion of the following (one “college semester credit hour” = 750 minutes of formal instruction):

1. 32 college semester credit hours in higher mathematics and basic sciences, which includes courses beyond algebra and trigonometry that emphasize concepts and principles instead of basic computation. Basic science courses include chemistry, calculus-based physics, biology, and earth science (geology, ecology).
2. 12 college semester credit hours in general education that will complement the technical engineering content, such as philosophy, religion, history, literature, fine arts, sociology, political science, economics, communication, and others.
3. 48 college semester hours of engineering science or design courses that are taught within the college of engineering with roots in mathematics and basic sciences that will carry knowledge further toward a creative application of principles. These include mechanics, thermodynamics, circuits, material science, and others.

Although accreditation, or some form thereof, is an important quality-control feature of an engineering education, programs that lack formal accreditation by an

independent agency can still provide students with adequate preparation for a future career in the public or private sector. One of the most important benefits to accreditation, however, is recognition by engineering societies, licensing agencies, and employers. It is easier to assess the depth and breadth of education with known standards, outcomes, and objectives that are applied uniformly across institutions. Since the standards may be known by the public, however, each institution has the ability to develop their own program in compliance with accepted characteristics, such as those published by ABET or NCEES.

2.2.4 Training

On-the-job training is one of the most influential parts of a professional career by which skills of judgment are developed. Education provides understanding of how and why things work, but just as with so many other realities of life ... sometimes you just have to experience it. There is tremendous value in sitting at a drafting table or design station with a set of drawings laid out, discussing drainage patterns from an existing topographic survey, and brainstorming with licensed professionals about land modifications for future development. Professional engineers who have created and assembled calculations over a period of years can instruct new employees on relevant strategies for justifying designs and coordinating activities with the needs of building departments. Jobsite inspection visits build interpersonal skills, instructs on cooperation and division of labor, and provides excitement in seeing concept turn into reality. Interaction with colleagues, clients, and the general public in a professional setting also gives new employees a sense of community and teaches them that the profession is deeply rooted in helping

people and protecting the planet, for the present and the future.

The quality and amount of practical experience attained can also help in the arrangement of personnel into helpful classifications that benefit the company as well as the individual. The Gulf Engineering Union (GEU), for example, is a professional organization based in the Arabian Gulf, founded in Kuwait in 1997 that consists of a number of individual engineering societies, namely, the Bahrain Society of Engineers, Society of Engineers—UAE, Kuwait Society of Engineers, Oman Society of Engineers, Saudi Council of Engineers, and Qatar Society of Engineers. The GEU has defined three levels of practice in the field of engineering based primarily on experience.¹³ The first level adopts the title *engineer* and is reserved for those who have a bachelor's degree or equivalent in engineering or architecture from an accredited university or institute. The second level, *professional engineer*, includes applicants who have passed relevant exams and either (1) has documented experience as an engineer of at least four years after graduation, or (2) has documented experience as an engineer of at least one year after obtaining either a master's degree or a PhD in engineering.

The third level identified by the GEU is granted the title *consulting engineer*, which requires recommendation from a consulting engineer who has supervised the applicant's professional work and one of the following: (1) a professional engineer with at least fifteen years of documented experience after graduation and passes a personal interview with the relevant committee formed by the council; (2) a professional engineer who has obtained a master's degree in engineering, has documented experience of at least ten years after graduation, and passes a personal interview with the relevant committee formed by the council; or (3) a professional engineer who

has obtained a PhD in engineering, has documented experience of at least ten years after graduation, and passes a personal interview with the relevant committee formed by the council.

2.2.5 The Role of Competency Exams

Exams are required by most state licensing boards to determine whether candidates meet requirements to practice as a *minimally competent* professional engineer. That classification is important since it conveys the understanding that perfection or impeccable knowledge and skill is not required to practice. In the United States, most licensing boards use exams that have been developed by NCEES. The first exam on the road to licensure, generally, is the Fundamentals of Engineering (FE) exam (also known as the Engineer-in-Training exam), which is offered in seven specialties. The exam related to the practice of civil engineering, for example, includes questions from the categories of math and science, ethics and professional practice, economics, statics and dynamics of solids, solid and fluid materials and mechanics, surveying, water resources, and specialized questions from engineering fields like environmental, structural, geotechnical, transportation, and construction.

Most states will require three or four years of experience under the watchful eye of a professional who is duly licensed in the same discipline before qualifying to take the Principles of Practice (PE) exam which, again, is specific to individual fields of engineering. The PE-Civil exam includes 40 multiple choice questions in the morning to cover the breadth of civil engineering practice, and includes 40 multiple choice questions in the afternoon to explore the depth of required knowledge within one of five associated specialties (the candidate selects one), including

construction, geotechnical, structural, transportation, and water resources plus environmental. The breadth portion of the exam covers project planning, means and methods, soil and structural mechanics, hydraulics and hydrology, geometrics, materials, and site development. The structural-specific depth portion of the exam includes questions on analysis, design and details of structures, codes, and construction.

A special 16-hour structural engineering exam was introduced by NCEES in April 2011 for licensing agencies who require further evidence of specialized knowledge by those who will be responsible for designs of more complex structures. The exam is administered over a period of two days: The first day includes multiple choice and constructed response (essay) questions on vertical and incidental lateral forces, and the second day covers lateral forces with the same format. Since the codes and material design specifications for buildings and bridges are different, NCEES develops separate exams for candidates with these different specialties.

Exams that test competency in engineering subjects are produced using a format that assures coordination with the needs of the profession. A job analysis is performed through research, interviews, and questionnaires to determine tasks that practitioners commonly perform—not necessarily on a daily basis, but tasks suitable for an examination should not be those that are *rarely* exercised in the workplace.

Questions would include matters of knowledge and skill (where applicable) needed to perform these tasks. Since the standard is a basic level of competence, a job analysis will typically place emphasis on tasks performed by engineers with a modest amount of experience. The length of an exam is based on a history of administration and statistics related to candidate performance: it is usually long enough (but not too long) so that examinees must have a really good idea of

how to solve the problems without spending too much time looking through their reference materials, otherwise they will not be able to complete it within the allotted time. Exams are written and graded (as applies) by licensed, practicing engineers from a variety of work settings and regions.

2.3 Minimally Competent

An optimized combination of education, training, and successful completion of exams (using well-defined methods for setting pass scores) establishes a candidate's status as *minimally competent* to complete engineering tasks on a professional level. This term is not exclusive to the engineering profession, but can also be found in the licensure requirements for most professions. A document written to help faculty create exam questions for students at the University of Illinois College of Medicine describes conditions relative to the minimally competent (also called "borderline") student, which is mostly suitable for engineering students as well.¹⁴ This document identifies such students as "on the cusp of failing" with a knowledge base somewhere between competence and incompetence.

Accordingly, the minimally competent engineering student (1) has a solid basis of information, (2) can define terms, recall factual information, and make simple connections between previous and current material, (3) is familiar with simple design problems that include the application of engineering fundamentals, and (4) can make distinctions between viable, relatively similar solutions and answer questions on simple situations. This same student would have difficulty (1) following complex problems with a large amount of data, (2) fully understanding the conclusions of case studies involving complex structures or infrastructure systems, (3) connecting and integrating

concepts, (4) explaining the meaning of tests and samples if not fully described within a report, and (5) deciding which tests are necessary to determine physical properties needed to complete a design.

This document also includes a section of characteristics that define a failing or incompetent university-level student. Such a student (1) lacks content knowledge or cannot recall information, (2) cannot make connections and integrate knowledge even with assistance, (3) lacks insight that they need help—in other words, they are not aware of what they do not know, and (4) has difficulty picking up on cues provided in exam problem statements. These conditions were explored for the work and habits of students, and the level set for entry into a profession as a licensed practitioner is obviously going to be higher. However, some of these same principles apply, including a distinction between simple and complex problems and the ability to mine information.

2.3.1 Body of Knowledge

In 2004, the American Society of Civil Engineers (ASCE) published the first edition of a document to outline a body of knowledge area necessary for entry into the profession of civil engineering. The third edition of this document, *Civil Engineering Body of Knowledge (CEBOK)*,¹⁵ was published in 2019 and draws information from the *Engineering Competency Model* published by the U.S. Department of Labor in 2016 (this will be discussed in more detail later in this chapter), and the *Graduate Attributes and Professional Competencies* published by the International Engineering Alliance in 2013. It summarizes 21 outcomes, placed into four categories, as shown in [Fig. 2.6](#).

Foundational Outcomes:

1. Mathematics
2. Natural Sciences
3. Social Sciences
4. Humanities

Outcomes in the Fundamentals of Engineering:

1. Materials Science
2. Engineering Mechanics
3. Experiment Methods and Data Analysis
4. Critical Thinking and Problem Solving

Technical Outcomes:

1. Project Management
2. Engineering Economics
3. Risk and Uncertainty
4. Breadth in Civil Engineering Areas
5. Design
6. Depth in a Civil Engineering Area
7. Sustainability

Professional Outcomes:

1. Communication
2. Teamwork and Leadership
3. Lifelong Learning
4. Professional Attitudes
5. Professional Responsibilities
6. Ethical Responsibilities

Figure 2.6 Outcome subject areas expressed by ASCE's *Civil Engineering Body of Knowledge, Version 3*.

Commonly recognized areas of knowledge include mathematics, natural sciences (chemistry, physics), engineering fundamentals, and other technical and professional subjects, but some areas do not come to mind

as quickly. These include social sciences, humanities, and attitudes. Within the social sciences, some of the disciplines that are not immediately recognized for a civil or structural engineering education are anthropology, geography, law, political science, sociology, psychology, and history. One of the

factors that relate the technical aspects of these subjects with those of civil engineering is the gathering and analysis of data in order to make judgments or arrive at conclusions on matters important to society. Effective delivery of engineering services depends on a recognition of the wider social framework affected by the work. Political science, for example, provides insight into project funding and the approval process. A basic understanding of psychology can help a civil engineer understand why people perceive things differently, how to assess patterns of behavior, and fine-tune skills in communication and persuasion.

Studies in the humanities are oftentimes categorized under the heading of *social sciences*, but many of these areas deserve their own classification so that the emphasis on personal and societal human virtue and expression can be accurately recognized. These include foreign languages, literature, philosophy, religion, visual and performing arts. On September 29, 1965, the United States Congress enacted the *National Foundation on the Arts and the Humanities Act of 1965* in an effort to promote progress and scholarship in the humanities and the arts. It was amended on May 31, 1984 and on December 20, 1985. It defined humanities to include the study and interpretation of modern and classical language, linguistics, literature, history, jurisprudence, philosophy, archaeology, comparative religion, ethics, art (history, criticism, and theory), and other social sciences that include elements of humanistic content and employ humanistic methods. Some of the findings noted by the United States Congress are

particularly relevant to the societal impact of civil engineering, including the expression of ideas, the enhancement of culture, and sustenance for the future:

1. "An advanced civilization must not limit its efforts to science and technology alone, but must give full value and support to the other great branches of scholarly and cultural activity in order to achieve a better understanding of the past, a better analysis of the present, and a better view of the future."
2. "Democracy demands wisdom and vision in its citizens. It must therefore foster and support a form of education, and access to the arts and the humanities, designed to make people of all backgrounds and wherever located masters of their technology and not its unthinking servants."
3. "The arts and humanities reflect the high place accorded by the American people to the nation's rich cultural heritage and to the fostering of mutual respect for the diverse beliefs and values of all persons and groups."
4. "The practice of art and the study of humanities require constant dedication and devotion. While no government can call a great artist or scholar into existence, it is necessary and appropriate for the Federal Government to help create and sustain not only a climate encouraging freedom of thought, imagination, and inquiry, but also the material conditions facilitating the release of this creative talent."
5. "To fulfill its educational mission, achieve an orderly continuation of free society, and provide models of excellence to the American people, the Federal Government must transmit the achievement and

values of civilization from the past via the present to the future, and make widely available the greatest achievements of art.”

2.3.1.1 Teamwork

Professional and personal attitudes can be described as legally mandated actions and behaviors, but they are also a matter of choice. People are generally predisposed to react in a certain way to conflict or problems that need to be resolved, and not all attitudes are constructive. An engineer’s reaction to a situation can lead to a lawsuit or to a mutually beneficial and lifelong relationship. Society requires civility in the behavior of professionals as a sign that they take their work and responsibilities seriously. It takes practice and commitment to express facts, figures, and feelings in a respectful and meaningful way, just as it takes practice and commitment to master the technical aspects of engineering.

All employers expect their team members to treat one another with respect and kindness, otherwise the environment becomes hostile and unmanageable. Employees are often required to attend educational events and complete learning objectives that focus on human interaction because a formal education curriculum does not usually cover the range of issues that can be experienced in the workplace. As human beings interact with one another, it becomes clear that *motive* is one of the strongest elements of decision making when it comes to attitudes through interaction with fellow employees, clients, colleagues, or other members of the public. The psychologist Lawrence Kohlberg explained the motive of behavior through a progression of moral development that human beings tend to follow in their thinking, which appears

to be consistent regardless of race or culture. Kohlberg identified six stages¹⁶:

Stage 1: Action is motivated by avoidance of punishment.

Stage 2: Action is motivated by desire for reward or benefit.

Stage 3: Action is motivated by anticipation of disapproval of others, actual or imagined.

Stage 4: Action is motivated by anticipation of dishonor, that is, institutionalized blame for failure of duty, and by guilt over concrete harm done to others.

Stage 5: Action is motivated by concern about maintaining respect of equals and of the community (assuming their respect is based on reason rather than emotions), as well as concern about own self-respect, that is, to avoid judging self as irrational, inconsistent, and nonpurposeful.

Stage 6: Action is motivated by concern about self-condemnation for violating one's own principles (differentiates between community respect and self-respect). Motivation also differentiates between self-respect for generally achieving rationality and self-respect for maintaining moral principles.

A professional engineer's motive for moral interaction with others should be founded on the basis of creativity, cooperation, curiosity, and confidence. Creativity demonstrates a desire to seek new solutions, especially when obvious or well-known answers no longer satisfy the needs of a fast-paced world. It expands the scope of engineering services that can be offered for a diverse range of projects and finds options for resolving issues involving personal interactions. A creative engineer is not afraid to express her own thoughts, ideas, or feelings and is willing to

accept criticism so that she can improve her ability to discover solutions. Teamwork is best represented by a genuine spirit of cooperation, proving that each person's contributions, thoughts, and feelings are important and respected. Harmony does not require strict agreement or unity in thought, but it does include acceptance of multiple contributions by individual members to achieve goals and to move projects forward.

Interactions with a curious engineer are filled with honest questions and shared responses. Curiosity motivates people to take some risk in achieving an objective because there is great reward in discovering something new or in examining the preferences or convictions of others. The risk may involve hurt feelings or a need to modify one's own entrenched positions, but temporary pain will be replaced with the excitement of a broadened perspective. A vivid imagination leads to comprehensive solutions and improves meaningful interaction, but development of a healthy imagination requires confidence. Confidence is something that is built up over time as one gains a sense of accomplishment from personal and professional achievement. It involves preparation and observation:

1. Prepare questions or discussion topics to be shared during an approaching meeting.
2. Observe the structure and flow of a conversation before contributing.
3. Honestly evaluate your capabilities and talents to find a balance between too little and too much confidence.

2.3.2 What Is Moral Competence?

Just as competence in the technical and business aspects of engineering requires study and diligent practice, these

same commitments are necessary to develop confidence and competence in ethical or moral matters. The practice of such matters could be construed as subjective (“Who are *you* to tell me how to live my life?”), but that is a different argument. Regardless of what position a person takes on a moral issue or ethical dilemma, constructive communication and potential resolution of conflict require all interested parties to exercise due diligence and honesty in explaining, defending, or persuading others to accept that position.

Moral competence must be pursued primarily through the development of moral sensitivity and ability to understand and work through ethical issues. In their book *Ethics in Engineering*, Mike Martin and Ronald Schinzinger identify 10 practical skills and areas of commitment that help an engineer reflect on moral issues, which should be embraced, practiced, and strengthened over the course of one’s career¹⁷:

1. Moral awareness: proficiency in recognizing moral problems and issues in engineering.
2. Cogent moral reasoning: comprehending, clarifying, and assessing arguments on opposing sides of moral issues.
3. Moral coherence: forming consistent and comprehensive viewpoints based upon a consideration of relevant facts.
4. Moral imagination: discerning alternative responses to moral issues and receptivity to creative solutions for practical difficulties.
5. Moral communication: precision in use of a common ethical language.
6. Moral reasonableness: the willingness and ability to be morally reasonable.

7. Respect for persons: genuine concern for the well-being of others as well as oneself.
8. Tolerance of diversity: within a broad range, respect for ethnic and religious differences and acceptance of reasonable differences in moral perspectives.
9. Moral hope: enriched appreciation of the possibilities of using rational dialogue in resolving moral conflicts.
10. Integrity: maintaining moral integrity and integrating one's professional life and personal convictions.

2.4 Negligence in Practice

The legal term used to identify instances of negligence or incompetence by a professional is *malpractice*, and expert testimony is usually required to identify what a reasonable or prudent professional would have done under similar circumstances in the same region of practice. This includes the concept of *standard of care*, which will be discussed at length in [Chap. 4](#). The determination of reasonable care generally includes consideration of the foreseeable likelihood that a person's conduct will result in harm, the foreseeable severity of that harm, and the burden of precautions to eliminate or reduce the risk of harm. In general, negligence implies that although a person appears to possess sufficient knowledge and skill, that person failed to apply them in accordance with a predefined standard. An example of negligence could be a noticeable lack of coordination of construction documents for which the engineer is responsible, which may include misidentified details (a qualified contractor would likely be able to work around this), unbuildable details (typically remedied through communication during the construction phase), or inappropriate details (those which deviate from clear, unmistakable code requirements).

Incompetence implies a lack of knowledge or ability to properly complete a task. It does not mean that such a person is unintelligent or intentionally careless and, just as for claims of negligence, determining incompetence requires careful consideration of all factors contributing to a complaint so that reasonable and excusable errors can be distinguished from acts of incompetence (or negligence). Sometimes the label as negligent or incompetent results from a combination of multiple errors that a reasonable and careful person would have managed with better competence and attention. Infrequent or reasonably innocuous negligent or incompetent acts may not rise to the level of malpractice depending on the individual, the circumstances, the project, and the results.

In order for a plaintiff to establish an act of engineering malpractice in a lawsuit, four elements need to be proven:

1. The engineer owed a duty to the plaintiff to exercise the customary skill expected within the profession. If the plaintiff, however, failed to exercise due care, and that breach contributed to the accident under investigation, the plaintiff cannot recover damages even if the engineer was negligent.¹⁸
2. The engineer breached that duty by performing negligent work. In his article, *Couldn't Care Less: A Malpractice Primer for Structural Engineers, Part 1*, Matthew Rehtien clarifies, "Because an engineer need only exercise ordinary care, it is not a warrant of his or her plans. In other words, an engineer is not liable (at least not in malpractice) for every aspect of his or her design that causes injury—only for those where the engineer failed to exercise proper care."¹⁹
3. The plaintiff suffered some type of injury or damage. The awarding of compensatory damages, for example, would usually take into account the depreciation in

value of a damaged asset and the cost to repair or replace it.

4. Damages suffered were a direct (proximate) cause of the engineer's negligent behavior. Proximate cause requires two things. First of all, the engineer's act is a substantial factor in the cause of another person's injuries or damage to property. Second, the court does not conclude that it is unfair to impose liability on the engineer even if the substantial factor element requires it. This can happen when a chain of events is established that only remotely connects the negligent acts to the injuries or damage in such a way that imposing strict liability would be inherently unfair.

2.4.1 Criminal Negligence

In the United States, reckless actions by an engineer can also invite criminal penalties since the influence of their work extends to a large number of people. Attorney Michael Willats puts it this way: "When an engineer acts in a way that consciously deviates from the duties imposed on him through these licensing requirements, and someone dies as a result, criminal liability must attach to his actions."²⁰ A key requirement for liability would be awareness of risk in one's actions and creation of that risk through a deficient design imposes a duty on that individual to prevent people from being harmed by it, and the failure to perform this duty may create criminal liability. Professional liability insurance and statutes of repose lessen the direct impact of civil claims upon an individual or corporation but, according to Mr. Willats, the imposition of additional criminal penalties will help deter the production of *recklessly negligent* designs.

In April 1994, the Superior Court of San Mateo County in California dealt with the issue of criminal negligence thought to have been committed by an officer within a

corporation.²¹ The case involved the escape of a horse from a business ranch onto a nearby highway, which collided with a car and caused the death of a passenger. The corporation and its president were both charged with involuntary manslaughter based on a number of things, including the finding that horses have escaped the property numerous times in the past and locations of corral fencing where evidence of significant deterioration over time (and where horses have escaped before) could be plainly observed. The court first had to determine whether the killing was unlawful. This would be defined through California law²² as occurring during the commission of a misdemeanor inherently dangerous to human life, or in the commission of an act ordinarily lawful but which involves a high risk of death or bodily harm, and which is done without due caution or regard. Further, involuntary manslaughter includes negligent acts which are aggravated, reckless, and gross and which are such a departure from what would be the conduct of an ordinarily prudent, careful person under the same circumstances as to be contrary to a proper regard for human life or danger to human life or to constitute indifference to the consequences of such actions.

The court references two California cases, one in 1905 and the other in 1988, stating, "In the context of negligent homicide, such an officer [of a corporation] would be said not to be liable unless he or she was personally aware of the omissions or other behavior that gives rise to the criminal negligence. The decisions involving criminal liability of corporate officers, either expressly or impliedly, focus either on the officer's direct participation in illegal conduct, or his or her knowledge and control of the illegal behavior. The mere fact of the officer's position at the apex of the corporate hierarchy does not automatically bestow liability." In the case at hand, however, the court agreed that there was sufficient evidence to prove that the president of the

Ranch had the required knowledge and awareness of the negligent acts and conditions on the property, as well as the risks created by the horses, to suspect him of the criminal negligence necessary for the charge of involuntary manslaughter to be imposed.

Gross negligence is defined by the Board of Professional Engineers and Professional Land Surveyors in the State of Wyoming as a substantial or habitual deviation from the standard of professional care, any technical standard issued by a recognized professional organization, state laws and ordinances, or other applicable regulations.²³ Gross negligence is not necessarily reckless negligence. The term *recklessness* is defined frequently in cases where an automobile accident occurred and there is an injured party. For example, attorneys at the Law Offices of Brent C. Miller, P.A. in Florida explain the serious nature of recklessness quite well: "Recklessness is more serious than negligence because recklessness involves a state of mind on the part of the reckless driver that is more difficult to excuse. To act recklessly, the defendant must actually know of an unreasonable risk of harm to others, and cause harm to the plaintiff by acting in knowing disregard of that risk. Recklessness means not that the defendant should have known better, but did know better and went ahead regardless of that knowledge."²⁴

2.5 Uncertainty and Expectation

If engineers knew everything that would happen on a project beforehand, they could put together a perfectly outlined scope of services proposal and request an adequate fee that accounts for hours spent on the project plus a reasonable amount commensurate with the risk. Even with perfect foresight, however, there would still be risk but it would be far easier to manage. Since no one has this

mysterious ability to see all possible outcomes of a development project, it is important to understand how to deal with uncertainties before they come up. Uncertainties can lead to errors in the design process (but it is not inevitable) and errors in design can lead to uncertainty during construction (but it is not inevitable). It is not a question of whether there will be uncertainties, but rather how one deals with them when they are recognized.

The incidence, cause, or consequence of uncertainty is often viewed differently by stakeholders on a project, primarily designers, contractors, and owners. In 2014, McGraw-Hill Construction published a comprehensive SmartMarket Report entitled *Managing Uncertainty and Expectations in Building Design and Construction*²⁵ that included survey results and feedback from roundtable discussions and other industry leaders with the objective of advancing the level of shared understanding among owners, design professionals, and construction firms about the mutual challenges they face in the design and construction of a building. The hope is that with the assembled information, project teams will be in a better position to identify, anticipate, and mitigate conditions and factors that lead to uncertainty. Owners, it is hoped, will be in a better position to adjust their expectations of performance from the design and construction teams to a level that is more closely aligned with the capabilities of the team and the complexity of the project.

Perfection is a lofty goal, but it is probably safe to say that everyone hopes for perfection yet understands that it is likely not achievable for moderately or fully complex projects (perhaps there is a better chance at perfection for simple projects). For those surveyed regarding a reasonably complex project, 10% of owners, architects, and contractors (combined) believed that construction documents could be perfect, which included 7% of the owners and 13% of the

architects. Among that percentage of respondents who believe in the possibility of perfect documents, 16% of owners and contractors feel as though they have worked with such documents and 18% of architects believe they have produced them. Interestingly, whereas only 7% of owners believed that perfection of documents was possible, 21% of surveyed owners felt that it is still reasonable to expect perfection in construction documents.

The report summarized seven of the most common sources of uncertainty in a construction project: (1) Unforeseen site or construction issues, which was ranked highest by contractors and owners, (2) design errors, (3) design omissions, (4) contractor-caused delays, (5) owner program or design changes, which ranked highest among architects, (6) accelerated schedule, and (7) construction coordination issues. The top factors reported by all three groups (combined) that would effectively reduce uncertainties included taking a collaborative approach with shared liability (8%), a clear process for dealing with issues that arise (10%), early involvement of the entire project team (34%), and no significant errors on drawings (48%). Some common issues that cause project uncertainty are discussed below.

2.5.1 Unforeseen or Inaccurate/Incomplete Assessment of Site Conditions

Oftentimes, a geotechnical engineer will produce a preliminary site assessment that serves an important function but if complex design decisions are made based on that data without refinement (or fully understanding the limitations of that assessment), problems can arise during construction that may be costly to mitigate. These problems

can include the discovery of pockets of poor soils, buried structures, utility lines, and even hazardous materials that can cause significant delays. An engineer can prepare for this type of uncertainty through some or all of the following actions:

1. Assist the owner with developing criteria that should be investigated or sampled in the field.
2. Arrange a predesign meeting with the local building department to discuss the scope and complexity of the project and the site. There should be records available that can help formulate the criteria mentioned above for the subject site. Additionally, documentation issued for a permitted structure nearby might illuminate potential design challenges for the team.
3. Visit the site and carefully study existing documentation, such as topographic surveys, environmental impact reports, master plans, or other documentation that could be available from the owner, other members of the design team, or the building department (as discussed above).
4. Express concerns and discuss solutions or procedures in anything unforeseen arises during initial surveying, sampling, or construction. Prompt and informed communication will be critical.

2.5.2 Incomplete Coordination of Design Documents

A variety of factors influence the preparation of construction documents, including communication of design intent between the engineers and the technicians or draftspersons, unexpected requirements from plans examiners within the governing jurisdiction, changes

imposed by the owner or architectural team, communication among members of the design team, and expectations of completion time. There may also be intermediate stages that documents need to be released for review, bidding, or other purposes, including schematic design, several generations of design development, submittal for building department review, and construction-ready (after any corrections or changes have been made). Incorrect or insufficient details can lead to volumes of requests for information (RFIs) or change orders, installation of something inadequate and unintended, and even project shut down by the building department's inspector if the issues are significant.

An engineer can prepare for this type of uncertainty through some or all of the following actions:

1. Make sure the scope of services being offered are clear and unambiguous. Include tasks that will be done, and mention tasks that are excluded by previous arrangement.
2. Ask questions about common areas that require extensive coordination, such as mechanical-electrical-plumbing systems and identify who will be responsible for the coordination effort and how that effort is to be approached.
3. Communicate early and throughout the whole design process.
4. Perform a *one-thousand-foot overview* of the drawings from all consultants during schematic and design development stages. This is a more focused examination than the traditional thirty-thousand-foot overview.

2.5.3 Changes in Design or Owner Program Requirements

It is uncommon for a project to begin pencil-to-paper with absolute knowledge of the final product of design. Goals can be made and changed, even intentions or desires can affect how a project is delivered or managed. Changes can happen along the way as the owner continues to develop needs or requirements and the architect or lead designer may have a different perception of those changes (or incorporate changes herself). Program requirements can also be affected by the decisions of building officials on matters of legitimate disagreement over code intent and basic needs or goals. Many of these course changes are unpredictable and unanticipated and can lead to a loss of coordination between consultants, overlapping of responsibilities (thereby wasting time), schedule delays, budget overruns, and a potential loss of the sense of how the project is supposed to come together in the end.

An engineer can prepare for this type of uncertainty through some or all of the following actions:

1. Include contract language that limits the amount and scope of design changes. A certain amount of change should be expected and built into the agreed budget and schedule, but it should be reasonably manageable and not result in a significant amount of extra work, such as a change in the building structural system or a different mechanism for controlling stormwater.
2. As soon as the effect of any design change is understood, clearly communicate your needs to the client. It may be difficult to secure an additional fee or time to complete your tasks, depending on the original contract language, but it is still important to discuss and to keep track of.

3. Include a contingency in your design fee to cover unknown expenses as best as can be predicted (which may not be very good). Caution needs to be exercised, of course, in a competitive bidding environment.
4. Learn from past successes and failures in contract negotiations and project billings.

2.6 A Model for Competency

The Employment and Training Administration within the U.S. Department of Labor developed a tool called the *Engineering Competency Model*, first published in August 2015 and last updated in December 2017 that identifies the knowledge and skills needed for workers to perform successfully in an engineering-related field of employment. The information is arranged in the form of a pyramid (see [Fig. 2.7](#)), with four primary tiers and two optional tiers, to represent increasing specialization of the proficiencies noted. Tiers are further divided into blocks to identify competency areas. The model is not intended to identify every relevant area of competency and knowledge, but to serve as a tool to stimulate further exploration and adaptation to fit individual or institutional needs. A site dedicated to exploration and adaptation of the model is the Competency Model Clearinghouse (<http://www.careeronestop.org/competencymodel/>). Material is presented to support the Department's definition of *competency*, which is "a cluster of related knowledge, skills, and abilities that affects a major part of one's job, that correlates with performance on the job, that can be measured against well-accepted standards, and that can be improved through training, development, and experience."

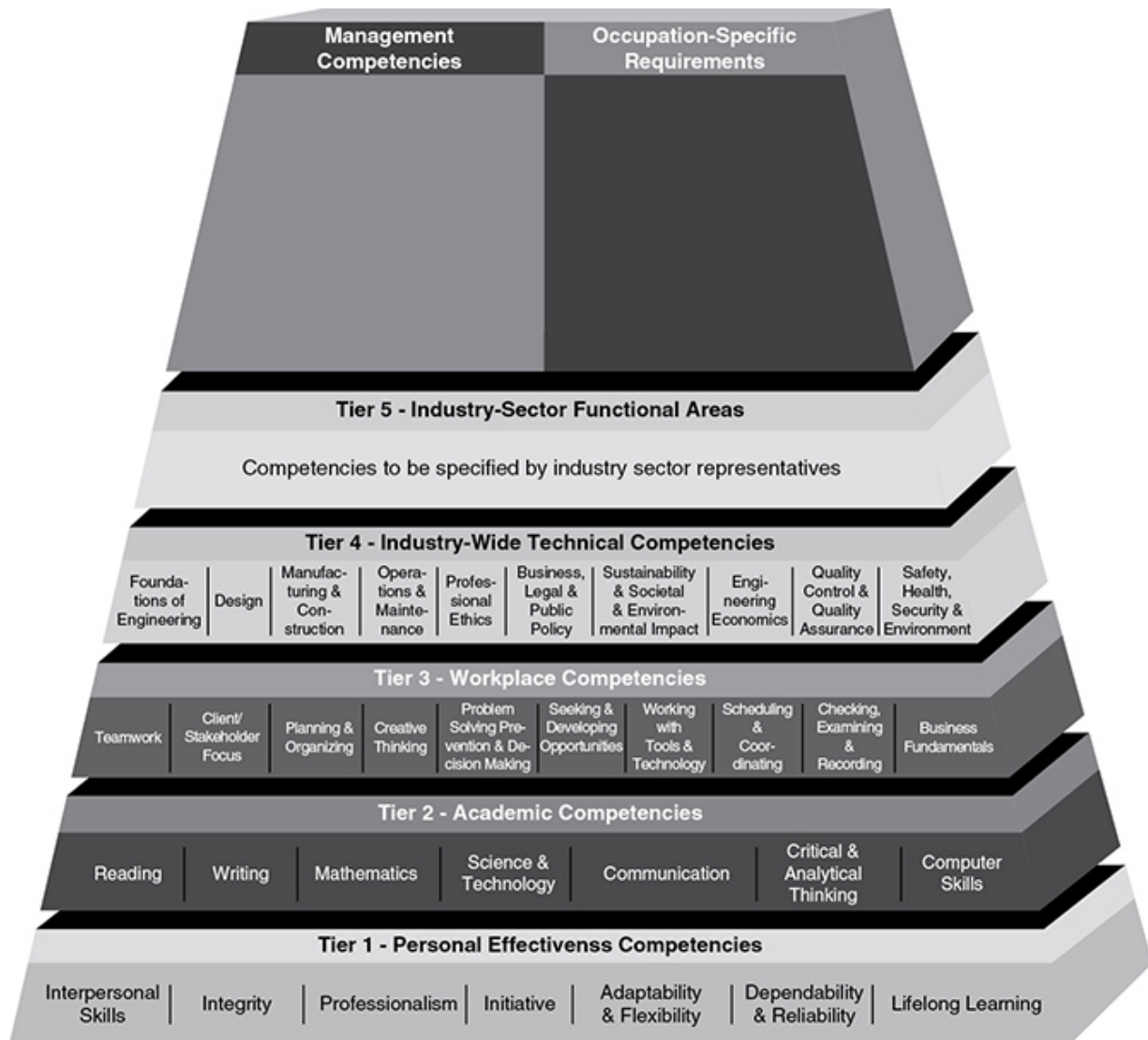


Figure 2.7 Engineering Competency Model pyramid created by the Employment and Training Administration of the U.S. Department of Labor. (*Source:* Engineering Competency Model by the U.S. Department of Labor.)

2.6.1 Foundational Competencies (Tiers 1-3)

Tiers 1 through 3, forming the base of the pyramid, identify *work-readiness skills* that most employers require from their staff. Tier 1, “Personal Effectiveness Competencies,” is

divided into seven segments: interpersonal skills, integrity, professionalism, initiative, adaptability and flexibility, dependability and reliability, and lifelong learning. The honing of interpersonal skills begins with acceptance of others and continues with the courage to respect diversity and to see the value in a diverse group of persons, working together to achieve common goals. There must be a basic sense of responsibility for behavior, which can help an employee recognize a strained relationship, when communication has broken down, and if some unconscious bias is creating problems. Demonstration of integrity in the workplace would include taking individual and collective (when applicable) responsibility, being accountable, and acting with fairness and honesty toward everyone. An employee displays professionalism when she maintains composure and a good attitude under any circumstance, behaves in a consistent and relatively predictable manner, honors commitments in a timely manner, and follows directions.

Tier 2 emphasizes *academic competencies*, which include the subjects of reading, writing, mathematics, science and technology, communication, critical and analytical thinking, and computer skills. Engineers need to critically analyze and evaluate technical writings so that data will be relevant to the work at hand. Data are used to enhance the design process, and communication (including writing, drawing, and speaking) must be clear, unambiguous, and persuasive to garner support of conclusions and to welcome feedback or alternate viewpoints. A logical thought process is necessary to critically review, analyze, synthesize, compare, and interpret information; to identify strengths and weaknesses of alternative solutions to problems; and to quickly understand and integrate new information.

Workplace competencies are summarized as tier 3, including teamwork, addressing the needs of clients and

stakeholders, planning and organizing work, introducing creativity and innovation in the decision-making process, seeking opportunities on a personal as well as a company-wide level, using modern tools and technology, and proficiency with basic business fundamentals. Valuable employees understand how their company works and how resources are collected and used responsibly. Basic legal and regulatory requirements should be understood and followed, which may be directly related to the work of an employee or may be more applicable to the company as a whole.

Recommended Additional Reading

1. Charles Duhigg, *The Power of Habit—Why We Do What We Do in Life and Business* (New York: Random House Trade Paperbacks, 2014).
2. Dale Carnegie, *How to Win Friends and Influence People* (New York: Pocket Books, 1998).
3. W. J. King and James Skakoon, *The Unwritten Laws of Engineering* (New York: American Society of Mechanical Engineers, 2019).

2.6.2 Industry-Wide Competencies (Tier 4)

Competencies found within tier 4 of the pyramid cover knowledge, skills, and abilities that can be used to benefit workers over the breadth of the engineering industry regardless of one's chosen sector. It identifies foundations of engineering; design, manufacturing, and construction; operations and maintenance; professional ethics; business, legal, and public policy; sustainability and societal and environmental impact; engineering economics; quality

control and quality assurance; and safety, health, security, and environment. Each of these categories includes a list of potential tasks and knowledge areas. For example, competency areas related to the impact of work on society include an ability to analyze the impact of a project on diverse stakeholders, to estimate life cycle project costs and benefits, assess and communicate intended and unintended impacts on the environment and society, prepare and deliver presentations, and integrate the arts and humanities with engineering activities and decisions.

Foundations of engineering combine elements from tiers 2 and 3 into detailed work-related functions, incorporating engineering science, natural science, and humanities/social sciences. An engineer should understand how to incorporate these areas into design decisions, for example, by recognizing the application of technology (engineering science), applying critical thinking skills through application of the scientific method (natural science), and developing alternative technical possibilities based on general public input (social science). Public input could be gathered through interviews, questionnaires, or by meeting with focus groups or interested stakeholders. Data, ideas, concerns, and requests could then be organized into categories related to the work, such as aesthetic, environmental, logistics, functionality, and human services. Positive interaction with the public is an important part of moving the profession of engineering forward by trust, honesty, and respect.

Recommended Additional Reading

1. Richard Hamming, *The Art of Doing Science and Engineering: Learning to Learn* (San Francisco, Stripe Press, 2020).

2. Richard Feynman, *Six Easy Pieces* (New York: Basic Books, 2011).
3. David Beer and David McMurrey, *A Guide to Writing as an Engineer* (New York: John Wiley and Sons, 2019).

2.6.3 Suggested Tier 5 Competencies for Civil and Structural Engineering

The model includes an element of flexibility with tier 5, which is dedicated to individual industry sectors, such as civil engineering and structural engineering, to identify task-related functions. I would like to propose the addition of tier 5, *Civil and Structural Engineering Functional Competencies*, as follows (summarized in [Fig. 2.8](#)):

Tier 5: Civil and Structural Engineering Competency Areas	
5.1	Surveying
5.2	Development of Land
5.3	Rules and Regulations
5.4	Infrastructure
5.5	Loads
5.6	Analysis
5.7	Materials of Construction
5.8	Construction Observation
5.9	Forensic Science

Figure 2.8 Proposed tier 5 in the Engineering Competency Model for civil and structural engineering competency areas.

5.1 Surveying

Subcategories: Instruments/Equipment, protocols/procedures, calculations, drawings

5.2 Development of Land

Subcategories: Construction equipment, construction management, grading and drainage, master planning, geological materials, jobsite logistics and control, management of waste

5.3 Rules and Regulations

Subcategories: Federal codes, state codes, local ordinances, governing bodies, labor laws, material-specific design standards

5.4 Infrastructure

Subcategories: Urban and suburban services, roads and highways, railways, waterways, bridges, buildings, utilities, communication centers and systems, water supply, wastewater, stormwater management, sustainability

5.5 Loads

Subcategories: Weights, use of structure or land, earthquakes, wind, potential results of climate change, flood and tsunami, soil and surcharge, combinations

5.6 Analysis

Subcategories: Mathematical modeling, hand-based analysis, computer-based analysis, static methods, dynamic methods, peer review, demand versus resistance, structural forms

5.7 Materials of Construction

Subcategories: Steel, concrete, masonry, wood, composites

5.8 Construction Observation

Subcategories: Licensing board requirements, insurance carrier requirements, company and jobsite protocols, tools, methods, risk, responsibility, limitations

5.9 Forensic Science

Subcategories: Case studies, investigation tools, collecting data, interpretation of data, research, justification of conclusions, communication of findings, making recommendations

Recommended Additional Reading

1. Jaimie Masterson et al., *Planning for Community Resilience: A Handbook for Reducing Vulnerability to Disasters* (Washington, DC: Island Press, 2014).
2. J. E. Gordon, *Structures—Why Things Don't Fall Down* (New York: Hachette Books, 2020).
3. Justin Sweet and Marc Schneier, *Construction Law for Design Professionals, Construction Managers, and Contractors* (Stamford, CT: Cengage Learning, 2015).

2.7 A Model for Self-Improvement

Understanding competency and what it means for engineering practice is only part of the process of professional development. You must *choose* to be competent and strive to improve your position in a way that honors the profession and respects the diversity around you. Engineering societies and licensing bodies fully promote active personal and professional growth for the betterment of society in a multitude of ways. Some elements regarding improvement of oneself are noted in the code of ethics published by the South African Institute of Civil Engineering,²⁶ including (1) adopt a balanced, disciplined, and comprehensive approach to problem solving, (2) maintain and broaden competence and encourage others to do the same, (3) apply skill, judgment, and initiative to contribute positively to the well-being of society, (4)

endeavor to be fully informed about relevant public bodies, community needs, and perceptions that may affect work, and (5) seek and encourage excellence in the practice of the art and science of civil engineering and technology.

Suggested activities to help you grow in competence (and confidence) are listed in [Fig. 2.9](#). The first three items listed do not require interaction and are simple to execute. One of the abilities of a competent engineer is to correlate old knowledge with new findings or expanded subject data, which can be done at any time with any frequency. Common building codes are published on a three-year cycle, and new information is always presented, so there is already a timely need to refresh and examine one's knowledge base.

Technical publications from a variety of agencies should be consulted for general industry news and case studies of engineering in practice. The remaining seven items require some interaction with others, including professionals, students, and even less-familiar members of the public (social media, conferences). Interactions with students, whether through career day presentations or a mentorship arrangement, provide valuable insight from the perspective of someone who has not yet gotten bogged down into the often complicated details of running a business, working with clients and building departments, or managing a project. One of the ways the profession itself benefits from these interactions is the engineer who is in the teaching role can instill excitement (or better than a mild interest) in others, who may not know a whole lot about the practice of engineering but will walk away with a deeper appreciation, even if an alternate career path is chosen.

1. Relearn old subjects
2. Keep up with magazines published by engineering associations
3. Learn new subjects
4. Mentor engineering graduates
5. Join an engineering-related committee
6. Contribute to engineering-related posts on social media
7. Write articles for engineering publications
8. Attend relevant webinars or conferences
9. Network with other engineers
10. Participate in career days

Figure 2.9 Strategies for maintaining and improving engineering competence.

Engineers in positions of management are not only responsible for their own professional development, but also for those who are under their care and supervision. ABET provides several pertinent recommendations for engineering managers²⁷:

1. Encourage engineering employees to further their education.
2. Encourage engineering employees to become registered.
3. Encourage engineering employees to attend and present papers at professional and technical society meetings.
4. Assign professional engineers duties of a nature which will utilize their full training and experience, insofar as possible, and delegate lesser functions to subprofessionals or to technicians.
5. Provide prospective employees with complete information on working conditions and their proposed

status of employment, and after employment keep them informed of any changes.

The process of growth includes a recognition of current knowledge and skills, a desire to expand and enhance current capabilities, knowing where and how to access resources, seeking advice and counsel of others, assessment of growth and achievement of learning outcomes or goals, strength and courage to stay focused and diversified in material, and enjoyment. One of the most significant parts of having a career or profession is the enjoyment of completing tasks, working with others, and the opportunity to make the world a better place, one project at a time.

2.8 Review Questions

- 2.1.** From a general perspective, what is the basis for measuring an engineer's competence?
- 2.2.** What quality may cause an employee to be offered more responsibility with higher pay?
- 2.3.** When considering a career path, what do professionals possess that students may find attractive?
- 2.4.** What is a chartered engineer in the Technical Academy Scotland?
- 2.5.** Name two key differences between a profession and a career.
- 2.6.** What qualifies the practice of land surveying to be identified as a profession?
- 2-7.** How do structural engineers communicate the requirements of their designs?

2-8. What are some of the things an accrediting agency requires of a university program?

2-9. What is one of the most influential means of developing engineering judgment?

2.10. What professional skills are built through jobsite inspection training?

2.11. What does minimally competent mean?

2.12. How are the technical aspects of the social sciences related to those of civil engineering?

2.13. How does the United States Congress define humanities?

2.14. What four character qualities should motivate an engineer toward moral interaction with others?

2.15. What types of things are taken into account when determining the exercise of reasonable care in a negligence case?

2.16. According to attorney Michael Willats, what action of an engineer requires serious consideration of criminal liability?

2.17. How is competency defined by the U.S. Department of Labor?

2.18. In tier 4 of the Engineering Competency Model, what are the competencies related to the impact of engineering work on society?

2.19. What are three of the recommendations from ABET for engineering managers related to the professional development of employees?

2.20. What are key elements in the process of growth in competency of a professional engineer?

2.9 Discussion Questions

2.1D. List five jobs a child under the age of 10 might be given by his parents and identify three tasks for each job that could be improved with practice or instruction.

2.2D. One of the characteristics of a profession is that members must make a personal commitment to a predefined ethical code. What are some of the positive aspects of a personal commitment? What about a predefined ethical code?

2.3D. What are some of the benefits to obtaining a master's degree in an engineering field? List at least five.

2.4D. Explain the practical experience an engineering graduate might gain in her first year with a professional company. What types of additional things should she have experienced by the end of her third year?

2.5D. List five subjects within the social sciences and humanities that are relevant to a civil engineering body of knowledge, and provide three reasons for each.

2.6D. Select one of the findings of the United States Congress published with the *National Foundation on the Arts and the Humanities Act of 1965* and give three examples of how it can be related to the activities of civil or structural engineers.

2.7D. What are some of the characteristics of harmony and teamwork? Provide five examples of how these are exhibited on a design team with multiple consultants and specialties.

2.8D. Obtain a copy of NSPE BER Case No. 09-12, *Professional Competence—Environmental Issues*, from the NSPE website

(<https://www.nspe.org/resources/ethics/ethics-resources/board-ethical-review-cases/professional-competence-environmental>). Do you agree or disagree with the Board's opinion? What information or special notation should Engineer A include in the inspection report?

2.9D. Describe a situation in which a civil or structural engineer may have been reckless in their duties.

2.10D. Explain how the natural sciences, humanities, and social sciences are incorporated into engineering decisions. Refer to the foundation of engineering in tier 4 of the Engineering Competency Model.

¹NACE Center for Career Development and Talent Acquisition, "Career Readiness Defined." National Association of Colleges and Employers, 2021.

<https://www.nacweb.org/career-readiness/competencies/career-readiness-defined>.

²*Professional Engineers Act*, California Business and Professions Code, Sections 6700 through 6799, 2020.

³*Wyoming Surveyors and Engineers Practice Act*, Wyoming Statutes, Sections 33-29-201 through 33-29-801, 2018.

⁴Technical Academy Scotland, "Professional Development." <https://www.techacademyscot.com/professional-development/chartered-engineer/>.

⁵Jawad Saleem Qureshi, *Summary for Prime Minister of Pakistan—Service Structure for the Engineers* (Islamabad, Pakistan: Pakistan Engineering Council, 2016).

⁶S. Surbhi, "Difference Between Profession and Career," Key Differences, March 19, 2018, <https://keydifferences.com/difference-between-profession-and-career.html>.

⁷*Bixenmann v. Dickinson Land Surveyors, Inc.* 882 NW 2d 910 (Nebraska Supreme Court, 2016).

⁸California Code of Regulations, Title 16, Division 29, Section 3003.

⁹American Institute of Professional Geologists (AIPG), *AIPG Code of Ethics* (Westminster, CO: AIPG, September 14, 2019).

¹⁰Massachusetts General Laws, Part I, Title XVI, Chapter 112, Section 81J (December 31, 2020).

¹¹ABET Engineering Accreditation Commission, *Criteria for Accrediting Engineering Programs, 2021-2022 Accreditation Cycle* (Baltimore, MD: ABET, 2020).

¹²NCEES, *Engineering Education Standard* (Clemson, SC: NCEES, 2019).

¹³The Supreme Council of the Gulf Engineering Union, "Engineers Qualifying and Classification System." Gulf Engineering Union, 2016.

<https://www.enggcc.org/EN/content.aspx?ID=5>.

¹⁴University of Illinois College of Medicine, Determining Individual Exam Question Minimal Pass Level (MPL), accessed July 13, 2020,

https://www.med.illinois.edu/facultydev/teachingskills/ProblemBased/TestQuestions/Determining_Individual_M-2_ExamQuestion_Minimal_Pass_Level_-_2013-2014.pdf.

¹⁵Civil Engineering Body of Knowledge 3 Task Committee of ASCE, *Civil Engineering Body of Knowledge—Preparing the Future Civil Engineer*, 3rd ed. (Reston, VA: ASCE, 2019).

¹⁶Lawrence Kohlberg and Clive Beck, eds., "Stages of Moral Development as a Basis for Moral Education," *Moral Education: Interdisciplinary Approaches* (Toronto, Ontario, Canada: University of Toronto Press, 1971).

¹⁷Mike W. Martin and Roland Schinzinger, *Ethics in Engineering*, 4th ed. (New York: McGraw-Hill, 2005).

¹⁸Richard A. Posner, "A Theory of Negligence," *Journal of Legal Studies* 29 (1972).

¹⁹Matthew R. Rechten, “Couldn’t Care Less: A Malpractice Primer for Structural Engineers, Part 1,” *Structure Magazine* 21, no. 6 (2014).

²⁰Michael Willats, “Death by Reckless Design: The Need for Stricter Criminal Statutes for Engineering-Related Homicides,” 58 *Catholic University Law Review* 567 (2009).

²¹*Sea Horse Ranch, Inc. v. Superior Court*, 24 Cal. App. 4th 446—Cal: Court of Appeal, 1st Appellate Dist., 5th Div. 1994.

²²State of California Penal Code, Part 1, Title 8, Chapter 1, Section 192.

²³State of Wyoming Board of Professional Engineers and Professional Land Surveyors, *Rules and Regulations* (December 16, 2020) and *State Statutes* Title 33, Chapter 29 (July 1, 2018).

²⁴The Law Offices of Brent C. Miller, P.A., “What Is the Difference Between Negligence and Recklessness?” October 16, 2014, <https://www.bcmillerlaw.com/posts/what-is-the-difference-between-negligence-and-recklessness/>.

²⁵Harvey M. Bernstein, ed., *SmartMarket Report: Managing Uncertainty and Expectations in Design and Construction* (Bedford, MA: McGraw-Hill Construction, 2014).

²⁶South African Institution of Civil Engineering (SAICE), *Code of Ethics for Members* (Vorna Valley, Midrand, South Africa: SAICE, 2021).

²⁷ABET, *Suggested Guidelines for Use with the Fundamental Canons of Ethics* (Baltimore, MD: ABET, 1977).

CHAPTER 3

Professional Responsibility

As discussed in [Chap. 2](#), the practice of engineering is not simply a career—it is a profession. As professionals, engineers have inherent responsibilities to the public, clients, employers, colleagues, the profession itself, and even to themselves. Those who successfully enter the profession are identified by specific credentials and only those who are duly licensed are allowed to adopt these credentials (this will be discussed in more detail later in this chapter). The Illinois Society of Professional Engineers summarizes the importance of a Professional Engineer (PE) credential on their website: “To the public, the PE credential is the assurance that competent professionals are engaged in the practice of engineering. To a client, it means you have the credentials to earn their trust. To an employer, it signals your ability to take on a higher level of responsibility. Among your colleagues, it demands respect. To yourself, it’s a symbol of pride and a measure of your own hard-won achievement.”¹

A list of common responsibilities and delegated authorities of professional civil and structural engineers is

presented in [Fig. 3.1](#). These are generally understood by the public and are widely recognized by licensing agencies and professional societies. Although there are varying levels of skill and competence within the field, basic proficiency with a set of technical subjects is expected and adoption of applicable ethical canons is assumed. The granting of a license means that a candidate has successfully completed all prerequisites, and the continued use of that license means that a professional continues to develop her skills and base of knowledge in such a way that benefits present and future generations. Issues related to competence are discussed in greater detail in Chap. 2, and the requisite standard of care in practice is presented more fully in [Chap. 4](#).

1. You will be in responsible charge of your own work and that of others.
2. You are responsible to train others and pass along what you've learned over the years.
3. You may speak with authority when offering solutions to engineering problems.
4. The quality of your work product is expected to be on a higher level.
5. You must recognize the limits of your skills and knowledge and practice within your capabilities.
6. The breadth and depth of your skills and knowledge must grow over time.
7. You have the authority to interpret applicable state and federal laws, standards, and codes.
8. You are accountable for your own actions and behavior.

Figure 3.1 Common responsibilities and areas of authority for professional engineers.

The Jamaica Institute of Engineers (JIE), founded in 1977, summarizes professional responsibility quite well: “A professional engineer owes certain duties to the public, to his employers, to other members of his profession, and to himself, and shall act at all times with (1) fidelity to public needs, (2) fairness and loyalty to his associates, employers, clients, subordinates, and employees, and (3) devotion to high ideals of personal honor and professional integrity.”² Intentional loyalty to the public and sensitivity to the needs of society often go unnoticed, as these concerns will be

wrapped up within an engineer's compliant work and thoughtful interactions with others.

Making a choice to treat all persons with fairness can be done as a matter of professional obligation or one of heartfelt principle. Although both matters of commitment get the job done, it is the *motivation* embodied as personal principal that makes a tremendous difference (motivation was explored in detail in [Chap. 2](#)). The third element emphasized by the JIE is also common among codes of conduct published around the world. Groups representing the profession of engineering consistently encourage *excellence*, not just an ability to get by, in matters of technical competence and moral attentiveness.

3.1 The Public

Engineers design and oversee the construction of infrastructure and facilities that are used by the public. There may be an immediate client within the private sector or even a public sector agency, but ultimately members of the public are also affected, directly and indirectly. Employees who enter the workplace, for example, are not direct clients of engineers who design buildings or parking facilities that they use, and those persons are typically unaware of how these engineered systems work and how they themselves might be subjected to risk. Engineers are aware of the risks and understand principles of care in the execution of their duties, and since the extent of harm that may be caused by an engineering failure can affect many people and their livelihoods, responsibility to the whole of the public becomes clear. Ultimate decisions on the direction a project will take do not always rest with the consulting engineers, but they do have discretion on which projects to accept and have authority to express judgment on engineering matters in an effort to convince and

influence the decision makers on appropriate courses of action.

The ethical responsibilities of professional civil and structural engineers to the public are commonly the first to be referenced in published codes of conduct. In fact, the Institution of Engineers (India) identifies the link between engineers and the whole of humanity. Section 3.0 of their ethical code states, “The tenets of the code of ethics are based on the recognition that a common tie exists among humanity and that the Institution of Engineers (India) derives its value from the people, so that the actions of its corporate members should indicate the member’s highest regard for equality of opportunity, social justice, and fairness.”³ Fédération Européenne d’Associations Nationales d’Ingénieurs (FEANI), a federation of professional engineer associations from 33 European countries, succinctly states, “The decisions and actions of engineers have a large impact on the environment and on society. The engineering profession thus has an obligation to ensure that it works in the public interest and with regard for health, safety, and sustainability.”⁴

A general instruction provided in most codes of conduct published by engineering societies or licensing agencies is to *hold paramount the health, safety, and welfare of the public*. The practical application of this tenet may be somewhat vague and will be discussed in more detail in [Chap. 6](#). As such, there can be legitimate disagreement on the execution of this responsibility, especially when there are differing rational beliefs about how to proceed. Robert Baum writes that engineers are *sometimes* justified in working on projects that they personally believe will result in harm to the general public or to specific groups, but the key is to provide criteria that adequately identifies specific situations in which the engineer is justified in participating in these types of projects.⁵

Baum suggests that these criteria (for justification) can be found in the field of medical practice. A patient must (typically) freely give consent for a physician to perform any treatment, even if the doctor believes with all her heart that the treatment is necessary for the health, safety, and welfare of the patient. The ability to enter into communication, not only with the patient but with other individuals (family, etc.), and to provide input on proposed treatment, is the key to making an appropriate and mutually agreeable decision. In relating this scenario to the practice of engineering, the “patient” may be viewed as the public, and Baum summarizes three responsibilities that an engineer must adopt for a meaningful consideration of the needs of the public.

1. Recognize the right of each individual potentially affected by a project to participate (to an appropriate degree) in the making of decisions concerning that project.
2. Do everything in their power to provide complete, accurate, and understandable information to all potentially affected parties.
3. Carry out, to the best of their ability, assignments which have been appropriately approved by the potentially affected parties, even if the engineer believes that they may (or even will) have harmful consequences.

Some would argue against Baum’s seeming concession to the influence of others who may not hold a similar position as the responsible engineer but, rather, I believe the recommendations form a reasonable compromise that can be reached among professionals who may all have scientifically defensible positions. In fact, that is the reason why he explores these options in the first place—as a means

of clarifying somewhat vague and arbitrary tenets of ethical codes with full recognition that professionals can have legitimate differences of judgment and opinion. Baum concludes his chapter with an interesting and powerful statement: “We have been trying to make infallible and omniscient deities out of mortal and finite professional engineers for more than fifty years to no avail. It is time now to try to make real progress by developing realistic and reasonable codes and guidelines that engineers can follow and the public can accept and respect.” No member of society is infallible or omniscient.

3.1.1 Licensure

As a profession where the decisions of members can have a significant impact on the lives of other people, licensing is an important way for society to recognize persons who have met a set of minimum standards of practice. It allows the public to extend trust not only to licensees but also to societies and governing bodies who create standards and requirements for competent practice. Licensing of engineers and land surveyors began in 1907 when the state of Wyoming enacted legislation to help prevent incompetent and unqualified individuals from performing surveys affecting property ownership and water rights. California formally adopted the Professional Engineers Act in 1929 after collapse of the St. Francis Dam and the state of Texas enacted a similar act following a public school gas explosion in 1937. The State of Montana Legislature was one of the last governments to formally enact professional engineer licensing laws, doing so in 1947. [Figure 3.2](#) presents the year in which each of the contiguous United States adopted an engineering licensure law.

1907	Wyoming
1908	Louisiana
1917	Florida
1919	Colorado, Idaho, Iowa, Michigan, Nevada, Oregon
1920	New York, Virginia
1921	Arizona, Indiana, Minnesota, New Jersey, North Carolina, Pennsylvania, Tennessee, West Virginia
1922	South Carolina
1923	Hawaii
1925	Arkansas, South Dakota
1928	Mississippi
1929	California
1931	Kansas, Wisconsin
1933	Ohio
1935	Alabama, Connecticut, Maine, New Mexico, Oklahoma, Utah, Washington
1937	Georgia, Nebraska, Texas
1938	Kentucky, Rhode Island
1939	Alaska, Maryland, Vermont
1941	Delaware, Massachusetts, Missouri
1943	North Dakota
1945	Illinois, New Hampshire
1947	Montana

Figure 3.2 Years in which engineering licensing laws were adopted by states.

Licensed individuals are required to add an appropriately identified stamp and their formal signature to engineering documents that they have completed, or to those for which they have exercised responsible charge. Each individual

state can set its own rules, but this is generally true, with some exceptions. In fact, it is common for licensed professionals to stamp and sign documents that were physically prepared by a different person (or persons), inside the office or outside, but the key element is that the professional who takes responsibility for the work must be the one who decides the technical requirements, manages the necessary computations, directly influences the layout and information presented in construction drawings, and orders reports or testing as needed to validate design decisions. Some states will allow that professional to step into a project after the initial set of documents has already been generated, but the engineer will take complete responsibility for those documents and the understanding is that any engineering-related decisions have been reviewed and approved, or modified and corrected, by the licensee's thorough and thoughtful review. Oftentimes, this requires direct involvement of the engineer from the very beginning of the design process.

Several advisory opinions have been published by the National Society of Professional Engineers Board of Ethical Review (NSPE BER) on the question of stamping and signing documents. Case No. 86-2⁶ introduced a chief engineer within a large engineering firm who places his seal and signature on some of the plans prepared by both registered engineers (who do not stamp the plans) and unlicensed graduate engineers who work under his general supervision. He does not usually have the time to give any of these documents or designs a thorough review, but he trusts the ability of those who completed the documents. In a supervisory role, the chief engineer helps to establish concepts, design requirements, and reviews elements or the status of the design as it progresses. When consulted on technical matters, he provides answers and direction.

The most relevant canon from the NSPE code of ethics (taken from the most current edition) is from Section II.2(b): “Engineers shall not affix their signatures to any plans or documents dealing with subject matter in which they lack competence, nor to any plan or document not prepared under their direction and control.”⁷ The NSPE BER recognizes the importance of an engineering manager, especially within a larger firm, to provide guidance, direction, and counsel to those under his responsible charge, but when he affixes his official stamp and signature, he needs to take a very active role in the direction and control of the project. The term “direction” means (1) guidance or supervision of action or conduct, (2) an explicit instruction or order, and (3) a channel or direct course of thought or action.⁸ The term “control” means (1) to exercise restraining or directing influence over and (2) to have power over or rule.⁹ Without knowing every action taken or the real extent of involvement, the NSPE BER concluded that it was most likely unethical for the chief engineer to seal and sign these documents, as he does not appear to be exercising sufficient review or direct supervision of their preparation.

Another advisory opinion (Case No. 16-2, issued February 23, 2017)¹⁰ included a professional engineer (“Engineer A”) with significant expertise in fire protection engineering who was requested by a fire sprinkler contractor to review, stamp, and sign a layout document prepared by the contractor without assistance or supervision of a professional engineer. The NSPE BER’s opinion is as follows: “Engineer A should decline to review, sign, and seal the fire sprinkler contractor’s proposed layout design documents developed solely by the fire sprinkler contractor. Instead, Engineer A should propose that Engineer A should initiate the design process, taking into account an evaluation of the broad range of hazards and protection schemes required to develop a workable, integrated solution to address fire

safety concerns, and then move forward in preparing design documents for the fire protection system.” It is certainly feasible for Engineer A and the contractor to work together on this effort, but direct supervisory control of design decisions and document preparation by Engineer A is essential.

3.1.1.1 Responsible Charge

As discussed above, licensure requires that a professional engineer assume *responsible charge* for the production of any documents necessary to communicate a design for which she exercises engineering judgment and will affix a stamp and signature, signifying that the documents comply with relevant codes and standards and are ready for construction. The term is defined by professional societies and licensing boards, but it usually means having direct control of and personal supervision over work that involves the practice of engineering (another term that is defined by societies and boards). The responsible licensee must have the authority to set any design conditions or standards and can completely start from scratch if not satisfied with a set of preexisting construction drawings, such as for an older project that an owner wants to have built again.

3.1.1.2 Conflicts of Interest

Licensure opens up a wide range of opportunities for professional engineers who can legally use their skills and talents, in a way recognized by society, to improve conditions around the world. As a result, ethical dilemmas that involve numerous parties may surface that require strategic resolution. One of those situations involves conflict of interest. An advisory opinion to analyze the ethics related to potential conflicts of interest was published by the NSPE

BER, Case No. 15-1, on March 15, 2016.¹¹ The advisory opinion involved an engineer who served as a top official within a state's highway department and wanted to leave in order to become an executive within a local architectural/engineering company. The State reminded the engineer of an existing law that requires top highway officials to wait for 1 year after terminating employment with the highway department before accepting a position with a firm that does business with said department. The engineer leaves the highway department but joins the firm within 1 year as an independent contractor instead of an employee.

The NSPE BER asks, "Was it ethical for the engineer to leave the state highway department and join the architectural/engineering firm as an independent contractor instead of an employee?" Relevant principles within the NSPE code of ethics include:

1. Engineers, in the fulfillment of their professional duties, shall avoid deceptive acts.
2. Engineers shall act for each employer or client as faithful agents or trustees.
3. Engineers shall not, without the consent of all interested parties, promote or arrange for new employment or practice in connection with a specific project for which the engineer has gained particular and specialized knowledge.

In short, the NSPE BER concluded that it was unethical for the engineer to accept employment from the private architecture/engineering firm as an independent contractor instead of an executive employee as an apparent way to circumvent state law. At a minimum, a potential conflict of interest obviously exists between obligations made to the state highway department and those with the new firm.

Although the change of employment has been disclosed, the agreement made with the highway department for a 1-year hiatus after leaving employment is not satisfied by disguising employment as an independent contractor.

The matter involving conflict of interest is described in most regulations by engineering licensing agencies, addressing not only independent judgment but also quality of the work product. The statutes of North Dakota, for example, explain that registrants are to make full prior disclosures to their employers or clients of all known or potential conflicts of interest that could influence, or even appear to influence, their judgment or the quality of their services.¹² If the employer or client objects to the association or financial interest, the engineer is required to withdraw from such association (or refuse the offending service or item). Registrants who provide advisory services to a governmental board must recuse themselves from participation in projects that could fall under the authority of that board or department. Lastly, registrants shall not accept employment when duty to the client or the public would conflict with personal interests of the registrant or another client.

3.2 Employers, Clients, and Colleagues

Collectively, employers, clients, and colleagues form a professional's working environment—those persons with whom interaction occurs almost on a daily basis in the process of doing business and earning a living. Personal and professional responsibilities are of particular importance for a setting that one engages in so frequently over the course of her career. In fact, the conditions that should be present within a professional environment are little different from what one should expect in any other place. However, some

situations of ordinary work within an engineering office that may create a more stressful working environment than may be present in a different place of work include extensive hours worked by salaried employees, added risk inherent in the construction industry, multiple levels of leadership and oversight, the need to stay current with changing codes and standards, shared responsibility for the economic health of the company, meaningful and intentional interactions with colleagues inside and outside the organization, and maintenance of client relationships. All of these activities have a technical or professional procedure to them, but they can also present ethical challenges.

In a paper published by the American Society for Engineering Education (ASEE) entitled “Cheating in College and the Workplace: An examination of engineering undergraduates’ ethical behavior,”¹³ the authors explored potential correlation between engagement in unethical behavior in college and unethical behavior in graduate school and in a professional workplace. Although there were limitations on the extent of the research, including a less-than-desirable sample size and inherent differences between part-time working students and full-time professionals, the findings of the research are nonetheless instructive. They found that there were four primary influences within a university setting on a decision to engage in unethical behavior. These included (1) the student’s perception that her peers engage in this behavior, (2) the extent to which the student acted unethically in high school, (3) the frequency with which a student perceives he is tempted to cheat, and (4) the context of the situation, such as cheating on an examination versus a computer program. In a professional setting, the context of temptation ranged from stealing office supplies to falsifying quality assurance documents.

The study found that participants decided to engage in unethical behavior in both academic and professional settings at about the same rate. However, the most significant differences within each setting were evidenced by the context of that behavior. In a college setting, less than 15% of students who were tempted to cheat on an exam actually did versus more than 45% of those tempted to cheat on a homework assignment. In a professional setting, less than 55% of those who were tempted did falsify records, whereas more than 70% who were tempted to improperly use office supplies followed through. With regard to the perception of peer behavior, 50.2% of participants believed that other students were cheating on exams, but only 34.7% believed that unethical behavior was taking place within the office. Since context was found to be a critical motivator for unethical behavior in each setting, the authors summarized the reported frequency of temptations, and those in the workplace can be seen in [Fig. 3.3](#).

Context	Times Tempted to Violate Workplace Policies (Ever)				
	Never	Once	2–5 Times	6–10 Times	More than 10
Take credit for others work	86.9%	4.6%	3.8%	0.8%	0.0%
Accept improper gifts from vendors	85.4%	5.4%	4.6%	0.8%	0.0%
Ignore safety problems	81.5%	7.7%	5.4%	1.5%	0.0%
Lie about work quality	78.5%	6.2%	6.2%	3.8%	1.5%
Ignore product quality problems	74.6%	6.9%	12.3%	1.5%	0.8%
Falsify records	64.6%	6.9%	17.7%	2.3%	4.6%
Improper use of company resources	47.7%	13.8%	24.6%	2.3%	6.2%

Figure 3.3 Frequency of temptation of employed engineering students to behave unethically in a workplace setting as a function of context. (*Source: Carpenter et al., “Cheating in College and the Workplace: An examination of engineering undergraduates’ ethical behavior,” Proceedings of the 2005 American Society for Engineering Education Annual Conference and Exposition.*)

In another study published by the ASEE, researchers examined the perception of encountering ethical dilemmas among different engineering job types. The highest frequency was reported by those working for nongovernmental/nonprofit (NGO) agencies and the lowest frequency was found within engineering research settings or nonengineering jobs. The findings related to NGO organizations were found to be of particular interest to the researchers, since individuals who are strongly motivated for the public good, and therefore would seem to have a high value for ethics, oftentimes choose to work for these agencies. It was thought that perhaps some of these findings are simply related to the likely condition that persons working in that setting are more sensitive to and aware of moral dilemmas than those who choose a different type of organization. Problematic integration with the cultural norms of other countries could also be a contributing factor to perception.

Companies produce moral working environments in a variety of ways, traditionally through written policies and training, but also by the behavior of owners and managers. The tone is set by the words and actions of leadership, including how clearly the types of things tolerated within the workplace are communicated, but all employees are responsible for their own behavior and contribution to that tone. The most direct result of how one perceives the condition of their working environment is the joy, or lack thereof, in coming to work. This affects their attention span, diligence, willingness to work extra hours to meet deadlines, and even perception of ethical dilemmas. Most workplaces require some employee training to address disruptive behaviors, such as sexual harassment, but these programs are often completed just for the sake of compliance with laws. On the surface, this seems like a robotic and impersonal way to provide training on important conditions,

but sometimes the issues being addressed require a certain sense of urgency that cannot be expressed through emotion or preference.

Professional engineers are instructed to be loyal to a number of different groups that may have competing interests and, as a result, the exercise of loyalty inevitably falls into some form of classification and hierarchy. It could easily be argued that the first sense of loyalty belongs to oneself, and any other loyalties would be defined through this primary lens. Two key characteristics of how loyalty will be exercised are intent and sincerity. If a person loves himself with minimal regard for others, or is indifferent about how others view him, his promises are likely to be shallow and tenuous. People around him will catch on, and they will likely lose respect and harbor negatively viewed impressions on his character that may or may not truly be warranted. Individuals should, therefore, examine themselves by answering questions of intent, such as:

1. How do I want to be thought of by others?
Trustworthy or dishonest? Kind or abusive?
2. How can I best support my family? Diligence or apathy? Hard work or thievery?
3. How can I best serve my employer? Excellence or minimal competence? Adherence to policies or lack of commitment?
4. How should I exercise my responsibility to the public?
Follow laws with due care or bend them? Be open and transparent or secretive and distant?

Loyalty to the public usually takes center stage in the hierarchy as the predominant ethical responsibility of a professional engineer—to consider the health, safety, and welfare of the public above all other matters. This is discussed further in [Chap. 6](#). The practice of land surveying

also represents a very important service, where the public must be confident that surveyors were responsible and acted with objectivity in their work and expression of findings or judgments, out of loyalty to current and future generations. The International Federation of Surveyors states, “The work of surveyors has cumulative and long-term effects on future generations. Many of the functions of surveyors, even those performed for private clients, are by their nature functions that have a lasting impact on society. Most information becomes public information at some point in time and may be used for purposes other than those for which it was initially intended. The information recorded by early surveyors and explorers has, for example, subsequently been used for the expansion of geographical knowledge and for land development. Similarly, land management systems designed for today create an environment in which future generations will live, work, and play. Principles of sustainable development require surveyors to work as much for the future as for the present.”¹⁴

Other responsibilities in the workplace include conflict management (see [Chap. 7](#)), confidentiality, conflicts of interest (discussed earlier in this chapter), and reporting unsafe or unethical behavior. Confidentiality has been briefly discussed in [Chap. 5](#). Unauthorized sharing of information is an example of abusing the truth, which can include the dissemination of trade secrets, disclosing confidential information from a client, or sharing results of an investigation with parties who did not order or pay for the service. Another potential breach of confidence can occur if an employee brings certain designs or information over from a former company, even if that employee originated the design or idea. It may be a simple matter of sharing typical construction details or specifications, but those products used for communication of ideas typically

belong to the organization as a whole, not to the individual or team that completed the work. An engineer's contract of employment should be clear on the matter of ownership—if it is not, clarity should be formally requested.

Whistleblowing presents a complicated ethical dilemma when measured against the requirement of loyalty that professionals have to those who may need to be reported. The act of whistleblowing occurs when an employee, or even former employee, conveys information about a significant moral problem committed by other persons within their organization to someone who is in a position to take action. This could actually occur through a structured mechanism within the company itself, such as a supervisor or the human resources department, but sometimes it involves deviation from formal company procedures or channels. Reported problems could be those that constitute serious threats to safety of persons or property, criminal behavior, unfair or illegal treatment of colleagues or clients, or unethical policies. The advice of an attorney should be sought before taking any action concerning potential legal liability.

Brian Martin, Emeritus Professor and social scientist at the University of Wollongong in NSW, Australia, has written many important papers from nearly every angle of whistleblowing, including issues related to retaliation of an offending organization. He uses the term *political jiu-jitsu*, coined by, and derived from, other sources, to emphasize the psychological transformation brought about in attackers by disciplined nonviolent resistance.¹⁵ When applied to organizations (*organizational jiu-jitsu*) likely to retaliate over serious matters, the idea is that management attacks on whistleblowing employees can backfire if those looking in perceive that the attacks are unfair. To maximize the potential for support of the whistleblower's actions, Martin

offers four proactive steps and four recommendations for personal behavior:

1. Exhaustively document claims and personal work performance in order to counter denials and the destruction of evidence.
2. Document attacks by management in order to mobilize support.
3. Ensure that the message is communicated to allies, opponents, and independent observers.
4. Be wary of official channels, which may inhibit mobilization of support by diverting effort and giving the impression that justice will be served.
5. Always act in an exemplary fashion—be polite and supportive of colleagues.
6. Be open about one's actions in order to counter possible claims of nefariousness.
7. Choose forms of action that allow safe participation by others.
8. Always consult carefully before acting to gauge how people will respond to the action and to management responses.

3.3 The Profession

Engineering societies universally encourage members to act in a way that upholds the honor, integrity, and dignity of the profession. From a practical standpoint, this means that engineers shall represent their own qualifications honestly, will not speak negatively and without objectivity toward other members of the profession in a rude and condescending manner, will make an effort to educate the

public and advocate for the profession, and will actively mentor graduates (or even younger children who may not consider such a career unless another person were to encourage them). This profession thrives on diversity, and much more of it is needed. As members encourage others to explore the possibilities and offer their expertise in a spirit of genuine attention to the well-being of others, the profession will benefit and grow in appreciation by societies and cultures around the world.

Adopting the title *engineer* when referring to oneself can be tricky, as licensing boards typically restrict the use of specific titles to those persons who are duly registered in the geographic region of practice. This is a way of protecting not only the public but also the profession. Protections commonly extend to descriptive titles using the word “engineer,” such as *professional engineer*, *registered engineer*, *civil engineer*, *structural engineer*, and others, but this is not a uniform practice or interpretation of law and rights.

An interesting case was decided by the United States District Court in December 2018 involving the Oregon State Board of Examiners for Engineering and Land Surveying (“Board”) over use of the title *engineer*.¹⁶ The plaintiff in the case, a citizen of the Kingdom of Sweden and a lawful permanent resident of the United States, earned the equivalent of a bachelor of science degree in electrical engineering in Sweden and spent his career working in the field of electronics. He did not possess an engineering license from any state. He became interested in traffic light timing and spent 3 years studying the standard method for calculating the duration of the light stages and wanted help in continuing this research. In September 2014, he contacted the Board asking for support and help, but they responded by notifying him that he violated engineering laws by referring to himself as an “electronics engineer” and

stating “I’m an engineer.” In April 2017, the plaintiff filed a complaint against the Board alleging that the engineering practice and title laws violate the First Amendment’s Speech and Petition Clauses, both to him directly and on its face overall.

The *practice laws* generally prohibit any person from practicing or offering to practice engineering in Oregon unless that person is registered to practice engineering in Oregon. The practice of engineering is further defined as “performing any professional service or creative work requiring engineering education, training, and experience ... including consultation, investigation, testimony, evaluation, planning, design and services during construction, manufacture or fabrication.” In its evaluation, the court concluded that the plaintiff failed to demonstrate that the practice laws present an unacceptable risk of suppressing ideas, especially since the supreme court has long recognized the authority of states to regulate professional practice and conduct, even if that conduct incidentally involves speech.

The *title laws*, however, turned out to be a different story. These laws define *engineer*, *professional engineer*, and *registered engineer* to describe an individual who is registered in the state and holds a valid certificate to practice engineering. The court decided that the title laws restricted speech based on content. In this case, the plaintiff wants to communicate a certain message (“I am an engineer”), and whether he may do so under the title laws depends on what he actually says. In order to justify this restriction, the state must prove that the regulations are narrowly tailored to serve compelling state interests. With regard to the use of the term *engineer*, the court offered the following conclusions:

1. “The statutes (*title laws*) prohibit truthfully describing oneself as an ‘engineer’ in any context. This restriction

clearly controls and suppresses protected speech.”

2. “While a state may regulate misleading commercial speech, the term ‘engineer,’ standing alone, is neither actually nor inherently misleading. A statement is inherently misleading when the particular method by which the information is imparted to consumers is inherently conducive to deception and coercion.”
3. “Courts have long recognized that the term ‘engineer’ has a generic meaning separate from ‘professional engineer’, and that the term has enjoyed widespread usage in job titles in our society to describe positions which require no professional training.”
4. “The Board justifies the title laws only by arguing that the term ‘engineer’ is misleading, but nothing in the record supports the conclusion that a reasonable person would assume that an individual who calls herself an ‘engineer’ is necessarily a registered professional engineer.”

Do the findings of this case suddenly place the engineering profession and prestige in a state of uncertainty? Not really. There may be better ways to tighten up the definitions and usages of professional titles, but that is more a matter of education for the members of society as opposed to definitive changes within the industry. One who chooses to make a living as a civil or structural engineer understands the requirements of education, experience, and examination to become licensed to practice in an occupation recognized by the state or territory in which construction projects will be completed. The importance of a title, however, is also in the fact that any member of the public can find out the requirements for qualification and licensure that grants the authority to use the title in order to determine a person’s suitability for a task, at least as

recognized by a legislative body charged with protecting the public. There is important value in this ability that citizens have.

3.3.1 Serving as an Expert Witness

An engineer also represents the profession when serving as an expert witness in a court of law (see [Fig. 3.4](#)) or mediation arrangements. Expert testimony is required to establish ordinary care of licensed practitioners and to explain customary actions within a profession so that a jury or a judge can understand how the profession is supposed to function and what members are supposed to pay attention to. Ethical codes require honest evaluations and opinions of professional engineers, and sometimes the facts of a case may not point in the direction that the hiring party wants, but it is almost impossible for an engineer to know where things will go until after enough time has been spent reviewing the case history and documents. It is important for engineers who are hired as experts to have some sense of where the facts lead their judgment and opinion as soon as possible so they can inform the hiring party accordingly. This has also been discussed in [Chap. 2](#) related to the distinctions between error, negligence, and incompetence.



Figure 3.4 United States Supreme Court building. (Photo by Bill Mason on Unsplash.)

The Engineers and Geoscientists British Columbia published a *Guide to the Code of Ethics* to clarify principles that members need to be aware of and adhere to. Section 4.7.1 of the guide instructs members to distinguish between facts, assumptions, and opinions when giving testimony or summarizing the results of their work or understanding of engineering principles in all forms of communication.¹⁷ Facts, it is explained, are statements that can be supported and proven by data or that have received certification from a credible source. These can be declared as truth, but they must be stated with precision, clarity, and with careful attention and diligence to ensure accuracy and reliability.

Assumptions are needed to fill in the gaps between facts so that well-reasoned conclusions can be offered. These should be clearly identified and explained, where possible, as to the range of error that could be expected. Last, opinions are beliefs based on facts, assumptions, knowledge, and experience, which should be stated professionally and obviously with objectivity, fairness, and independence.

In his book, *The Expert Expert Witness*,¹⁸ Professor Stanley Brodsky provides numerous guidelines and interesting anecdotes to help people prepare for work as an expert witness and to complete their task honorably and effectively. Some of these recommendations are included below (not an exhaustive list):

1. Do not allow your reports or testimony to be recast into simple-minded and arbitrary groupings of the attorney's choice, such as assigning shallow letter grades to an action.
2. Seek to become authentically yourself as a professional and as a witness.
3. Never make up answers. Keep your answers carefully within the context of what you know and remember.
4. When necessary, prepare yourself with peer-reviewed research to defend the nature of your theories, principles, and methodologies.
5. Never accept attorney condensation, summary, or conclusions as your only working materials. Your responsibility is to review and assess the case personally and professionally.
6. Do not be immediately agreeable to affirmations of common sense until you have thought through the specific meanings of the questions for your data, conclusions, and opinions.

7. Maintaining integrity on the stand calls for careful listening, avoidance of anticipatory answers, and staying faithful to your findings and knowledge.

3.4 Review Questions

- 3.1.** What are the six groups presented in this chapter that a professional engineer is responsible to?
- 3.2.** When a license to practice engineering is granted, what does society expect is true of the recipient?
- 3.3.** What is it that makes an engineer's responsibility to all of society clear?
- 3.4.** What should a corporate member's actions indicate as their highest regard according to the Institution of Engineers (India)?
- 3.5.** What are some of the requirements for an engineer who is in *responsible charge* of a project?
- 3.6.** According to the statutes of North Dakota, what is a responsibility of a registrant who wants to serve on a governmental advisory board?
- 3.7.** Identify at least three situations of ordinary work within an engineering office that may create a more stressful working environment than may be present in a different place of work.
- 3.8.** What four primary influences are reported by the American Society for Engineering Education (ASEE) on a decision by college students to engage in unethical behavior?
- 3.9.** Why did the ASEE believe the perception of ethical dilemmas was higher among those who worked for NGO organizations?

- 3.10.** How is the tone set for creating a moral working environment within a professional business?
- 3.11.** What is the definition of whistleblowing?
- 3.12.** What are the recommendations offered by Brian Martin for a whistleblower's personal behavior in order to maximize the potential for support by others?
- 3.13.** Why might it be tricky to claim the title *engineer*?
- 3.14.** Why is having a professional title important to other members of the public?
- 3.15.** List three recommendations by Professor Stanley Brodsky for engineers who serve as expert witnesses.

3.5 Discussion Questions

- 3.1D.** List one responsibility that a professional engineer has for each of the six groups presented at the beginning of the chapter. Identify a different item for each group.
- 3.2D.** Do you agree with Robert Baum's statement that engineers are sometimes justified in working on projects that they personally believe will result in harm to the general public? Why or why not?
- 3.3D.** What steps would be involved in the process of disseminating relevant information to all potentially affected parties related to a project with which an engineer may have reservations about? Refer to Robert Baum's discussion on the matter.
- 3.4D.** List at least five strategies for resolving ethical dilemmas.
- 3.5D.** The statutes of North Dakota require that a licensee provide full disclosure to an employer or client

of a personal conflict of interest. Suppose an engineer forgets to disclose something important and has already begun work on a conflicting project. What steps should be taken to resolve the dilemma? Keep in mind that the work has already begun and it may be difficult to shift personnel around.

3.6D. Offer five potential consequences of a dishonest land survey and explain why such data obtained could prove to be problematic to future users.

3.7D. Explain why it may not be permissible to bring construction details from projects completed with a previous company over to your new company? What would be some permissible ways to share knowledge or things learned?

3.8D. Obtain a copy of NSPE BER Case No. 19-1, *Disclosure of Personal Information*, from the NSPE website (<https://www.nspe.org/resources/ethics/ethics-resources/board-ethical-review-cases/disclosure-personal-information>). Provide at least three potential consequences that Engineer A might face if he withheld information about his autism, and three potential consequences if he fully reveals the information. Describe a suitable context by which Engineer A could reveal his condition.

3.9D. Do you agree with the conclusions offered by the United States District Court regarding the use of the term *engineer* in the State of Oregon? Why or why not?

3.10D. Research and find five other practical recommendations for engineers who serve as expert witnesses (than those mentioned in this chapter). Identify your source.

¹“What Is a Professional Engineer?” Illinois Society of Professional Engineers, accessed March 21, 2020, https://www.illinoisengineer.com/illinoisengineer/licensure/what_is_a_PE.

²Jamaica Institute of Engineers, *Code of Ethics*, accessed November 15, 2020, <https://www.jiejamaica.org/code-of-ethics/>.

³The Institution of Engineers (India), *Code of Ethics for Corporate Members* (West Bengal, Kolkata, India: The Institution of Engineers (India), March 1, 2004).

⁴FEANI, *Ethics and Conduct of Professional Engineers* (Brussels, Belgium: FEANI, September 29, 2006).

⁵Robert Baum, James H. Schaub, and Karl Pavlovic, eds., “The Limits of Professional Responsibility,” *Engineering Professionalism and Ethics* (New York: John Wiley and Sons, 1983).

⁶F. Wendell Beard et al., *Report on a Case by the Board of Ethical Review, Case No. 86-2, Signing and Sealing Plans Not Prepared by Engineer* (Alexandria, VA: NSPE, 2016).

⁷National Society of Professional Engineers (NSPE), *Code of Ethics for Engineers* (Alexandria, VA: NSPE, July 2019).

⁸*Merriam-Webster’s Collegiate Dictionary*, 10th ed., s.v. “direction.”

⁹*Ibid.*, s.v. “control.”

¹⁰John C. Branch et al., *Report on a Case by the Board of Ethical Review, Case No. 16-2, Signing and Sealing of Documents—Fire Sprinkler Layout Drawings* (Alexandria, VA: NSPE, 2016).

¹¹Robert J. Andreoli et al., *Report on a Case by the Board of Ethical Review, Case No. 15-1, Conflict of Interest—Former Government Official—Independent Contractor for Firm* (Alexandria, VA: NSPE, 2016).

¹²State of North Dakota Board of Registration for Professional Engineers and Land Surveyors, *Rules of*

Professional Conduct, Code of Ethics, NDCC 43-19.1-24, Section 28-03.1-01-10.

¹³Donald Carpenter, Trevor Harding, and Cynthia Finelli, “Cheating in College and the Workplace: An Examination of Engineering Undergraduates Ethical Behavior,” *Proceedings of the 2005 American Society for Engineering Education Annual Conference and Exposition*, June 2005, Portland, Oregon, <https://peer.asee.org/15462>.

¹⁴Ken Allred et al., *FIG Publication 17—Statement of Ethical Principles and Model Code of Professional Conduct* (London, UK: The International Federation of Surveyors, September 1998).

¹⁵Brian Martin and Will Rifkin, “The Dynamics of Employee Dissent: Whistleblowers and Organizational Jiu-Jitsu,” accessed May 16, 2021, <https://documents.uow.edu.au/~bmartin/pubs/04por.html>.

¹⁶*Järlström v. Aldridge*, 366 F. Supp. 3d 1205—Dist. Court, D. Oregon 2018.

¹⁷Engineers and Geoscientists BC, *Guide to the Code of Ethics* (Burnaby, British Columbia, Canada: Engineers and Geoscientists BC, 2021), pp. 20–21.

¹⁸Stanley L. Brodsky, *The Expert Expert Witness* (Washington, DC: American Psychological Association, 1999).

CHAPTER 4

Legal Expectation of Care in Practice

This is probably a good place to, again, state that I am not an attorney and am not dispensing legal advice.

However, as a licensed professional engineer, I have an adequate base of knowledge on legal issues that engineers face in their daily practice and believe I can provide good information to help you understand and explore these issues. Citing legal cases can be tricky because they are region- and project-specific—rulings and laws vary widely across the country (any country), and even within the same jurisdiction depending on which court reviews the case.

However, those who practice law have a very strong determination to use and establish precedent in presenting and deciding cases, and overall the track record is admirable. Though there can be a wide range of applications, and laws vary from state to state (be sure to check your own state or region's laws), much can still be learned from studying court opinions and rulings.

Most of us are familiar with the depiction of justice as a lady, typically wearing a blindfold and holding a balance in one hand and a sword in the other. Some creations, such as

the bronze statue shown in [Fig. 4.1](#), also include a book and a snake at her feet. She is called Justitia, the personification of justice in Roman art, and is linked with Themis, the Greek goddess over divine law and order. In Roman mythology, Justitia represents one of the four virtues (justice), along with prudence, fortitude, and temperance. In Greek mythology, Themis was a daughter of Uranus (a personification of heaven) and Gaea (a personification of earth) and served as a messenger, delivering rules of conduct established by the elder gods. She taught mankind the primal laws of justice and morality which included precepts of piety, hospitality, governance of affairs, conduct of assembly, and offerings to various gods. Serving as a counselor to Zeus, king of the gods, Themis was responsible for notifying him when the rules of conduct were breached (she was also one of Zeus' earliest wives).



Figure 4.1 Lady Justice and her tools: blindfold, balance, and sword.

The blindfold for Lady Justice is an invention of the 16th century, thought to have been added to signify the tolerance or ignorance of the legal system to abuse and injustice. Since that time, however, it has come to symbolize the impartiality of justice: she could discern between good and evil and pass a just sentence without being influenced

by what she saw with regard to the accused or the accuser. She could not be swayed by richness or poverty, by power or weakness, by title or privilege. Each case would be judged equally according to its merits rather than the circumstances of the parties involved. The scales of justice are carried to represent fairness in weighing the evidence of a case. This common interpretation is filtered through the tenets of the Age of Enlightenment (17th and 18th centuries), which stressed reason, logic, criticism, and freedom of thought, implying a mechanistic process in determining whether the scales would tilt toward innocence or guilt. They have also represented the balance of individual needs against those of society.

The sword symbolizes authority to carry out a sentence and is reminiscent of supreme leaders and monarchs of older times. It is usually unsheathed, indicating that justice will be swift, and double-edged, indicating that it can cut at either party with equal strength. As a symbol of protection, individuals are meant to feel safe under the authority of the law or to fear it if they intend to do harm.

The symbol of justice serves as a link between natural law and rational law, incorporating the culture of the divine with the culture of civil society and defending the inherent right of the individual by recognizing the responsibilities of society and of law. She reminds us that fair and equitable treatment in matters of law is one of our highest virtues, and that this value also extends to simple matters of human interaction: how we treat one another. We cannot separate ethics or morality from law, but there are important distinctions to understand in order to build a better appreciation of our responsibilities as engineers and as human beings.

4.1 What Is the Law?

When the law is brought up with regard to our behavior, we immediately imagine punishment or various consequences. We are taught this from early infancy when our parents used some form of reinforcement, either positive or negative, to help us understand what behaviors are good or bad. Good behaviors are *generally* those that do not cause harm to oneself or to another, whereas bad behaviors are presented as dangerous, destructive, or disruptive. As we get older, our knowledge base of what is good and bad grows according to outside influences and to our own research. As responsible citizens of a healthy society, the law plays a crucial role in helping us evaluate our desires and control our actions, hopefully in an effort to improve society but oftentimes we adjust our behaviors in order to avoid punishment or negative consequences. We discussed motive in great detail in [Chap. 2](#).

Merriam-Webster's Collegiate Dictionary defines *law* as “a binding custom or practice of a community; a rule of conduct or action prescribed or formally recognized as binding or enforced by a controlling authority.”¹ In the United States, according to the *Constitution*, Congress, which consists of a House of Representatives and a Senate, is given the authority to create rules and laws for the government and for society as a whole. The Executive Branch, of which the President is head, is responsible for implementing and enforcing laws created by Congress. There are currently 15 individual executive departments, whose head is appointed by the President and confirmed by the Senate. The Judicial Branch of the federal government is tasked with interpreting the laws of Congress, and the Supreme Court is the highest court of the land. In Federalist Paper No. 78, Alexander Hamilton wrote, “The interpretation of the laws is the proper and peculiar province of the courts. A constitution is, in fact, and must be regarded by the judges, as a fundamental law. It therefore belongs to them

to ascertain its meaning, as well as the meaning of any particular act proceeding from the legislative body.”²

The purpose of the law, it could be argued, is primarily to protect the fundamental rights and freedoms of every individual citizen. It does this by establishing standards of conduct and by resolving disputes. When we consider the vast accumulation of laws and regulations over the many years of a country’s existence, however, the inherent complication of the law quickly becomes apparent. How can a person be certain he has not broken a particular law in the exercise of an ordinary duty? People typically remember laws regarding major crimes such as murder, thievery, acts of cheating, and so forth, but the line between what is legal and illegal may not always be readily discernable. In order to manage such a broad spectrum, those who are part of a profession focus on aspects of the law that are pertinent to their own area of practice. Having a clear understanding of ethical principles can help one navigate through the administration of the law, even though the law does not necessarily regulate all aspects of ethics and morality.

Precedent and historical analysis of legal decisions are important functions needed to help future societies apply equivalent rulings on similar cases with similar facts and evidence, so that individuals in similar situations are treated equally instead of based on a judge’s personal views or beliefs. Any case that has been decided in the past has the potential of establishing precedent (in some sense, in part usually) for an equivalent ruling on a more recent case. In order for a prior case to be considered as a binding precedent, it must address the same legal questions as applied to similar facts and it also must have been decided by the same court or a superior court within the hierarchy. The legal system includes checks and balances on the use and legitimacy of precedent, including actions by Congress, and even powers to overturn a court’s own rulings through a

Careful case-by-case review and assessment of the merits of taking such action.

4.1.1 Civil, Criminal, and Ethical Crimes

The breaking of a law requires some type of consequence. Consequence takes the form of compensation: if another person is wronged, that person should be compensated by whomever caused the event. Compensation that an individual or entity receives can take the form of a court order against the other party to do or to refrain from doing something, or it can include monetary damages.

Compensation given to a victim can also take the form of prison time for the perpetrator, or even a penalty of death if the crime is significantly brutal and causes the death of another person.

Evidence in a case may prove a willingness to commit wrong, or the action being examined could be involuntary—a true accident. A civil crime is usually referred to as a wrong committed by an individual member or entity within society against another person, persons, or entity. The burden of proof for a civil matter is based on clear and convincing evidence, or a high probability of occurrence, which is less stringent than a criminal matter. Matters of compensation for civil crimes include something called *torts*, which will be discussed later in this chapter.

A criminal offense is viewed as one that was committed against society as a whole, and the accused is therefore sued by a governing body within some level of the court system, whether federal, state, or local. Because penalties can be more severe in criminal cases, the burden of proof rises to a requirement of belief in guilt beyond a reasonable doubt. An engineer could be brought under a criminal suit for negligence that is so gross as to show blatant disregard

for the safety of human life. Culpable negligence has also been characterized as a reckless disregard of the probabilities of fatal consequences to others as a result of the willful creation of an unreasonable risk.³ Concepts of negligence and criminal liability are discussed more fully in [Chap. 2](#).

It can be difficult to assign a legal consequence, or punishment, to an individual who commits an ethical offense unless evidence clearly shows that some law has been broken. There are laws against defrauding another or damaging their reputation, but judgments related to ethics also focus on intentions and attitudes, which are difficult to prove with evidence. To treat others with hostility is certainly annoying and disruptive, but it may not rise to the level of illegality. Virtues like honoring diversity and respectful communication are strongly encouraged by most engineering societies, but issuing consequences for someone who doesn't share those same values is almost impossible to do with fairness and impartiality. Oftentimes, consequences come in the form of reduced business (people don't like to be around others who are hostile and disrespectful), a lack of professional colleagues who choose to maintain association, and a loss of future opportunities.

4.2 Construction Regulations

In the United States, it is generally understood that states retain the authority to regulate construction within their own boundaries through the Tenth Amendment to the *Constitution*. This amendment simply states, "The powers not delegated to the United States by the *Constitution*, nor prohibited by it to the States, are reserved to the States respectively, or to the people." States also have the power to establish and regulate local governments, retaining a position of supremacy over city, county, or regional

governments and other special districts. All of these governing bodies must work together to ensure their citizens receive necessary services, and oftentimes the local level is the most expedient platform to make sure this happens. Some states, therefore, transfer some of their power to local jurisdictions through a charter that carefully defines accepted responsibilities and conditions of authority (this is called *home rule*). Under home rule, municipal governing bodies operate with relative autonomy (according to their charter) without interference from the state, though they are still subject to requirements of the federal and state constitutions.

Figure 4.2 summarizes essential elements of *Dillon's Rule*, which is used for identifying the ordinary authority of local governing bodies within a state (lacking a special charter), named after Iowa Supreme Court justice John F. Dillon (1831–1914 CE). Dillon's Rule is based on the idea that since the Federal *Constitution* makes no mention of local governments, the direct implication is that these bodies are simply creations of the state and they serve at the pleasure of the state. James Madison describes this condition in Federalist Paper No. 45, where he offers, "The powers reserved to the several States will extend to all the objects which, in the ordinary course of affairs, concern the lives, liberties, and properties of the people, and the internal order, improvement, and prosperity of the State."⁴ Even under a system where state powers are particularly dominant, local jurisdictions are commonly given authority to establish zoning regulations, develop planning models and restrictions, impose some forms of taxation, and other duties that are more suited to the people who are directly affected.

A municipal agency can only exercise the following powers:

1. Those that are explicitly granted by the state
2. Those necessarily implied or incident to powers explicitly granted
3. Those absolutely essential (not simply convenient) to the objects and purposes of the municipal government
4. Those which are proven *beyond any reasonable doubt* to have been conferred by the state

Figure 4.2 Elements of Dillon's Rule regarding state powers.

The field of construction law is complex and involves several important topics. When a working relationship is being formed, the parties will enter into some type of agreement. This contract requires adherence to specific rules that can differ across state boundaries. If things go wrong, the language in these contracts ends up being critical to managing disputes. The American Institute of Architects publishes some boilerplate contracts useful to their members, and the Coalition of American Structural Engineers develops guidelines and contracts that outline best practices for risk management.

Accidents and mistakes in the construction industry can lead to damage, injury, or death, and an engineer can be brought into a potential dispute that assigns responsibility and a requirement for compensation. The area of law that deals with the wrongful actions of an individual or entity, causing damage or injury to another individual or entity for which some form of compensation is warranted, is called *Tort Law*. Many of the characteristics of today's tort system were introduced by King Henry II of England (1154–1189 CE), who is said to have formed the basis of English Common Law. Liability can be assessed for a variety of different conditions, which are summarized (in part) in [Fig. 4.3](#).

General areas of tort liability:

1. Fault of the defendant
 - a. Strict liability, such as for a manufactured product
 - b. Negligence or gross negligence
 - c. Intentional acts
2. Injuries caused to other persons
 - a. Wrongful death
 - b. Assault/battery
 - c. Infliction of emotional distress
 - d. False imprisonment
3. Property-related nuisance or harm
 - a. Trespassing
 - b. Fraud/misrepresentation
 - c. Unfair competition

Figure 4.3 Examples of tort liability.

4.2.1 Planning and Construction Codes

The area of construction law that an engineer deals with on a nearly daily basis is that related to regional planning, technical design, and quality of the built environment. Planning of a region is most often done on a local level, as people who are directly involved in making decisions should also be those who must live with those decisions. The process includes the design and development of land and can be just as much a political process as it is a technical one. Urban planning includes management of city growth, defining the use of different areas by zones, transportation system improvement, protection of historical resources, and assisting with the development of a business-friendly environment.

Civil engineers work closely with urban planners to make sure designed systems will comply with local laws and fit into the region's layout. Any disturbance of the land may have rippling effects over a larger area than a local engineer may be aware of, therefore coordination of a project with future plans for a region is vital. Cities, counties, and other jurisdictions procure and adopt a set of codes to define minimum requirements for how rainwater needs to drain away from a site, distances that need to exist between structures and property lines, slopes that will be adequate to maintain gravity flow of piping, and numerous other issues that either have a history of good performance or requirements that meet newer innovations or legislation.

Early regulations for construction of buildings evolved in reaction to some type of disaster, usually a major fire. Fire-resistant materials were developed and separation between structures became mandatory. Minimum requirements for structural safety also became more common and in 1921, the Building Code Committee of the U.S. Department of Commerce was formed in recognition of a general public demand for greater uniformity and economy in building code requirements. The committee published its first resource, *Recommended Minimum Requirements for Small Dwelling Construction* in 1923 and a second report, *Minimum Live Loads Allowable for Use in Design of Buildings*, was published in 1925. These recommendations were available for individual states to adopt and use for the regulation of construction within their boundaries.

State and local governments rarely write their own construction codes, but rather adopt model codes that are written by a group of committees who specialize in different areas. As a model code, the regulations have no effect on law until a governing jurisdiction adopts it for use within its boundaries. The International Code Council (ICC) is the most prolific producer of building codes, and the International

Building Code (IBC) is one of the primary documents that detail minimum requirements for design and construction of structures. Section 101.3 of the IBC states, “The purpose of this code is to establish the minimum requirements to provide a reasonable level of safety, public health and general welfare through structural strength, means of egress facilities, stability, sanitation, adequate light and ventilation, energy conservation, and safety to life and property from fire, explosion and other hazards, and to provide a reasonable level of safety to fire fighters and emergency responders during emergency operations.”⁵ Model codes are published by the ICC every 3 years to stay up to date with the latest findings from research and testing. An attempt is also made to avoid unnecessarily increasing construction costs and to give equal consideration to common materials used in creating structures.

Chapter 35 of the IBC identifies standards for design, materials, and methods of construction produced by other agencies and committees that are referenced throughout the code. Section 102.4 of the IBC explains that these other standards shall be considered part of the IBC itself to the prescribed extent of that reference. Furthermore, where conflicts occur between the IBC and standards referenced therein, the provisions of the IBC are to govern. This is an important provision that greatly simplifies the process of adoption and use of a state’s set of construction codes. The year of publication of the standards listed are those intended for adoption with that specific edition of the IBC, but a state is not obligated to adopt the latest edition of any standard or code. This makes it particularly important for an engineer who does business in multiple states to determine which edition of each relevant standard is in effect.

4.2.2 Ethical Concerns with Adopted Codes

The adoption and use of technical codes for the design of structures used by the public raises some ethical issues as well. What if a state or local jurisdiction requires the use of an older standard? Advances in our understanding of how buildings resist load could have been discovered and incorporated into newer code documents, and these may be missing from an older set of regulations. Common codes of ethical standards published by numerous engineering societies include a requirement to hold paramount the safety, health, and welfare of the public (see [Chap. 6](#))—would this imply the use of the latest scientific developments? Not necessarily. Construction is regulated by state governments within their boundaries, and those bodies adopt standards believed to be appropriate for their specific region. Structures built within those boundaries require compliance with the adopted codes and standards that a governing jurisdiction has determined are necessary to protect the safety, health, and welfare of the public—their goal is the same as that advanced in common engineering ethical codes.

When conflicts occur between adopted standards and other documents that an engineer believes are more appropriate to fulfill the exhortation to hold the safety, health, and welfare of the public paramount, there are a few options that could be considered in the design process (this is certainly not an exhaustive list):

1. Make sure the design complies with the provisions of the state's adopted code as well as with those requirements found in documents the engineer believes to be more pertinent. When there are conflicts, make sure the more stringent provisions are accounted for.

2. Appeal to the building official to allow the use of a newer code or more relevant standard of design for the project at hand. This should include sufficient justification through articles, commentaries, supplemental calculations, or other suitable references.
3. Identify the specific issues that warrant consideration of using a newer code or standard and encourage the legislative body of the state to make changes.
4. Seek the assistance of nationwide engineering societies, or from the ICC itself, for some type of formal opinion regarding the issues believed to put the safety, health, or welfare of the public into question.
5. Submit your design with additional justification or opinion provided through peer review. The building official would still have to approve the design but including the assistance of another duly qualified engineer helps to boost the validity of design decisions.
6. Refuse to offer engineering services for projects within that state's boundaries.

There may be practical limitations to fulfilling any one of the above courses of action, which could lead to some type of blended approach that includes the acceptance of the building official who is charged with enforcing the state's construction codes.

An interesting perspective is provided in the ruling for the case of *Hoffert v. Owatonna Inn Towne Motel, Inc.* (Minnesota, 1972), where a governing jurisdiction's liability or responsibility for constructed facilities within their boundaries does not fall within the intent of construction codes or services.⁶ The court stated, "Building codes, the issuance of building permits, and building inspections are

devices used by municipalities to make sure that construction within the corporate limits of the municipality meets the standards established. As such, they are designed to protect the public and are not meant to be an insurance policy by which the municipality guarantees that each building is built in compliance with the building codes and zoning codes. The charge for building permits is to offset expenses incurred by the city in promoting this public interest and is in no way an insurance premium which makes the city liable for each item of defective construction in the premises.”

4.3 Licensing an Engineer

Another legal aspect of an engineer’s duty is compliance with the requirements for professional licensure. In the United States, each state has the authority to define qualifications for someone to take the title of *professional engineer* to work on projects within their boundaries, and these qualifications are fairly consistent across states. The standard of care for engineering practice does not require perfection, or even exemplary service, but minimal competence that can be demonstrated through a variety of means such as experience, education, and an examination. This is discussed in more detail in Chaps. 2 and 3.

Although requirements can vary between states, most licensing boards require a minimum of 4 years of verifiable work under the direction of an engineer who is licensed in the same discipline. An engineering education program typically requires accreditation by the Engineering Accreditation Committee of the Accreditation Board for Engineering and Technology (EAC/ABET), and a state can impose more stringent requirements, such as a need for a graduate degree. Examinations play an important role in judging the ability of an applicant to apply knowledge to

engineering problems. A fundamentals exam is usually required, commonly taken before a student completes their educational program, then another exam that is specific to the engineering discipline being sought. The National Council of Examiners for Engineering and Surveying (NCEES) develops and grades exams that can be used for licensure, making the process quite simple for any state and allowing for ease of reciprocity (obtaining licensure in multiple states).

4.3.1 Standards of Practice and Conduct

Licensing agencies set their own requirements for eligibility, but they also define standards of practice and conduct to which licensees are expected to follow. Standards of practice are generally applied to the work of an engineer who serves in responsible charge of a project, which means that she maintains control over engineering-related decisions throughout the extent of the project. She makes those decisions herself, or others over whom she provides supervisory control may also be authorized to make decisions. This is discussed further in [chapter 3](#). Standards of conduct are typically defined under simple admonitions, such as “don’t cheat,” “be honest,” and “be kind.”

When an engineer violates provisions of the licensing agency’s practice act, that agency can impose a variety of consequences, such as a fine, suspension of license, or revocation of license. A complaint filed against an engineer is followed up by an investigation, which may include the services of a subject matter expert who will review the technical merits of the complaint. Upon receipt of the expert’s report, a board of delegates will review other facts of the case and decide upon necessary action.

Issues that are characterized by apparent ethical failures on the part of the licensee can be difficult to decide conclusively, as many of these issues are directly related to intent and can change depending on circumstances. The Tennessee Board of Architectural and Engineering Examiners identifies some instances of definable, legal issues related to conduct: “The Rules of Professional Conduct, which carry the enforcement of law, specify proper conduct of practice (or title in the case of registered interior designers), service in areas of competence, the need for objectivity and truth in public statements, the avoidance of conflicts of interest and improper acceptance of work, and misconduct in practice.”⁷

4.4 Defining a Standard of Care

Mistakes are unintentional (for the most part) and a person generally strives to be understood when communicating something. People process information differently, and what appears to be complete for the purpose of communicating something to one person may be insufficient to another. What does that mean to the communicator? Teachers learn how to present material to a wide variety of students with different modes of learning, but engineers do not typically have that training. It is difficult to manage expectations that can vary significantly from one’s own, but it is part of the practice of engineering. Over time, an engineer learns the level of expectation of individual clients and adjusts the mode and extent of communication accordingly, but that same engineer’s personal preference or concept of what is complete remains the same. Sometimes when a client believes an engineer has provided incomplete work, expectations are not met and the client may question the competence of the engineer.

Fortunately, the legal system recognizes the fact that humans (i.e., engineers, doctors, attorneys) are not perfect and takes great measures to clearly define what is expected in the execution of professional duties. That expectation is called *standard of care*, which includes recognition of several key qualities of an engineer and his work, summarized in Fig. 4.4. The standard of care is usually defined and scrutinized on the basis of technical professional activities, not necessarily matters of ethics or moral behavior, although it can be and, in fact, has been. In 2008, a case heard in Iowa identified the relevance of engineering ethical codes in establishing a standard of care in the exercise of professional responsibility.⁸ Referencing the Iowa licensing board's ethical code, as well as that published by the American Society of Civil Engineers, the opinion states, "The administrative and ethical codes, on the other hand, in nearly identical language requires engineers to be 'objective and truthful' and to include 'all relevant

1. A requirement for care exists.
2. Ordinary knowledge and experience are possessed for the work being performed.
3. Reasonable judgment and diligence are employed in the execution of contractual duties.
4. "Ordinary" and "reasonable" are defined through the following:
 - a. Typical practice of a reputable professional on the same type of project
 - b. Performance of work required in a similar locality
 - c. Professional behavior and execution of work under similar circumstances and conditions

Figure 4.4 Key elements that typically define standard of care.

and pertinent information' in their reports, statements, and testimony ... a violation of professional ethical standards is some evidence of negligence."

An engineer can practice with ordinary and reasonable competence in completing calculations and drawings for a

project, for example, and at the same time bill the client for hours not worked on that same project. Dishonesty can carry a legally defined punishment, but it can also simply be a matter of character. Whether an engineer chooses to follow a standard of care for fear of being sued, or out of a selfless respect for the profession, rarely would factor into a jury's decision as to whether that standard was met. If blatant disregard for care can be shown through the course of a trial or investigation, it would reveal itself by specific, observable actions and not through imagining the intent of that person's heart. This is also discussed in detail in [Chap. 2](#).

4.4.1 What About Murphy's Law?

Scientific findings would be incomprehensible without statistics. During our lab classes in college, we quickly learned that measurements are variable. We could measure the same phenomenon multiple times, using the same instruments and conditions (as best as we could establish them), and come up with different results each time. The field of statistics allows us to establish data as fact within prescribed intervals of confidence. A special inspector could run compression tests on multiple concrete cylinders, taken under the same conditions from the same batch, and come up with a whole range of values. An engineer who reviews these disparate values can use the method of standard deviation, along with other tools in the most current edition of the concrete building code, to confidently conclude that the concrete as placed meets the specifications on the construction documents even though there are differences (sometimes large differences) between the values.

This is simply how science works. It does not mean the instruments are faulty, the inspector is incompetent, or the methods are unreliable. Rather, those who work in scientific

fields understand the limitations of human beings in developing methods, establishing theories, and in executing their duties. They understand the inconsistencies and variabilities that exist in physical phenomena studied and are able to reconcile these things with other (imperfect, but useful) tools, such as statistics. Some errors in the scientific process are simply unavoidable, but they are managed to the best degree possible.

What about random mistakes or accidents? Professionals have specialized training such that they are better able to execute certain tasks than a person who lacks the necessary knowledge or skill, but this does not mean they are expected to recognize all dangers or potential accidental occurrences. Professionals can take measures to narrow the possibility of accidents or mistakes, but it would be unreasonable to assume the avoidance of all possible uncertainty. In medicine, an *adverse event* is defined as an injury caused to a patient by a medical practitioner that prolonged hospitalization, produced a disability or death, or both. It is further recognized that not all adverse events are preventable, and not all adverse events result from negligent acts of the practitioner. Suppose a patient, for example, is prescribed an antibiotic and develops an *unforeseeable* allergic reaction requiring extended hospitalization. This adverse event does not rise to the level of negligence, assuming the physician carried out her duties as would be expected of ordinary practitioners in a similar locality under similar conditions. If she failed to review the patient's chart, and that chart clearly identified an allergic condition due to the specific antibiotic prescribed, then the adverse event resulted from a potentially negligent act.

Inevitable adverse events are oftentimes identified to be results of Murphy's Law: "What can go wrong will go wrong." The "law" is said to have originated in the 1940s during testing of deceleration effects of rocket sleds at Edwards Air

Force Base in Kern County, California. One of the engineers working on the project, Captain Edward A. Murphy, discovered a transducer malfunction that was apparently due to a mistake in wiring by a technician. Frustrated with the technician, Murphy reportedly exclaimed, "If there is any way to do it wrong, he will." Since that time, countless sub-laws have been created in the image of Murphy, such as "you will always find something in the last place you look," "a dropped tool will always roll to the least accessible location," and "dropped toast will always land on the buttered side."

If something is doomed to happen, how can anyone be responsible for it? When these types of consequences happen to a person, he will usually blame no one but himself: after all, he was the one who chose to change traffic lanes and, inevitably, the new lane moved much slower than the one he left. He was not responsible for the speed at which the lane moved—it was simply an honest decision with an unfortunate consequence. The consequence was not that the lane moved slowly, but that the driver arrived at his destination later than originally desired. The only control the driver had over the situation was to avoid changing lanes in the first place. However, it might have been possible to study the speed of the lanes for a period of time before executing the move in order to gain a better understanding of the probability of the new lane being a faster one. If the probability is high, then the move is warranted. Random occurrences beyond the driver's control are difficult to factor into the decision-making process, lightening the sting of responsibility. It was simply a choice that turned out to be the least favored of two possible choices. Granted, there could have been other consequences (an accident, loss of a job due to tardiness), and these would be dealt with on their own accord.

A professional engineer is responsible to practice with reasonable care, not perfection or with uncanny foresight. Things can and do go wrong, and these may or may not result directly from an individual's choice. Human beings make risky choices all the time, and we hold out a certain level of confidence that everything will (for the most part) work out fine. Technological advancements are made with knowledge of accompanying risk, but society is willing to accept that risk *as long as it can be managed as carefully and responsibly as possible*. Engineers design structures that have not been built before, which is a process open to a variety of risks. However, that risk is managed by education, training, experience, appropriate judgment, reasonable and mindful execution of duties, and a recognition of personal limitations. That's the key: management of risk, not an impossible hope that risk doesn't exist. If an event is truly inevitable, there is a possibility that a person's negligence changed conditions such that an avoidable event became an inevitable event and there could be some responsibility to bear. Risk management is discussed more fully in [Chap. 3](#).

4.4.2 Judicial Interpretations of Care and Duty

As we have already seen, the standard of care relevant to an engineer's work is simple in context, but it can be qualified by any number of real-world situations and conditions. To exercise the same ordinary care that a duly licensed engineer practicing in a similar locality, under similar conditions, would do almost implies foresight and an ability to read minds or judge actions of persons who are unknown and not directly involved in one's own personal work. Basic principles can be introduced to shed light on the specifics of that care, but when the standard of an

engineer's work is brought into question, defining that required care falls into the hands of experts who must convince a jury, or other legal entity, as to the validity of their conclusions as they pertain to a specific case at hand.

Conclusions and definitions that have been delivered in real court cases can help one understand the broad scope of conditions that can affect an engineer's decisions on a project and also demonstrate the value of human interpretation and respect for facts (as a general outcome).

4.4.2.1 Seiler v. Levitz Furniture Co.⁹

Construction of a two-story furniture showroom and warehouse building for the Levitz Furniture Company began in September 1968 and concluded with the store opening in June 1969. On August 1, 1970, a major flood occurred from nearby Naamans Creek (New Castle County, Delaware), causing water to enter the basement of the building and rise to a height of between 18 and 24 in, causing damage to stored merchandise. The watershed area is shown in [Fig. 4.5](#). A dike was built between December 1970 and June 1971 to help prevent future flooding, but it was not successful in stopping two additional floods (August 28, 1971 and September 13, 1971). The project architect, Seymour Seiler, was one of the parties to a suit brought on by the building owners for defective construction.

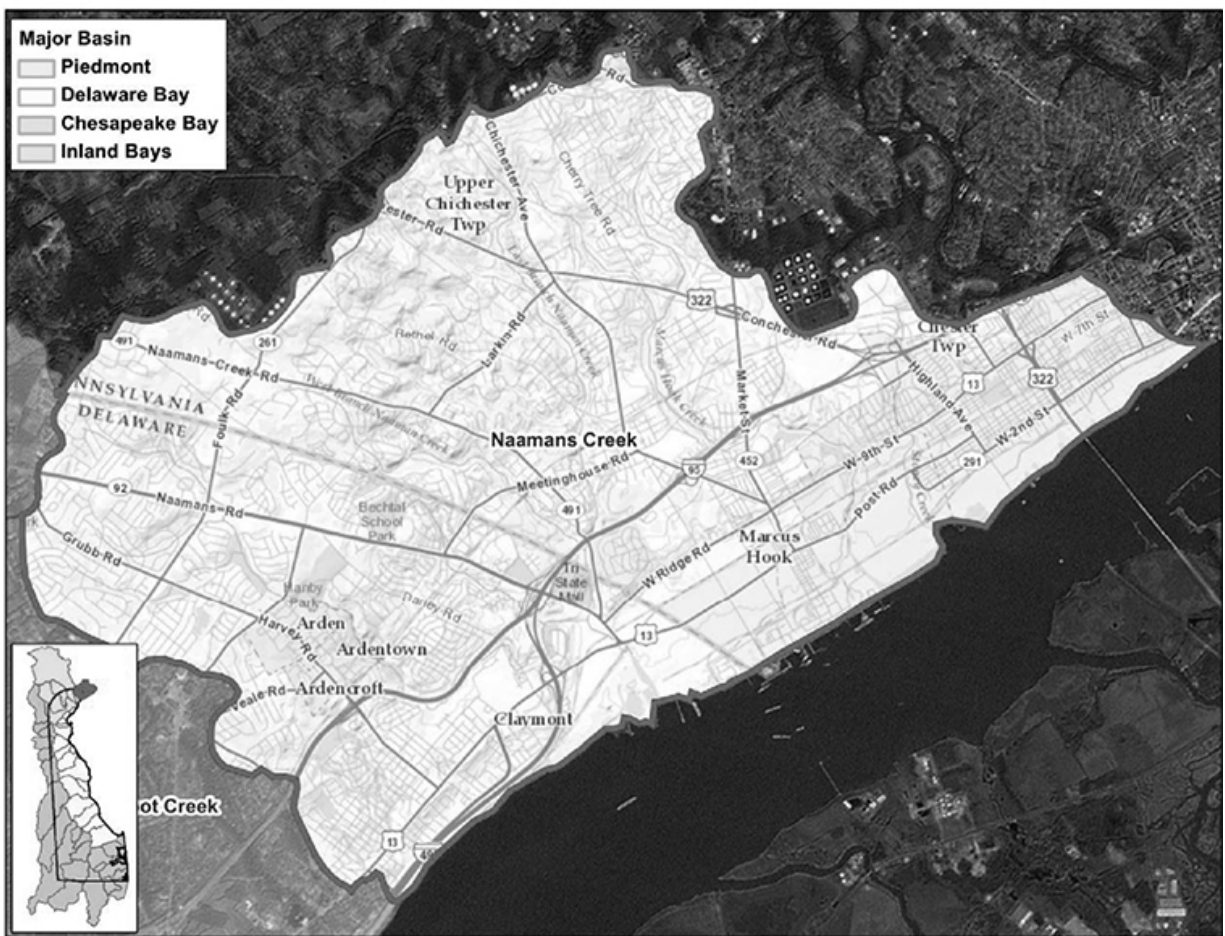


Figure 4.5 Naamans Creek Watershed. (Image accessed through <http://delawarewatersheds.org/piedmont/naamans-creek/>.)

After a 10-week trial, the Superior Court of Delaware found in favor of the plaintiff and concluded that all defendants were liable for damages caused by the flooding. The Supreme Court agreed with that ruling upon review of an appeal by the defendants. It was determined that Seiler acknowledged an investigation of the area's potential for flooding was necessary, and that he claimed to have performed such an investigation. It was also shown he had prior knowledge that flood waters had topped a nearby road in the past, but he disregarded advice from a county official

on setting the finish floor elevation of the building. It was clear that the architect knew the flooding potential of the region and was responsible for obtaining data and determining an appropriate course of action.

One of the interesting conclusions of this case was that the court had to decide the definition for a standard of care applicable to architects and engineers since, before this time, there was no definition for this care formalized in a Delaware court decision. It was recognized that the standard of care for professional persons had been fairly well defined through litigation involving physicians and surgeons, and the court decided that the professional responsibility of an architect or engineer did not differ in principle from that of a physician. In order to supplement their conclusion regarding care, the court introduced a definition from a construction-related case in Philadelphia that appeared to fit the criteria they were looking for:

An architect is bound to perform with reasonable care the duties for which he contracts. His client has the right to regard him as skilled in the science of the construction of buildings, and to expect that he will use reasonable and ordinary care and diligence in the application of his professional knowledge to accomplish the purpose for which he is retained. While he does not guarantee a perfect plan or a satisfactory result, he does by his contract imply that he enjoys ordinary skill and ability in his profession and that he will exercise these attributes without neglect and with a certain exactness of performance to effectuate work properly done.¹⁰

It is helpful to note that the court did not hold the architect to an unattainable standard. No warranty was expected for perfection, or even for a satisfactory result, but that he would diligently execute his duties using reasonable

and ordinary care. Expert witnesses may be required to define what those duties might have consisted of with relation to the particulars of the case, unless they are so obvious that the lay person would have no trouble understanding the requirement for those tasks. In this particular case, the architect had sufficient data and other information showing the need for suitable flood resistance and he failed to exercise care in the use of that data that other architects or engineers in good standing would have done.

4.4.2.2 City of Mounds View v. Walijarvi¹¹

In September 1973, the City of Mounds View, Minnesota, hired Kenneth H. Walijarvi and his architectural firm to design an addition to the city hall building. After construction had begun, the city expressed concern over excessive dampness being experienced in the basement portion of the addition, and Mr. Walijarvi responded (in writing) by assuring the city that the design of the lower level would result in a watertight and damp-free environment when construction is complete. The letter further reminds the city that the contractor also bears responsibility in constructing a watertight and damp-free condition.

Sometime later, significant water seepage into the basement occurred, causing extensive and costly damage. The city sued the architect and his firm, alleging the plans were negligently prepared and that the letter constituted an express warranty for the result. The trial court concluded that the letter did not constitute a warranty for services, only an opinion. The Supreme Court of Minnesota agreed that the city had a right to pursue a standard malpractice action by proving the design was, in fact, negligent, and it

also agreed with the trial court's decision regarding the issuance of a warranty.

Several interesting conclusions were offered by the Supreme Court about the performance of those in professional fields, being based on their examination of current legislation and of preceding court opinions. Section 424 of their opinion states, "The reasoning underlying the general rule as it applies both to architects and other vendors of professional services is relatively straightforward. Architects, doctors, engineers, attorneys, and others deal in somewhat inexact sciences and are continually called upon to exercise their skilled judgment in order to anticipate and provide for random factors which are incapable of precise measurement. The indeterminate nature of these factors makes it impossible for professional service people to gauge them with complete accuracy in every instance. Thus, doctors cannot promise that every operation will be successful; a lawyer can never be certain that a contract he drafts is without latent ambiguity; and an architect cannot be certain that a structural design will interact with natural forces as anticipated. Because of the inescapable possibility of error which inheres in these services, the law has traditionally required, not perfect results, but rather the exercise of that skill and judgment which can be reasonably expected from similarly situated professionals."

The same section further explains, "If every facet of structural design consisted of little more than the mechanical application of immutable physical properties, we could accept the rule of strict liability which the city proposes. But even in the present state of relative technological enlightenment, the keenest engineering minds can err in their most searching assessment of the natural factors which determine whether structural components will adequately serve their intended purpose."

4.4.2.3 Black+Vernooy Architects v. Smith¹²

The circumstances leading to this suit were tragic. Members of the Smith family were visiting friends who recently had a new vacation home built. Some of those members stood on a balcony connected to the upper-level master bedroom, and the balcony collapsed to the ground, causing paralysis to one of the plaintiffs. The Smiths sued the homeowners, the general contractor, and the subcontractor who actually built the deck, as well as the architects for damages due to injuries suffered on the basis of negligence. [Figure 4.6](#) shows a general woodframe balcony that is typical for many structures.



Figure 4.6 A common woodframe balcony showing signs of disrepair. (Image from “Cantilevered Balcony Safety” by Andy Engel, Fine Homebuilding, August 6, 2015.)

The plaintiffs recovered damages from the homeowners and the contractors, but an appellate court reversed the award of damages from the architects even though it upheld

the conclusion that they were partially responsible and negligent. The court identified that the architects did not owe a contractual duty of care to a third party, and that there was no legal precedent to recognize a form of common-law duty under these circumstances. This conclusion emphasized what is commonly required to prevail on a claim of negligence that (1) a legal duty was owed by one person to another, (2) a breach of that duty occurred, and (3) damages proximately resulted from that breach of duty. The courts define whether a duty exists based on the facts of a specific case, and *generally* an individual does not owe duty to take action to prevent harm to others.

4.4.2.4 Graves v. SE Downey Registered Land Surveyor¹³

The Graves family owned a plot of land in Bar Harbor that was bordered on two sides by land controlled or owned by the Acadia National Park (see [Fig. 4.7](#)). They wanted to divide the land into three lots, and their building contractor retained the services of a licensed land surveyor to do the work. During construction of a residence on one of the lots, a person from the National Park Service informed the owners that the house was north of their property line and was located on land of another where the Park had authority to prohibit construction (which they did). After unsuccessful negotiation, the owners had to pay a substantial sum to move the house farther south. A complaint was then filed against the land surveyors for breach of contract and professional negligence.



Figure 4.7 Bar Harbor, Maine, close to Acadia National Park. (Photo by management of the Bar Harbor Inn, August 2019, accessed through <https://www.tripadvisor.com/>.)

The expert witness retained by the owner's legal team testified that the surveyors did not exercise the skill, care, and diligence required of members of the surveying profession, and they "did not meet the standards of local practice exercised by reasonably prudent practitioners providing land surveying services in the Hancock County area." Specifically, the witness identified deficiencies in the execution of the survey to include reliance on extrinsic evidence to the exclusion of the direct record evidence of the boundary, as well as an erroneous conclusion by the surveyor that a gap existed between disputed boundaries whereas, in fact, the chain of title clearly identified them as contiguous. The court also drew upon rulings from other states to establish a standard of care. West Virginia, for example, holds the standard as the work of a reasonably prudent surveyor. Maryland and North Carolina provide that a surveyor must "exercise that degree of care which a

surveyor of ordinary skill and prudence would exercise under similar circumstances.”

4.5 Review Questions

- 4.1. What are the four virtues represented in Roman mythology, and how are they defined in modern times?
- 4.2. What are some of the things symbolized by the sword held by Lady Justice?
- 4.3. How is *the law* defined?
- 4.4. What is the difference between a civil crime and a criminal offense?
- 4.5. What is *home rule*?
- 4.6. Name three tasks performed by an urban planner.
- 4.7. What is the purpose of the International Building Code?
- 4.8. When conflicts exist between state requirements and newer codes, name three options that an engineer may consider in order to resolve potential legal issues?
- 4.9. What does *responsible charge* mean?
- 4-10. Write a single, concise sentence or paragraph to define the standard of care that commonly applies to an engineer’s work.
- 4.11. What is Murphy’s Law and how is it related to human responsibility (think of adverse events)?
- 4.12. Under what conditions will society typically agree to accept risk?
- 4.13. How does an engineer manage risk?
- 4.14. According to some of the conclusions in the *City of Mounds v. Walijarvi* case, what has the law

traditionally required of the services offered by design professionals?

4.15. What elements are commonly required to prove negligence of a design professional, according to *Black + Vernooy Architects v. Smith*?

4.6 Discussion Questions

4.1D. In weighing the evidence of a case brought against an engineer for negligence, why is it important to review decisions rendered in past cases?

4.2D. Do ethical codes of conduct strengthen the rights and freedoms of individuals or hinder them? Explain.

4.3D. Itemize at least five benefits to *home rule* and compare them with five benefits to *Dillon's Rule*.

4.4D. Explain potential benefits, and some of the potential limitations, of having a nationwide model code relating to technical engineering issues that individual states can adopt.

4.5D. Suppose you are a planner for a vibrant community, and a large pharmaceutical company wishes to build a factory near an environmentally sensitive area. What are some of the potential ethical issues that could arise in making planning decisions and getting them approved?

4.6D. What are some of the legal difficulties with providing engineering services in multiple states?

4.7D. Provide three examples that would demonstrate an engineer has not met the standard of care in his work.

4.8D. Describe an engineering-related example of an *adverse event*.

4.9D. In the *Seiler v. Levitz Furniture* case, describe how the architect could have met the necessary standard of care in his work and judgments.

4.10D. Do you agree with the conclusions in the *Black + Vernooy Architects v. Smith* case, wherein the architects did not owe a duty of care to a third party who might be hurt when using something that was designed by them? Why or why not?

¹Merriam-Webster's Collegiate Dictionary, 10th ed., s.v. "law."

²Alexander Hamilton, "The Judiciary Department (Federalist 78)." *McLean's Edition*, New York. May 28, 1788.

³*Smith v. State*, 20 So. 2d 701 (Mississippi Supreme Court, 1945).

⁴James Madison, "The Alleged Danger from the Powers of the Union to the State Governments Considered (Federalist 45)." *The Independent Journal*, New York. January 26, 1788.

⁵International Building Code, 2018 Edition, International Code Council, Country Club Hills, IL: 2018.

⁶*Hoffert v. Owatonna Inn Towne Motel, Inc.* 199 NW 2d 158 (Minnesota Supreme Court, 1972).

⁷Tennessee Board of Architectural and Engineering Examiners, "Reference Manual for Building Officials and Design Professionals." Tennessee Department of Commerce and Insurance, Nashville, TN: December 2015, p. 4

⁸*John T. Jones Const. Co. v. Hoot General Const.*, 543 F. Supp. 2d 982 (District Court, SD Iowa, 2008).

⁹*Seiler v. Levitz Furniture Co.*, 367 A.2d 999 (Supreme Court of Delaware, 1976).

¹⁰*Bloomsburg Mills, Inc. v. Sordoni Construction Co.*, 401 Pa. 358 (1960).

¹¹*City of Mounds View v. Walijarvi*, 263 N.W.2d 420 (Minnesota, 1978).

¹²*Black+Vernooy Architects v. Smith*, 346 S.W.3d 877 (Austin, Texas, 2011).

¹³*Graves v. SE Downey Registered Land Surveyor*, 2005 ME 116 (Supreme Judicial Court of Maine, 2005).

CHAPTER 5

Historical Development of Ethical Thought

Much of what we understand about ethics is learned from an early age, but as we get older, new experiences and influences develop our basic understanding into a more cohesive system. We begin to see patterns and formulate reasons for holding onto some standards and rejecting others. It is this organization of ideas that helps a person make sense of his surroundings and reminds him how he needs to interact with others ... to live his life in an honorable and worthy manner, to be accepted in the eyes of God and man (as the saying goes).

The study and debate of ethics is not new. Philosophers and theologians have shared their concepts of what is right and wrong throughout human history, and each generation has had to decide what system of ethics is most likely true, or at the very least, which system works best for them. The terms *true* and *best* are also subject to debate—when it comes to ethics and morals, human beings can have legitimate differences of opinion, as well as different

convictions of the meaning of these terms and how to defend them. Teachings on ethics from a broad range of sources can illuminate one's own understanding, assist in the codification of convictions, and offer practical insights on how standards apply to daily life.

Ethics is considered one of four main branches of philosophy, along with epistemology, logic, and metaphysics. Much of this was covered in [Chap. 1](#), and as a brief reminder, the term *ethics* is often synonymous with morals or the study of morality. Generally, it is an attempt to discover, understand, and qualify human activity that is right, acceptable, and necessary for a variety of reasons (honoring God, honoring humanity, respect for self, to benefit the development of a healthy society, etc.). Ethical theory considers the value of human rights as well as the virtue of individual character with an ultimate goal of understanding how human beings should behave toward one another, other life forms, and the environment.

Epistemology is the study of knowledge, both nature (what does it mean to know something) and extent (how much do we, or can we, know), that is primarily propositional. This type of knowledge includes those things which may be known independent of experience, requiring only the use of reason ("nonempirical," or a priori), and those things which are discovered through certain experiences of the senses and also explained by reason ("empirical," a posteriori). Nonempirical knowledge includes logical truths and abstract claims, which is usually where concepts of ethics are found. Empirical knowledge includes, among other things, observable characteristics of physical objects, geographical locations, or scientific discoveries.

In philosophy, *logic* is defined as the construction, analysis, and evaluation of arguments. An argument is an act of reasoning that includes a set of premises, which identify basic information about a problem to be studied,

and a conclusion that follows from the given information. An argument is shown to be *valid* if it would be contradictory to have the premises all true and conclusion false—it does not matter whether the premises are, in fact, true. However, an argument is *sound* if it is not only valid, but every premise is also true. Oftentimes, premises are educated guesses or are based on personal convictions, but the best ones are those understood by others to be certain and obvious. This will be explored in more detail in [Chap. 7](#).

The branch of philosophy known as *metaphysics* includes three main categories of interest: the nature of being, or existence (also known as ontology); the first causes of things; and things that do not change. Commentators during the Medieval era erroneously interpreted the meaning of metaphysics (Greek, “after or beyond physics”) to imply subject matter that went beyond the ordinary physical matters that we understand through Newton and Einstein. However, the original term was introduced close to 100 years after the death of Aristotle to simply refer to a collection of 14 of his books written on first philosophy, first science, wisdom, and theology.¹ These books were placed by an editor after a series of books about nature, the natural world, and things that are characterized by change, thus “after physics.”

Since my intent was to build a broad understanding of ethics, and to focus that breadth on matters that can be related to the field of engineering, I was intentionally selective in sources and subjects. This should be familiar, though, since engineers routinely select data to justify a position or defend a design to themselves or to others. Placing emphasis on selected subjects doesn’t mean that other subjects are less valid—it only means that time and space allow for a finite amount of data, and wise discovery and interpretation of that data will be suitable for the intent at hand.

5.1 Confucius (China, 551-479 BCE)

Teachings from the ancient philosopher, Confucius (K'ung Fu-tzu), continue to be a significant part of Chinese culture and thought, even though a variety of contextual interpretations and concepts of what was authoritative persist. He was raised in the city of Qufu, in the state of Lu (in the province of Shantung, or Shandong, shown in [Fig. 5.1](#)), as a member of an aristocratic class and spent time working for the provincial government in the public works and justice departments. It is believed that his teaching career did not begin with earnest until close to the age of 30, as he gathered a large number of students and shared his studies on ritual, music, history, government, and poetry.



Figure 5.1 The province of Shantung (Shandong), where Confucius was born and raised. (*Image from Unsplash.*)

At about the age of 53, Confucius and several students traveled throughout eastern China teaching and continuing to develop their particular philosophy and concepts of government. They were typically well-received and respected by rulers of various states, and they gathered many more disciples along the way. Not much is known about the later years of Confucius after he returned to Lu, though he suffered the loss of his only son and his favorite disciple several years before his own death in 479 BCE.

The four primary books of Confucian thought include *Analects*, *Mencius*, *Great Learning*, and *Doctrine of the Mean*, which detail the essence of Confucianism and formed the basis of Chinese state ideology in the first Han dynasty (206 BCE–8 CE). For additional background on what is believed to be the life of Confucius and the history of translation, see Jaroslav Pelikan's *Confucianism: The Analects of Confucius*.² In the *Analects*, there are three subjects that Confucius explains in greater depth than most of the other subjects: keeping promises, character traits of a gentleman, and the way of goodness. Since the book is a collection of sayings, teachings on these matters are sprinkled throughout the lessons, each instance being related to a particular topic of discussion. As we examine the development of these subjects, we will also see how they relate to codes of engineering ethics that are used around the world today.

5.1.1 Keeping Promises

As one of the first subjects to be introduced, the Master explained that being true to one's word is one of the most

important things to examine at the end of each day. Self-examination is an important part of developing one's character in order to identify weaknesses that require correction. Confucius characterized the keeping of promises in the following ways:

1. They should be observed punctually.
2. It is a learned response that requires practice and, when failing, requires acknowledgment and reconciliation.
3. The statement of a promise is cheaper than the execution of what is promised.
4. Do not recognize those who continually break their promises.
5. Those who are disloyal and untrustworthy in their speech will not hope to succeed.
6. Learn to love honorable promises and do not make pacts that you will later regret.
7. Learn to recognize false promises and cling to honesty.

The idea of keeping promises and fulfilling obligations is an important part of ethics promoted in engineering practice. For example, the code of ethics published by the Russian Center of Certification and Registration of APEC Professional Engineers states, "By key moral values of the Russian APEC Engineer, one implies responsibility for assumed obligations, ideas implementation and consequences of engineering activity, and open acknowledgment of his/her errors."³ By agreeing to complete professional services, an engineer not only promises to deliver the associated product (calculations, drawings, specifications) but also promises to complete

tasks with the requisite level of competence. Promises are expressed through interviews, written proposals, and executed contracts. Whether the engineer works in the public or private sector, being known as a person who keeps his word is an important characteristic for building trust and confidence.

Promises are usually kept in a business relationship involving sensitive materials, where confidentiality agreements constitute a binding pact that these things will not be revealed to those who are not party to the contract. However, since a professional civil or structural engineer is to uphold the health, safety, and welfare of the public as the highest ethical standard, there may be specific instances when those promises of confidentiality must be breached. The Texas Administrative Code, for example, states, “The engineer may reveal confidences and private information only with a fully informed client’s or employer’s consent, or when required by law or court order; or when those confidences, if left undisclosed, would constitute a threat to the health, safety, or welfare of the public.”⁴ This admonition is fairly consistent in most of the engineering ethical and licensing codes published in the United States.

In their publication, *Guide to the Code of Ethics*, the Engineers and Geoscientists British Columbia (Canada) call this responsibility “Duty to Report” and explain how a decision to void a promise toward confidentiality must be based on well-defined facts. There must be reasonable and probable evidence to convince a rational and objective professional that a problem poses a real risk of significant harm to the environment or to the health, safety, and welfare of the public, or that the problem is of an illegal or unethical nature. The term *significant harm* carries the element of urgency; however, some hazards that take time to develop can still pose a threat.⁵ [Figure 5.2](#) provides a list of considerations to guide an engineer in reporting a

significant risk of harm, illegal activity, or unethical behavior. A promise to maintain confidentiality is not to be taken lightly.

1. Ask whether there are reasonable and probable grounds to believe there is a problem.
2. Identify who to report.
3. Identify whom to inform.
4. Act promptly.
5. Record the steps being taken to report the risky, illegal, or unethical situation.
6. Follow up if the significantly risky, illegal, or unethical situation has been resolved.
7. Have another professional assess the problematic situation.
8. Stop the work to avoid further harm.
9. If you are the head of a public body, determine any other reporting requirements.

Figure 5.2 Considerations for an Engineer to Report Unethical Activity. (*Source: Guide to the Code of Ethics* by Engineers and Geoscientists BC, Canada.)

5.1.2 Character Traits of a Gentleman

According to Confucius, the gentleman exhibits characteristics that are honorable and desirable for the human race. He is well-spoken and clear in his communication, his manners are always respectful, and his movements are peaceful. In Chinese, the term for “gentleman” was originally used to describe a ruler, the son of a ruler, or any descendant of a ruling class or house, not only to describe the manner of birth but also the superiority in character and behavior. Eventually, the requirement of a noble birth disappeared, and character traits became more descriptive of the system that Confucius was trying to deliver. The original term takes on male-dominant language and intent, but the principles are most certainly applicable to persons of all gender identities—even though this may not have been the intent, we are free to make that association in our study and appreciation of the wisdom of ancient writers and philosophers.

The gentleman is also tied to the previous subject, keeping one's promises. In Book 1 of the *Analects*, the relationship between the gentleman and his superiors is described in careful detail, where he must demonstrate responsibility and reliability, otherwise he will lose their respect. In the business world, an unreliable engineer would likely lose her job after she loses the respect of her employer and her peers. She must first and foremost honor the subordinate relationship (employee to employer) as a reality of the working environment and the need for some form of a hierarchy. She honors this position with faithfulness, keeping her promises, and refusing to associate with those who do not hold similar viewpoints of respect (otherwise, she may be persuaded to lose respect for her employer or supervisor as well).

Another element of this position is that a gentleman must not be afraid to admit when he has made a mistake and must take positive steps toward amending any wrongs that have resulted. The code of conduct published by the Institution of Engineers Tanzania includes a familiar precept along this line: "An engineer shall accept personal responsibility for all work done by him or under his supervision or direction and shall take all reasonable steps to ensure that persons working under his authority are competent to carry out the tasks assigned to them."⁶

In Book II of the *Analects*, the main characteristic of the gentleman that sets the tone is that he does not tell others what to do or how to do it until he himself has done, and continues to do, the very same thing ... to practice what he preaches. This takes attention and diligence. With practice, the gentleman is able to see all sides of a question or an issue, without bias, and can therefore offer not only an informed conclusion, but a range of solutions, and is able to be of service. In the same way, an engineer must consider data, observations, and conduct research with a keen

awareness of any bias that may taint her findings and conclusions so that she can be as helpful as possible. This element of helpfulness characterizes the engineering profession, as problem solvers, whose work benefits the progress of humankind. A message of mentorship is also captured in this teaching. A student asked Confucius whether there was any form of encouragement by which he could induce the common people to be respectful and loyal. Confucius responded by saying, "Approach them with dignity, and they will respect you." He went on to say, "Promote those who are worthy, train those who are incompetent. That is the best form of encouragement."

This characteristic is explained in Book IV of the *Analects* as a result of humility. The gentleman would not dare to instruct someone else on matters of morality unless he can honestly say that he is also working to consistently exhibit those same matters. The gentleman understands that no one attains perfection in how they live their lives, but they should never give up trying. In fact, in Book VII of the *Analects*, Confucius said, "A faultless man I cannot hope to ever meet; the most hope for is to meet a man of fixed principles." The focus is on the character traits, not the reward or punishment. The gentleman does not mind if he is not put into a position of authority, but rather he focuses on whether or not he possesses the qualities that would entitle him to that position. Additionally, the gentleman does not mind if he is not recognized for doing good deeds, since he is too busy actually doing those deeds that entitle him to recognition. An honorable engineer wants to do what is right, even when there is temptation to make more money or rise in stature through less desirable means.

5.1.3 The Way of Goodness

Confucius inseparably ties the character of a gentleman with goodness. In Book IV of the *Analects*, he tells his pupils, “Never for a moment does a gentleman quit the way of Goodness.” The term “Way” is also used throughout the *Analects* as an indication that goodness is not a stagnant quality, but something that requires continual attention and focus. It can be viewed as a pathway toward a goal that is nearly impossible to attain, but is the most important pathway that one should be traveling. Again, in Book IV, the Master says, “I, for my part, have never yet seen one who really cared for Goodness, nor one who really abhorred wickedness. One who really cared for Goodness would never let any other consideration come first. One who abhorred wickedness would be so constantly doing Good that wickedness would never have a chance to get at him.”

The Way of Goodness is evidenced primarily by one’s deeds, and even then, Confucius stopped short of calling most people “good.” He would say that he didn’t know if that person was good or not, but he certainly acknowledged good deeds. Even for himself, Confucius said, “Far be it from me to make any such claim (of being a Good man).” As for deeds, the Way of Goodness includes courteous behavior to everyone, regardless of duration of acquaintance, benevolence beyond what is due to others, and justice in assigning and evaluating work or other duties (*Analects*, Book V). Goodness is grouped with wisdom and bravery in Book IX of the *Analects*, where goodness produces joy, wisdom produces confidence, and bravery produces conviction. These are also qualities that a competent engineer should strive for.

The Rules of Conduct published by the Zimbabwe Institution of Engineers⁷ include precepts related to goodness, wisdom, and bravery. Rule 1.0 states, “A member, in the course of his/her employment and in pursuance of his/her profession, shall have due regard for the public

interest.” This illustrates goodness well, as “due regard” does not stipulate the only regard, but it implies an honorable attention to the needs of others. The exercise of *wisdom* is necessary when an engineer is to reveal information or publish reports. Rule 3.2 states, “A member shall not publicly express an opinion on an engineering subject unless he/she is informed of the facts relating to that subject and has disclosed to the person or persons to whom the opinion is directed any association he/her (*sic*) may have with any party which may benefit from his/her statement, and then only when founded on adequate knowledge and honest conviction.” *Bravery* is needed to implement Rule 2.1, which states, “A member whose professional advice is not accepted shall take all reasonable steps to ensure that the person overruling or neglecting his/her advice is aware of any danger which the member believes may result from such overruling or neglect.”

5.2 Aristotle (Greece, 384–322 BCE)

Aristotle is one of the most well-known philosophers of all time (see [Fig. 5.3](#)), and his works continue to influence the thoughts and conclusions of modern teachers. He researched and wrote on a wide variety of subjects, including logic, metaphysics and general philosophy, ethics, politics, and even empirical biology. The development of formal logic is attributed to Aristotle, and he also pioneered the study of zoology. Many principles of philosophy that have been exercised throughout the ages have a strong foundation in the works of Aristotle, including a long history of terms and definitions.

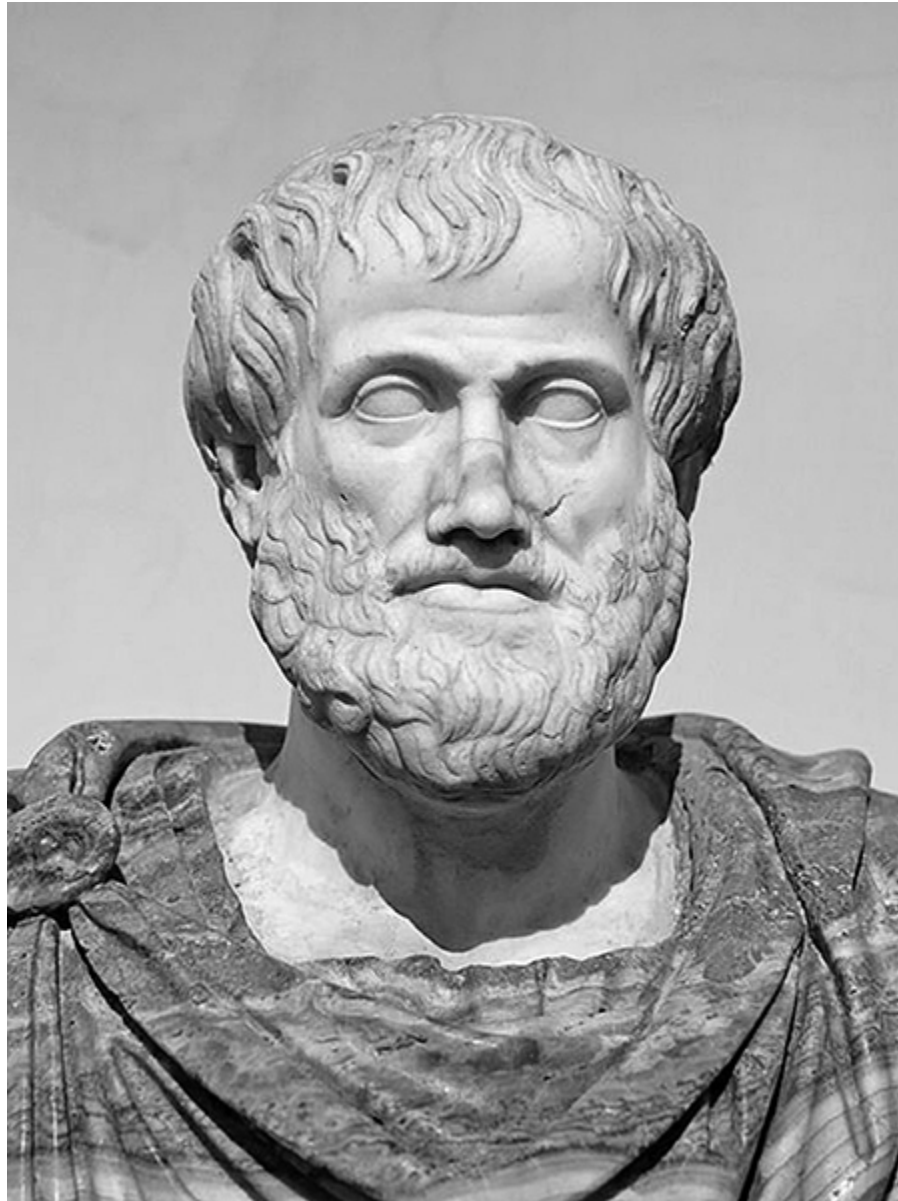


Figure 5.3 Well-known bust of Aristotle.

Aristotle was born in 384 BCE in the Chalcidic peninsula of Macedonia in northern Greece in the city of Stagira. His father was a physician who passed away when Aristotle was about 17, after which he moved to Athens where he joined the Academy of Plato and studied there for 20 years. After Plato's death, Aristotle relocated to Assos, close to the northwest coast of modern-day Turkey, where he continued

teaching philosophy and, it is thought, he expanded much of his study and writings on zoology and biology. He moved to the nearby island of Lesbos after about 3 years, where he was married and had a daughter.

Aristotle moved to Pella, the Macedonian capital, at the request of King Philip II to work as a tutor for Philip's 13-year-old son, Alexander, who would later become Alexander the Great. Historians differ about the amount of time this association continued, ranging between 2 and 8 years. After this time, Aristotle moved back to Athens where he set up his own school in a public exercise area. This school, taking the title *Lyceum*, came to be known as one of the earliest libraries of antiquity due to the vast collection of manuscripts, and students there conducted research on a vast number of subjects such as biology, mathematics, logic, music, history, psychology, ethics, politics, government, and the arts. After about 13 years, he left Athens for Chalcis, on an island off the coast of Attica, where he died in 322 BCE of natural causes.

5.2.1 The Essence of Moral Virtue

In Book II of *Nicomachean Ethics*,⁸ Aristotle explains that moral virtue lies as an average between two extremes, one involving excess and the other deficiency. For example, the virtue of modesty lies between the excess of shamelessness and the deficiency of lack of self-confidence; honesty lies between boastfulness (excess) and self-depreciation (deficiency); and gentleness lies between irascibility (excess) and apathy (deficiency). He comes to this conclusion by first deciding that moral virtue is not established by nature, but is actually the result of habit. Through nature, we put something into action that we already possess, such as the ability to see with our eyes—we had this ability even before we exercised that ability, as

it was part of our nature. Moral virtues are different. We obtain them by first exercising them. Therefore, moral virtues are neither contrary nor according to nature, but rather we are empowered by nature to receive them through education, training, and experience, and to perfect them by actually doing them on a regular basis.

Engineering societies often express this idea of a middle road on actions to take, keeping a reasonable view of the extremes of any position and attempting to make the best choice. The Association of German Engineers, for example, advises transparency and honesty in making difficult choices: “In cases of conflicting values, engineers give priority to the values of humanity over the dynamics of nature; to issues of human rights over technology implementation and exploitation; to public welfare over private interests; and to safety and security over functionality and profitability of their technical solutions. Engineers, however, are careful not to adopt such criteria in any dogmatic manner. They seek public dialogue in order to find acceptable balance and consensus concerning these conflicting values.”⁹

To understand virtue, in order to become *good*, Aristotle suggests an examination of the nature of actions, and even passions, since that is what commits virtue to habit. He explains that action and passion, and thereby virtues, are accompanied by pleasure and pain. It is on account of pleasure that we do bad things and on account of pain that we abstain from doing good things. He then reminds his audience of something his mentor, Plato, said, that we ought to have been brought up in a particular way from our very youth so as both to delight in and to be pained by the things that we ought—this introduces one’s character as a driving force in the performance of virtuous action. Finding the middle ground, Aristotle suggests, is not an easy task. Goodness, he concludes, is rare, laudable, and noble; it is

difficult to express goodness to the right person, to the right extent, at the right time, with the right motive, and in the right way.

5.2.2 The Nature of Happiness

One of the closing subjects in *Nicomachean Ethics* is the nature of happiness, as Aristotle declares to be the “end of human nature” in Book X. Happiness is desired in and of itself, and not for the sake of anything else, for happiness is self-sufficient. We choose everything for the sake of something else, except for happiness. Some work hard so that they can relax afterward with some sort of amusement, which is a good and necessary activity, but it is not an end itself. In fact, we need relaxation so that we can continue working after being recharged: relaxation is chosen for the sake of exertion. Work is also chosen for the sake of achieving (and affording) some type of amusement, which would then produce happiness (an end). He taught that a happy life is also a virtuous life, and though amusements have their place, one must continue to work on the habits of virtue.

Perfect happiness is found in contemplation and in reason, which helps a person make good choices about external goods necessary for existence, pleasure (relaxation), and the fulfillment of happiness. Attributes of the happiest of men are connected with the activity of reason, including self-sufficiency, an ability to relax without guilt, and having the strength to press forward without losing faith. Reason is defined as contemplative; which is to consider, study, and reflect on matters deeply (an intellectual virtue); and since the very nature of happiness is found in reason, a life that honors and practices contemplation would be the happiest of lives.

5.3 Ibn Miskawayh (Iran, 932-1030 CE)

Ibn Miskawayh, also known as Abu Ali Ahmad ibn Muhammad ibn Yaqub Miskawayh, or simply Miskawayh, was born in Rayy in Persia (near modern Teheran, Iran—see [Fig. 5.4](#)) around 930 CE, which was a golden era for the development and advancement of Islamic civilization. He spent most of his time here as a political minister, a scientist, historian, librarian, and well-versed philosopher. Little is known about his personal life, but it is believed that he converted to Islam from Zoroastrianism, which was the earlier religion of Iran. His writings on history reflected a view of nationalism, and he appeared to make use of as much source material as he could, rather than rely on simple legend.



Figure 5.4 Tughrul Tower at Rey near Tehran, Iran. (Image by David Stanley from Nanaimo, Canada, Creative Commons BY 2.0.)

His primary influence on early philosophy is the teaching of ethics, and the first major Islamic publication on the subject, *Refinement of Character*, was written by him. It includes discussion on practical ethical situations, behavior, and character development. He believed that the history of a nation offers much instruction about the morals of human beings. His most influential work of history was *Experiences of the Nations*, which was written with the benefit of official records because of his work as a vizier to various ruling officials. Miskawayh spent the last years of his life studying various subjects and writing and passed away at an old age

in 1030 CE at Isfahan, Persia (about 250 miles south of Teheran). One of the things that set him apart from his Muslim contemporaries was that he did not try to reconcile the tenets of philosophy with religious beliefs or requirements, but his opinions remained consistent with the function and content of Greek source material.

5.3.1 Cardinal Virtues

In the book, *Refinement of Character* (“First Discourse: The Principles of Ethics”),¹⁰ Miskawayh explains the development of four cardinal virtues: wisdom, temperance, courage, and justice. The soul, being moderate and not extraneous to itself, seeks true, honest knowledge and gains wisdom; when it does not indulge in the pursuit of its own desires, it attains temperance, followed by liberality. The term *indulge* is important, as it would focus on an almost insatiable drive to honor oneself before considering the needs or desires of others, which is not considered virtuous on most accounts. Self-reflection and improvement are important parts of most engineering codes of conduct, but holding the welfare of the public as paramount to all other canons is also universally (nearly) documented in these same codes. As has been discussed elsewhere in this book, it is certainly possible for a person to exhibit virtuous characteristics with selfish motives, but many philosophers (including Miskawayh) would suggest that this stems from a position of falsehood. It is difficult to find a person who is truly selfless, and our global society can still function well enough with virtue being expressed from different motivations.

When the activity of the soul is moderate, humble, and reasonably controlled, it gains the virtue of magnanimity (great of mind and heart), followed by courage. Finally, when all of these virtues have come together with proper recognition and practice, the virtue of justice will follow.

Justice is shown by Miskawayh to be expressed through eight divisions: friendship, concord, family fellowship, recompense, fair play, honest dealing, amiability, and piety. Friendship causes one to express interest in the concerns of others and choose to do all the good that she can. Concord is an agreement of opinions and beliefs that lead to cooperation, and fair play in a business relationship expresses fairness according to the interests of all persons concerned. Fairness is a quality that is also exemplified by professional engineers and land surveyors (as an activity within the realm of civil engineering) that displays unbiased performance, honesty, and integrity. According to the Code of Ethics published by the Professional Land Surveyors of Colorado,¹¹ "Surveyors shall be unbiased in performing services for the client, maintaining the highest standards of honesty and integrity, and offer impartial advice based on their accurate and conscientious measurements, data review, and legal principles while protecting the safety and welfare of the public at all times."

Miskawayh concludes his first discourse with an explanation that human beings naturally need one another, and happiness cannot be attained except through associations with other people. A person must, therefore, be friendly toward others, be attentive toward good associations with others, and hold them in sincere affection because all people complement one another. Virtues must be expressed to have any value, and one who does not associate with others lacks this opportunity. They are actions and deeds manifested when one participates and lives with other people, through a variety of dealings and associations (business and personal). We learn from others, and they learn from us. Virtues become more refined and meaningful in the process.

5.4 John Locke (England, 1632-1704 CE)

The works of John Locke form a foundation for philosophical and political thought, and inspired the period of European Enlightenment and the Constitution of the United States. Intellectuals who shaped the development of enlightenment were proponents of the use of logic and reason to help humanity understand the physical world and how they can improve their condition. This was to result in a more thorough development of knowledge, a more complete sense of freedom, and sustainable happiness. Locke intended to inspire people to use reason to search after truth and not simply accept the opinion of authorities, religion, or superstition.

John Locke (see [Fig. 5.5](#)) was born on August 29, 1632 in the small town of Wrington in Bristol, England to parents who were supportive of puritan religious ideas, though they remained with the Church of England. During his early years, John witnessed a civil war between the Crown and Parliament and ongoing conflict between Protestants, Anglicans, and Catholics. Charles I was defeated at the conclusion of the war and several long-standing institutions were abolished, including the monarchy, the House of Lords, and the Anglican church. In 1652, Locke went to Westminster School in London where he studied (primarily) Latin, Greek, Hebrew, Arabic, mathematics, and geography. At the age of 20, he moved on to Oxford college in Christ Church and graduated with both a bachelor's and a master's degree, eventually deciding to pursue medicine.

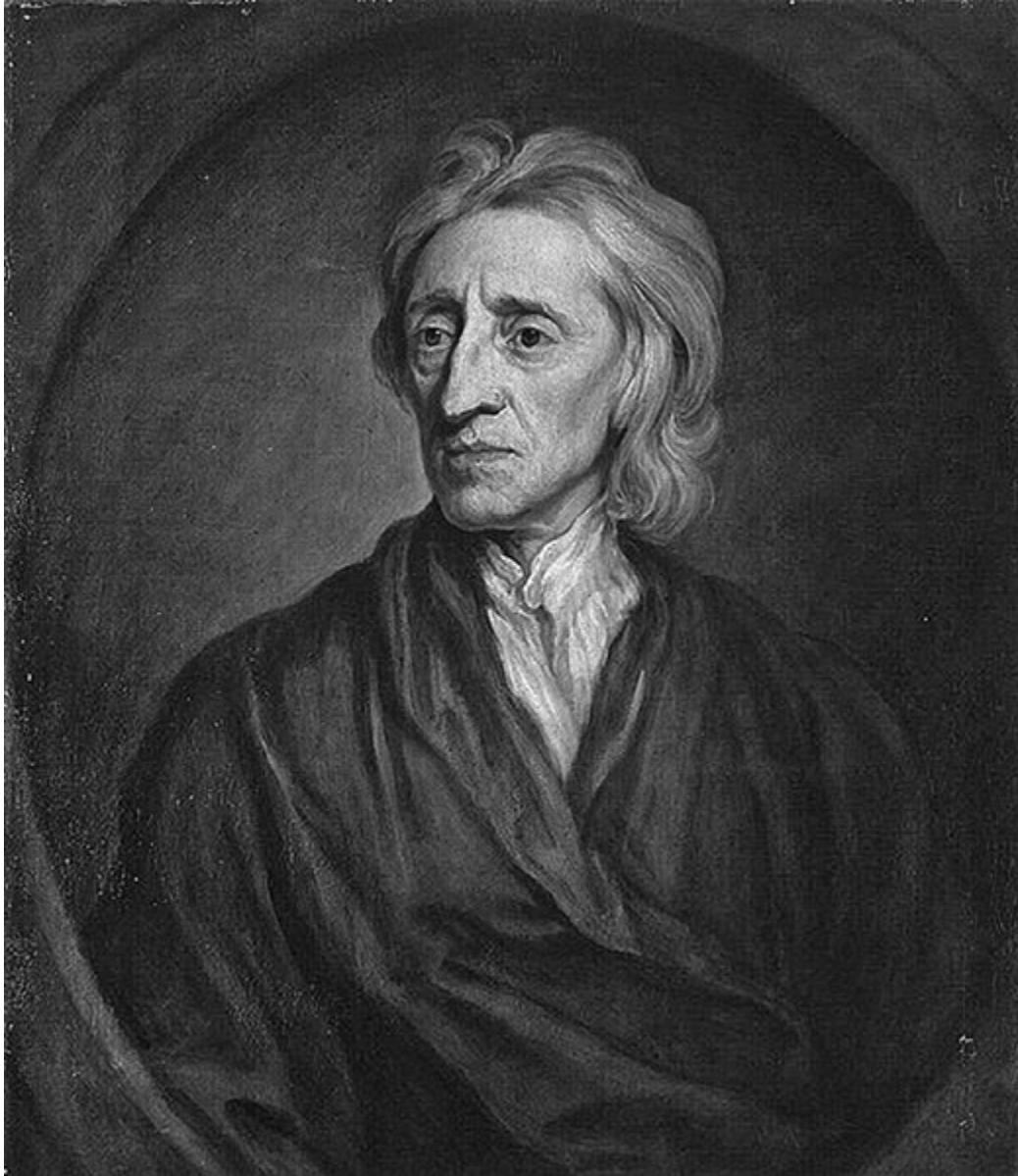


Figure 5.5 Portrait of John Locke.

After the monarchy was restored with Charles II in 1660, Locke's studies in the sciences flourished. He worked with eminent physicians of the time, and even collaborated with Robert Boyle on important research into human blood. In 1667, he moved in with Anthony Ashley Cooper (Lord Ashley), the future Earl of Shaftesbury, as a personal physician. Ashley was a founder of the Whig party, and no

doubt exerted great influence on Locke's political views. He spent some time traveling through different regions of France and was forced to flee to the Netherlands in June 1683 due to suspicion of his involvement in the Rye House Plot to execute the king and his brother.

After returning from exile in 1689, Locke published three of his best-known works, *An Essay Concerning Human Understanding*, *The Two Treatises of Government*, and *The Reasonableness of Christianity*. During the last 8 years of his life, he played an important part in reviving the Board of Trade and served with the directors until 1700. After his retirement, John went on to Oates in High Laver, Essex, England and passed away on October 28, 1704. The philosophies of John Locke had a significant impact on the evolution of the American government, primarily found in the belief that individual consent is the basis of a legitimate governing body, and those bodies should be limited rather than absolute. The government enters into a social contract with the people, and that government must function to protect certain inalienable rights, such as life, liberty, and ownership of property.

5.4.1 Pursuing Happiness

One of Locke's most influential books is *An Essay Concerning Human Understanding (Essay)*,¹² written as four distinct parts to define the sources and nature of human knowledge. In the first part, he explains that the human mind begins life without knowledge of any kind and progresses to adopt knowledge through experiences. The second part discusses how ideas are the product of experiences, which can be based on sensation (things of the external, physical world) and reflection (the working of our own minds). The third part explains the connection between ideas, knowledge, and language, and the fourth part

summarizes the limits of knowledge and the relationship between faith and reason.

In Chapter XX, section 2 of Book II of *Essay*, Locke presents the association of pleasure and pain with human passion in a manner similar to Aristotle. Pleasure and pain are defined in terms of what is good or evil, and these sensations dictate many of our passions. He explains that when we call something good, we are speaking of something that is likely to cause or increase pleasure, or to reduce the amount of pain we may be experiencing. Likewise, we understand evil is that which will cause or increase the level of pain, or to diminish pleasure. This distinction leads us to acknowledge the importance of happiness, as did Aristotle. This is a very simple way of viewing ethics and morality: do that which increases pleasure or happiness, and do not do that which is apt to cause or increase pain, in our lives or in the lives of others. In a fairly hedonistic manner, Locke sets the pursuit of happiness (careful and constant) as the highest perfection of intellectual nature (*Essay* II:XXI.51), but he also acknowledges that what makes one person happy does not necessarily make another person happy (*Essay* II: XXI.54)—with this, we realize the extension of the Golden Rule that we discussed earlier, namely, do unto others what they themselves would have you do to them.

5.4.2 Examining Freedom

The very first sentence in the first book of Locke's *Two Treatises of Government* (*Treatises*) serves as a suitable introduction to the importance of freedom: "Slavery is so vile and miserable an estate of man, and so directly opposite to the generous temper and courage of our nation, that it is hardly to be conceived, that an Englishman, much less a gentleman, should plead for it."¹³ Locke writes these

treatises against certain persons who deny the natural freedoms of mankind by claiming all of government is absolute monarchy—men, therefore, are not born free. Their “evidence” is argued to have existed from Adam, as a monarch over all creation, to the role of fathers, who serve as monarchs over their children. He challenges those who hold this opinion to provide evidence for their “proofs,” other than the mere repeating of the belief.

Upon completion of his argument against monarchical powers and against the belief that freedoms are not naturally present and available, Locke goes on in Book II to lay out a system of civil government that respects a sort of contract with its people. He begins by identifying political power as having the right to make laws and include the community in the effort of enforcing those laws and in the defense of the country, all in the name of the public good. To understand this power, one must understand the natural state of man, which he defines to be perfect freedom and equality. Locke believed that all persons are born into a perfect freedom to do what we want, when we want, and how we want within the bounds of the laws of nature. It is therefore a qualified freedom, subject not only to the laws of nature but also to the laws of family and community. As a community grows, social needs become more complex and the need to properly balance freedom and governmental restraint requires consistent attention.

Colonial slavery was somewhat rooted in the ideals of an absolute monarchy, therefore Locke’s writings against the monarchy influenced his views on slavery, freedom, and equality. In *Treatises*, Locke describes two forms of slavery: that which is legitimized as a state of war, where there is a conqueror and a captive who have mutually agreed to a limitation of power on one side and obedience on the other side (though still a “vile and miserable estate”); and that which is illegitimate as a result of the inconstant, uncertain,

unknown, absolute, arbitrary will of another. Freedoms are absolute, and any limitation or restriction of those freedoms must be imposed by some form of mutual agreement specific to involved parties, such as by law established by the members of a community (or of humanity). Examples of colonial slavery clearly violated any sort of natural law and were made illegitimate through the arbitrary and capricious will of another.

Equality is described as the foundation of our obligation to mutual love within humanity, as a duty that we owe one another, and from which justice and charity derive meaning. The preamble to the code of ethics published by the National Society of Professional Engineers emphasizes equity in the attention paid by engineers: “Accordingly, the services provided by engineers require honesty, impartiality, fairness, and equity ...”¹⁴ Equity is demonstrated when an engineer considers the needs of clients in an orderly manner, not preferring one client over another when agreeing to complete work for them and by billing services using the same protocols. Building officials should consider the needs of all members of the public to be equally relevant and deserving of quality, fair, and timely service. Further, engineers should treat one another with equal kindness, sensitivity, and respect. On a personal level, and perhaps on a professional level, it is clear that a person should give special regard to family members, and this is natural. Recognizing equity among fellow human beings as an obligation to mutual love, however, can help us evaluate our thoughts and actions with a meaningful perspective towards others, perhaps becoming more natural in the process.

Locke explains that freedom is liberty to follow my own will in all things, as long as the standing rule of law, which is to be common to every one of society, does not prohibit it (*Treatises* II: IV.22)—free from absolute and arbitrary power.

It is not unbridled, wanton freedom without care for others, but something that is cherished and protected as a part of nature itself. He makes it clear that freedom can only thrive when there is a communal agreement among people that establishes a comfortable, safe, and peaceable environment where one is able to securely enjoy their properties (*Treatises* II: VIII.95). Freedom must be found in order, such as codes of conduct and other rules that the profession of engineering is obligated to follow, but they are not intended to be burdensome. As John Locke indicates, freedom is found in the combined will of a community, who agree to subject themselves to laws because they need protection, and with that protection they are free to live their lives (Aristotle would encourage a life of contemplation, as the truest state of happiness).

5.5 Immanuel Kant (Germany, 1724-1804 CE)

A theory of ethics taught by Immanuel Kant (see [Fig. 5.6](#)) puts forth the idea that a person should always respect the humanity in others, and that a person should only act in accordance with rules that could hold for anyone. Human understanding and reason, he argues, is the source of the moral law and the basis for our belief in God, freedom, and the soul. One of Kant's most significant works, *Critique of Pure Reason*, published in 1781, was written in response to the radical skepticism of philosopher David Hume and laid out the most fundamental approaches to metaphysics and epistemology.



Figure 5.6 The birth home of Immanuel Kant in Königsburg.

Immanuel Kant was born on April 22, 1724 in Königsberg, Prussia (currently Kaliningrad, Russia) to parents who belonged to a sect of Lutheranism which emphasized the experience of religious emotions, reliance on divine grace, humility, and personal devotion. Though young Immanuel was not impressed with the tenets of their religion, he learned much about hard work and honesty from the artisan employment of his parents. At the age of 16, he enrolled at the University of Königsberg where he studied classics such as mathematics and physics, and philosophical subjects including logic, metaphysics, ethics, and natural law.

After his father's death in 1746, Kant left the university to work as a private tutor for several families in the area around the city. He eventually returned to the university as

an instructor and published many short essays on a wide range of subjects, including astronomy, physics, other earth sciences, and philosophy. These publications made Kant recognizable throughout Prussia and in 1770, Immanuel was given the position of Professor of Logic and Metaphysics, which he had been working toward since his return. He later expanded his studies and treatises to the fields of anthropology, rational theology, pedagogy, natural right, mineralogy, and even military fortifications. Kant continued to issue publications through the 1790s, mostly on philosophical subjects, and retired from teaching in 1796. He began showing signs of mental decline around 1800 but continued developing his system of thought in a series of partially finished papers that were not published until after his death on February 12, 1804.

5.5.1 Moral Laws as Categorical Imperatives

In the *Metaphysics of Morals*, Kant introduces us to the very nature of moral laws, explaining that they are categorical or unconditional imperatives, commanding or prohibiting certain actions. The imperatives address actions that are morally necessary, obligatory, possible, or impossible, and can also be thought of as a duty for human interaction. Like philosophers before, Kant links the observance or avoidance of moral duty with pleasure or pain (called “moral feeling”), but he goes on to explain that we cannot take those feelings into account when considering practical laws of reason. Through reason, one can apply a test of universality to the imperatives: consider whether an action would be acceptable if it were to be practiced universally. He states, “The Supreme Principle of the science of morals accordingly is this: Act according to a maxim which can likewise be valid

as a Universal Law. Every maxim which is not qualified according to this condition, is contrary to morality.”¹⁵

Without venturing into arguments of human contradiction and deep analysis of this simple principle, it can be recognized as very similar to the Golden Rule (see [Chap. 1](#)) with a more widespread focus, extending beyond the individual to an entire community (and further). Rather than considering whether we would want all of our office mates to speak respectfully to one another, we could ask ourselves if we would want that same thing for anyone who practices engineering. The answer would be “yes,” which lends credibility to a belief that the act of speaking respectfully to one another is a true and justifiable moral law, albeit very simple credibility. The formula of universality was not intended to be a discussion-ending proposition, but rather a test of the sufficiency of reasons for an action to take when we are faced with a choice. It seems to answer some questions and ignore a host of others, but it at least provides a convenient starting point.

5.5.2 Offices of Charity

In the fourth book in Kant’s *Metaphysics of Ethics*, “The Metaphysical Elements of the Doctrine of Virtue,” he discusses three character qualities that define *offices of charity*, namely, beneficence, gratitude, and sympathy. Charity is to be understood as the exercise of genuine love of our fellow human, and to actively befriend them. He describes the philanthropist as one who takes delight in the welfare of his fellows, considered merely as belonging to his own species.¹⁶ *Beneficence* is defined as the pleasure that we take in the prosperity and happiness of our neighbor. Kant shows that this fulfills the definition of a universal law, since we would want the very same thing for ourselves. To deal kindly toward our brethren of mankind who are in

distress, without hoping for anything in return, and to help them out of their troubles, he adds, is considered a mutual duty of all. In a similar manner of which has already been discussed in this book as a slight alteration to the Golden Rule, Kant explains that the exercise of kindness cannot be based on the force of my idea of what will make a person happy, but rather by studying that person's own ideas of well-being and acting according to his needs, not my own.

Gratitude is the honoring of another on account of some benefit we received from that person. It is a reverent sentiment with a sense of love and devotion and should be considered a duty that can be expressed in multiple ways. It does not need to convey an obligation to return an even greater kindness (this would be somewhat robotic and insincere), but simply that cordial goodwill demonstrates gratitude. Kant labels the act of *sympathy* as a duty called humanity, which can be expressed voluntarily or purely by emotion, and involves a sharing of joys and sorrows of others in a way that helps to develop genuine and effective benevolence.

These three stand in opposition to envy, ingratitude, and malice, which should be driven away from our will. A focus on true virtue requires a healthy consideration of self-improvement, which includes study, counsel, and usually the act of comparing oneself with others who exhibit traits that we wish to emulate. Comparison always requires careful attention and a strong commitment to what is honorable, otherwise we may find ourselves adopting characteristics that are not virtuous. There are so many resources available to help us make good choices and to properly instruct us on how to examine ourselves, which include personal interactions and study of past examples and instruction. Oftentimes our will needs to be brought into the light of reason and evaluated with regard for the mutual love of humanity.

5.6 Review Questions

- 5.1.** What are the four main branches of philosophy?
- 5.2.** What is the attempted goal of studying ethics?
- 5.3.** How is a valid logical argument defined? What about a sound logical argument?
- 5.4.** According to Confucius, what are the four characteristics of promises?
- 5.5.** What basic promises are offered in an agreement to complete professional services?
- 5.6.** According to the Engineers and Geoscientists British Columbia, what is to be the basis and rationale for exercising one's "Duty to Report"?
- 5.7.** According to the Rules of Conduct published by the Zimbabwe Institution of Engineers, what steps should an engineer take before publicly expressing a professional opinion that may involve other parties?
- 5.8.** How does Aristotle describe a perfect expression of goodness (although it is difficult)?
- 5.9.** What does Miskawayh present as the four cardinal virtues? Provide a definition for each virtue using a dictionary or other resource.
- 5.10.** How does Miskawayh describe the expression of justice?
- 5.11.** What does Miskawayh say about the quality of virtues when one associates with other people (does not keep to themselves)?
- 5.12.** How did John Locke describe a simple way of viewing ethics and morality?

- 5.13.** What does Locke present as the highest perfection of intellectual nature?
- 5.14.** According to Locke, what is the natural state of man?
- 5.15.** According to Immanuel Kant, what is the Supreme Principle of the science of morals?
- 5.16.** What three character qualities does Kant present as offices of charity?
- 5.17.** What are three things that define gratitude?
- 5.18.** How does Kant describe an act of sympathy?

5.7 Discussion Questions

- 5.1D.** Describe the difference between human rights and individual character when considering ethical theory.
- 5.2D.** Provide three example situations where it *may be permissible* to break a promise. If you don't think any promise should ever be broken, explain why.
- 5.3D.** Do you agree with Confucius that a person should not dare to instruct someone else on matters of morality unless they can honestly say that they are also working on those same matters? Why or why not? If the truth is being taught either way, why should it matter?
- 5.4D.** Aristotle explains that moral virtues typically lie between two extremes, one excess and the other deficiency. Provide three examples of this apart from those presented earlier.
- 5.5D.** Aristotle said that it is on account of pleasure that we do bad things and on account of pain that we abstain

from doing good things. Provide three examples of when this might be true regarding an engineer's activities.

5.6D. Miskawayh said that the history of a nation can tell us a lot about the morals of human beings. Do you agree or disagree? Why or why not?

5.7D. During the period of Enlightenment, intellectuals felt that the correct use of logic and reason would help people achieve a more sustainable happiness. Explain how this could be possible, or why it isn't possible (depending on whether you accept or reject the premise).

5.8D. Do you agree with John Locke's example of a simple way of viewing ethics and morality, namely, do that which increases pleasure or happiness and do not do that which is likely to cause or increase pain? Why or why not?

5.9D. Explain how Kant's Universal Law principle works and provide a practical example. Provide an example of where this principle might not really apply.

5.10D. Provide definitions for envy, ingratitude, and malice and explain how they stand in opposition to the offices of charity.

¹Peter van Inwagen and Meghan Sullivan, "Metaphysics," *The Stanford Encyclopedia of Philosophy* (Spring 2020 Edition), Edward N. Zalta, ed., <https://plato.stanford.edu/archives/spr2020/entries/metaphysics/>.

²Jaroslav Pelikan, ed., *Confucianism: The Analects of Confucius* (New York: Quality Paperback Book Club, 1992).

³Russian Center of Certification and Registration of APEC Professional Engineers. *Code of Ethics* (Tomsk, Russia:

Tomsk Polytechnic University, 2011).

⁴Texas Administrative Code—Texas Board of Professional Engineers and Land Surveyors. *Professional Conduct and Ethics*, Title 22, Part 6, Chapter 137, Subchapter C, Rule 137.61 (May 20, 2004).

⁵Engineers and Geoscientists BC. *Guide to the Code of Ethics* (Burnaby, British Columbia, Canada: Engineers and Geoscientists BC, 2021).

⁶Institution of Engineers Tanzania, *Code of Conduct and Ethics for Engineering Practice* (Dar es Salaam, Tanzania: Institution of Engineers Tanzania, July 22, 2020).

⁷Zimbabwe Institution of Engineers, *ZIE Rules of Conduct* (Harare, Zimbabwe: Zimbabwe Institution of Engineers, October 28, 2010).

⁸Aristotle, W. D. Ross, and J. O. Urmson, *The Nicomachean Ethics* (Oxford: Oxford University Press, 1980).

⁹Association of German Engineers, *Ethical Principles of the Engineering Profession* (Dusseldorf, Germany: Verein Deutscher Ingenieure, 2002).

¹⁰Abu Ali Ahmad ibn Muhammad ibn Yaqub Miskawayh and Constantine K. Zurayk, *Refinement of Character* (Chicago, IL: KAZI Publications, 2002).

¹¹Professional Land Surveyors of Colorado, *Code of Ethics* (Aurora, CO: Professional Land Surveyors of Colorado, 2010).

¹²John Locke, *The Works of John Locke in Nine Volumes* (London: Rivington, 1824), Vol. 1.

¹³John Locke, *The Works of John Locke in Nine Volumes* (London: Rivington, 1824), Vol. 4.

¹⁴National Society of Professional Engineers (NSPE), *Code of Ethics for Engineers* (Alexandria, VA: NSPE, July 2019).

¹⁵Immanuel Kant and Mary J. Gregor, *The Metaphysics of Morals* (Cambridge, UK: Cambridge University Press, 2013), p. 35.

¹⁶Immanuel Kant and J. W. Semple, *The Metaphysics of Ethics* (Edinburgh, UK: T&T Clark, 1886).

CHAPTER 6

Ethical Codes of Engineering Practice

The practice of engineering requires technical knowledge and skill, but membership within a profession requires a greater set of capabilities. We create new things for people and we often work in groups; therefore, interaction with others is frequent. Because of that, engineers also need to learn how to communicate with people from many different backgrounds and levels of technical understanding—not only to describe how to implement designs but also to teach young engineering graduates the tricks of the trade and to advocate for the profession.

Professional engineering organizations have a long history of development. During the Roman and Byzantine eras, many people who practiced the same trade organized themselves into *collegia* that could be recognized by the Roman Senate and given some form of legitimacy. These associations became known as *guilds* in the Middle Ages, where members passed along knowledge and skills of a profession and often developed some form of internal behavioral standards. The 18th century brought rapid scientific and technological advancement, and with it a need

for more formal requirements for training, education, and discipline. The Institution of Civil Engineers (ICE) was founded in England in 1818 and is thought to be the earliest of the *modern* professional engineering societies.¹ The group's first president, Thomas Telford (see [Fig. 6.1](#)), helped bring in many new members through his political and social connections and obtained a Royal Charter in 1828. Today, the institution supports more than 92,000 members worldwide.²



Figure 6.1 Thomas Telford, the first president of the Institution of Civil Engineers. (Copyright the Institution of Civil Engineers, 2019.)

With the benefit of history and the input of members, most engineering societies develop codes of professional conduct that include both technical instruction (“only practice in your area of expertise”) and ethical values (“act honorably”), and these documents are very similar between organizations. Internal rules of order are not subject to enforcement outside of the organization unless some form of a legal entity recognizes them and adopts them as a standard of expected practice by other members of the public. For example, engineering licensing agencies can incorporate these rules of conduct within their own board rules and expect those who receive a license to practice engineering to follow them. Violation of those rules can be subject to discipline, including suspension or loss of license, and even fines. It should also be recognized that it is not possible for any code of conduct to include instructions on every type of ethical dilemma that an engineer may be presented with in a real-world setting. However, these codes provide enough information to form a basic structure of moral expectations and, when coupled with an examination of ethical theories and case studies, engineers will be sufficiently equipped to make reasonable and rational decisions when necessary.

Codes of conduct can also be used by courts to identify an ethical standard of care recognized within the profession by which engineers should be bound (see [Chap. 4](#)), and violations could be interpreted as negligence and potentially subject to some form of punishment in a civil or even criminal lawsuit (see [Chap. 2](#)). Even if one is not a member of a formal society, the public recognizes common elements between societal ethical standards and will usually attribute

required behavior to anyone licensed to practice, whether or not their name appears on a role of members. It is important for professional engineers to know there is a common ground between different societies and to understand the relevance of more detailed moral rules published by individual societies.

Remember that professional codes of conduct are not intended to be tools of indoctrination. The methodology of emphasizing a particular set of principles helps to focus attention on matters pertinent to a specific group of individuals ... in our case, professional civil and structural engineers. Other moral or legal principles may be just as important as those summarized by engineering societies, and if they are not captured in word or spirit, the written canons can be modified by that society to better suit the needs of practitioners and of the public.

Ethical codes are meant to serve as reminders of how a person should behave and interact with fellow human beings. For engineers, there is also an element of ethics that focuses on the future, and rightly so. We do not create a system for draining stormwater from a plot of land that operates for a single day and only benefits the owner of that land. Surrounding regions (and persons) are also affected by our decisions, and future generations are affected as well. Resources are used to create new things, and the current generation must understand that they are responsible for using those resources wisely and sparingly so that future generations can have equal or greater benefit from available resources.

Deciding to follow a set of ethical standards does not require a religious experience or heartfelt devotion to any government. Engineers who are part of a professional organization are expected to adhere to that group's adopted set of standards. Licensed professional engineers must also perform their duties in compliance with the licensing board's

published code of conduct. However, so much can be gained by studying elements of ethical conduct promoted by a wide variety of engineering and philosophical organizations and publications. A broad set of tools and a deeper understanding of ethics can help an engineer seamlessly incorporate these principles into daily activities. The engineering groups represented in this chapter are by no means the only ones who publish codes of ethical conduct or advocate for the profession—in fact, many other societies and agencies are represented throughout this book.

Codes of conduct are intended to be accessible and open to comment or criticism by members of the engineering profession, the public, government agencies, or anyone else who has a stake in the activities and products of professional engineers. Members of the profession *should* make their voices heard and participate in the development of codes, standards, and guidelines, and they should also consider an active role within a professional society of their choosing, to continually enhance and improve the future of practice and how engineers are perceived by the world.

6.1 Common Rules

There are common expectations for professional practice that can be found in most of the canons published by engineering societies. These are instructions that have survived the development and adoption process and are easily recognizable by members of the public. A summary of these common rules is provided in [Fig. 6.2](#), and we will discuss each one individually.

Common foundational elements of professional engineering ethics:

1. Hold paramount the safety, health, and welfare of the public.
2. Be truthful and do not misrepresent yourself or others.
3. Treat others with dignity, respect, and fairness.
4. Practice within your area of competence and continue your development.
5. Adhere to principles of sustainable development.

Figure 6.2 Common foundational elements of professional engineering ethics.

1. Hold paramount the safety, health, and welfare of the public.

To *hold paramount* simply means to set as more important. In this canon, the recipient is the public, and the objects are safety, health, and welfare. This seems like a difficult responsibility that could involve thousands of moving parts, any one of which could escape a careful engineer's attention at any moment. The intention here is not a perfect knowledge of the needs of the public, but a careful assessment of how judgment needs to be applied for any given situation.

If we were to use the broadest terms, the *public* would include all persons. We are all part of the public. This means the safety, health, and welfare of employers, clients, colleagues, family, friends, strangers, and all others should be held as the most important goal. Such a broad characterization, however, makes it more difficult to understand how this provision applies to engineering practice. Specific instructions are provided by engineering ethical code documents to clarify the practical intent of this fundamental provision, including the following:

- A. Only approve documents that are in conformance with applicable codes and standards.

- B. Draw attention to hazards, including when your sound judgment on a safety matter is overruled.
- C. Do not aid or abet the practice of engineering by someone who is not duly licensed.
- D. Expose unethical or illegal activity through appropriate channels.
- E. Avoid conflicts of interest.
- F. Identify, evaluate, quantify, mitigate, and manage risks.

It is easy to see how the safety and welfare of the public are captured within this sample list of practical duties. *Safety* includes adherence to minimum standards of construction and attention to hazards that may cause harm to another, such as during a site investigation or in reviewing a set of design documents that include gross errors of judgment. *Welfare* includes an expectation that only qualified individuals will make engineering judgments that affect society, and licensed professional engineers need to be aware of these types of violations or when circumstances arise that will bring sound, reasoned judgment into conflict. The Architecture Practice Act of Illinois³ defines public safety (with relation to architecture) as “the state of being reasonably free from risk of danger, damage, or injury” and it defines public welfare as “the well-being of the building user resulting from the state of a physical environment that accommodates human activity.”

The *health* of the public is more difficult to identify from an engineering perspective (as something that would be distinct from safety). It is something separate from welfare, but can include elements of well-being, such as having the freedom and opportunity to participate in activities that increase happiness, advance the potential to achieve goals, and broaden the range of available choices for a variety of

lifestyle conditions (career, family, living space, recreation, etc.). Health is also key to choices that affect the environment, such as the emission of pollutants and disposal or reuse of waste products. The Architecture Practice Act of Illinois defines public health as “the state of well-being of the body or mind of the building user.”

An example of how the health of the public has been addressed as paramount is in the selection and use of fly ash in concrete mixtures and examination of potential hazards. Fly ash is a pozzolanic by-product of the combustion of pulverized coal in electric power generating plants and can be used as a substitute for cement in a concrete mix design, typically in the range of 15% to 30%, but it can also be used to replace more than 50% of the cement.⁴ It is known to reduce the impact that concrete has on the environment (a health benefit to the public), but it also contains trace amounts of arsenic and some heavy metals (dangerous to the health of the public). Several studies were conducted at universities in Germany and Canada to assess the risk to public health, and it was determined that leached amounts of these products were very low and there is very little risk of contamination to humans or the environment when fly ash is used in a good quality concrete mixture.⁵

There is a real danger in oversimplifying the application of this precept—it is not intended to categorically demand that an engineer’s duties and responsibilities are to be focused in a single direction without consideration of other factors. Professionals have legal obligations to contracts, privacy, employers, and clients that cannot be taken lightly or carelessly pushed to the side. In cases where there is conflict, you must honestly and objectively evaluate the situation and truthfully consider the conflicting elements. Sometimes a neutral third party can be helpful in assessing whether there is, in fact, conflict and can offer solutions that

may not be immediately apparent. Where real conflicts are apparent, these should be brought to the attention of other parties who will be affected by your decision.

A legal case that is sometimes used to illustrate the duty of an engineer to hold paramount the safety of the public is *Carvalho v. Toll Brothers & Developers*.⁶ In 1985, West Windsor Township of New Jersey hired Bergman Hatton Engineering Associates to prepare plans for the construction of a sewer line. Toll Brothers & Developers was the general contractor awarded the project. In December 1987, while working in an unshored 13-foot-deep trench, Francisco Carvalho, an employee of the subcontractor hired to do the excavation work, died when the trench collapsed and crushed him. Bergman Hatton's site representative engineer, as well as the contractor's superintendent, were present at the trench on that same day (likely not at the exact moment of the accident), watching Carvalho work.

Mr. Carvalho's widow sued the Township, the contractors, and Bergman Hatton for wrongful death. The trial court determined that the Township was not a party to the dispute, and the plaintiff settled with the contractors. Bergman Hatton moved for summary judgment, arguing that it owed no duty to Mr. Carvalho, and the trial court agreed. On Mrs. Carvalho's appeal, the New Jersey Appellate Division reversed the trial court's ruling, and the New Jersey Supreme Court upheld the reversal. In their opinion, the supreme court noted, "Courts consider initially the factor of foreseeability as the predicate for the duty to exercise reasonable care. The facts in this case point clearly to the foreseeability of the risk of injury to workers in the circumstances surrounding decedent's death." Following are some of the facts that led to the establishment of a duty that the engineer had in protecting the safety of the public (Mr. Carvalho)⁷:

- A. The contract specifically provided that trenching work shall be shored, braced, or supported as conditions may warrant. The supervising engineer was aware of this requirement and had the responsibility of observing that the contractors were following the plans and specifications.
- B. The supervising engineer was at the site when the accident happened, and he knew that trench boxes were not being used to shore this particular trench. He also testified that he observed water present in the general location of where the trench collapsed.
- C. A week prior to the accident, the engineer noted that this same trench was unstable, that water had pooled in the bottom, and the walls caved or slid onto the trench floor.
- D. The engineer acknowledged that he knew an unshored trench of 13 feet in depth could be dangerous and that he himself would not want to be in such a trench when it was in such a condition.

The appellate court concluded, “Bergman had the authority to stop the job if it was not being performed by Toll Brothers in accordance with the plans and specifications. Bergman placed its representative at the site as a full-time inspector to ensure Toll Brothers’ compliance with the plans and specifications. Of most significance is that the inspector was aware of water present in the trench and had seen the trench collapse several times prior to the date of the accident. He knew that the trench floor was unstable and water was abundant several days before the accident. With his knowledge of the unsafe nature of the trench, it was reasonably foreseeable to the inspector (and therefore to Bergman) that a workman may be injured or killed unless Bergman and its representatives took some other

reasonable step to prevent the injury. Fairness and policy dictate imposition of duty upon the engineer since, as a professional, he or she should not stand idly by with actual knowledge of unsafe safety practices on the jobsite and take no steps to prevent injury to the workers at risk.”

An engineer is not generally held liable for the safety operations of a contractor unless specific facts create such a duty, such as actual knowledge of a dangerous condition when supervising or observing the work. As an engineer gains more knowledge and experience, there is (rightly so) an expectation that she will also be more sensitive about what creates a dangerous condition and what measures can be taken to uphold the safety of the public when circumstances require such judgment.

The National Society of Professional Engineers explains the importance of this primary canon with relation to one’s own employment: “This obligation takes precedence over all other considerations, including obligations to keep confidential knowledge about the employer or client. In America, this obligation rises above the societal importance placed on teamwork. Painfully, it even takes precedence over the natural desire to keep one’s job. Engineers are well aware that engineering decisions can mean the difference between life and death, not only for one person but for entire communities. This is the ultimate meaning of public health and safety, and reinforces the principle that, to a member of the engineering profession, some things are more important than one’s own economic well-being.”⁸

2. Be truthful and do not misrepresent yourself or others.

This rule of conduct could even be shortened to the first two words “be truthful,” but the aspect of representation warrants added emphasis. Truth is what allows an engineer to make proper judgments about physical phenomena and

to focus attention where it is needed. An engineer represents facts in his design: gravity will cause water to flow downward, and a suitable (truthful) design must accommodate that fact by proper redirection into a system that can manage the accumulation and redistribution of stormwater. An earthquake has both vertical and horizontal components of acceleration, and an engineer must base her design on a truthful representation of the expected resultant forces and resistance characteristics of the building system.

As simple a concept as truth may be, philosophers have debated meanings and practical applications for centuries. The *correspondence theory of truth*, for example, states that truth corresponds with facts or reality. One of the earliest examples of this theory comes from Aristotle (384–322 BCE) who wrote, “To say of what is that it is not, or of what is not that it is, is false, while to say of what is that it is, and of what is not that it is not, is true.”⁹ Facts and reality are known to an engineer through the work of science, technical linguistics, and identity.

Phenomenon accepted as fact or real may be shown through the work of science (28-day compression strength testing of a set of concrete cylinders), properly understood by technical terms and explanations (statistical variation exists in measured strengths, which is accounted for through the application of standard deviation), and qualified by persons who are properly identified (certified lab technicians, scientists, or engineers).

Some practical instructions on truthful representation include:

- A. Make sure that your own understanding of engineering issues, such as environmental consequences of development, is as accurate and objective as possible.
- B. Do not falsify your qualifications, or those of another.

- C. Make objective comparisons of competing products based on the merits of their use.
- D. Present relevant facts honestly as they pertain to the confirmation of a proposed design.
- E. Do not take on independent work that has not been authorized by your employer.
- F. Have zero tolerance for bribery, fraud, and corruption in all forms and report violations.

Truthfulness is one of those moral laws that is readily accepted worldwide—if everyone chose to be untruthful, it would be extremely difficult (if not impossible) to advance the good of collective society and of all individual human beings, which is a basic desire that we all share. Exceptions have been proposed over the years under conditions where a falsehood may serve a greater, unselfish good, such as a Christian family intentionally deceiving Nazi soldiers during World War II about whether or not they were hiding Jews to protect their lives, but whether an exception is truly valid (or the motive is truly selfless) depends on many factors and oftentimes personal conviction. There are some philosophical and religious schools of thought that allow no exceptions for complete truthfulness, but the fact that human life can be messy and inconsistent seems to at least allow for the possibility of well-intentioned exceptions that would deliver highly preferred results, such as the protection of life. This does not promote a philosophy of the ends justifying the means—it simply illustrates the possibility of reasonable exceptions (at least those which can be honestly debated and not dismissed outright).

3. Treat others with dignity, respect, and fairness. *Dignity* carries forth the idea of being honored or esteemed, whereas *respect* implies a basic regard for another's feelings, characteristics, rights, and desires. Both terms

have been used interchangeably, and for our purposes they are mostly synonymous, but bestowing honor onto another person requires a certain humbleness that should define an engineer's attitude. Our position on matters can be hampered, to ourselves as well as to others, if we consistently show arrogance, pride, or belligerence, and these attitudes present themselves as a lack of respect for others.

Related canons of conduct include the following:

- A. Acknowledge the diverse historical, social, and cultural needs of the community.
- B. Keep employer and client proprietary information confidential.
- C. Avoid taking actions or making statements that are unfairly critical of a colleague.
- D. Encourage excellence in others' practice of the art and science of engineering.
- E. Promote diversity in engineering and provide opportunities for all practitioners and prospective members of the profession.

What does it mean to be fair with others? A simple explanation would be to treat one fellow human being the same as I would treat any other fellow human being, offering the same quality of service impartially and honestly. Anyone I associate with has an equal opportunity to benefit. Being fair does not mean that an engineer can't be discerning in the company he keeps, or in the clients s/he chooses to do business with. Most states have laws that govern against discrimination, but they can be difficult to prove or prosecute. The attitude of fairness begins with each individual as a choice and is presented to society through observable actions. [Chapter 1](#) explores additional

traits of good moral behavior and benefits of a sound ethical foundation.

4. Practice within your area of competence and continue your development.

Part of being a responsible professional is knowing one's limitations, which begins with acknowledgment of natural aptitudes. During our early school days, we discovered subjects that we excelled at, or that we enjoyed more than others. Friends and peers also recognized personal traits that defined our character, such as kindness, generosity, or selflessness. We found that other courses or personal qualities required more attention and if we wanted to excel at them, we needed to invest more time and energy in their development than for what came naturally. This same process continues into adulthood and remains an important part of career advancement. Competence as a professional engineer is discussed in greater depth in [Chap. 2](#).

Some practical instructions from different engineering ethical codes include:

- A. Consider capabilities, limitations, and implications of current and emerging technologies.
 - B. Keep knowledge and skills up to date by engaging in professional practice, participating in continuing education courses, reading technical literature, and attending professional meetings and seminars.
 - C. Inform employers or clients if a task requires qualifications and experience outside your areas of competence.
 - D. Adopt a balanced, disciplined, and comprehensive approach to problem solving.
5. Adhere to principles of sustainable development.

The United Nations World Commission on Environment and Development defines sustainable development in a succinct manner: it is that which meets the needs of the present without compromising the ability of future generations to meet their own needs.¹⁰ Engineers assist clients with development projects that may have short- and long-term environmental effects and appropriate consideration needs to be given to potential benefit or harm. These projects include agriculture, manipulation of waterways, changing the drainage patterns and characteristics of land, fixed structures that consume energy and emit waste products, and extraction of materials above and below the ground. Present development activity should not hinder the economic and social health of future generations or inadvertently remove options that could be critical to the operation of future technologies.

Engineering ethical codes offer the following reminders:

- A. Consider and balance societal, environmental, and economic impacts of engineering work.
- B. Promote the involvement of all stakeholders and the community in decisions and processes that may impact upon them and the environment.
- C. Respect nature indispensable to the survival and development of humanity while holding in esteem diverse civilizations and cultures.
- D. Strive to accomplish the beneficial objectives of a project with the lowest possible consumption of raw materials and energy and the lowest production of wastes and pollution.

Quality of life is a key benefit of engineering activity, affecting current clients and municipalities as well as future users of development projects. The capability of future engineers to assist in advancing the quality of life for others

must be sustained, which places an important responsibility onto present-day engineers to use resources wisely, appropriately manage elements of nature, and encourage the success and strength of the engineering profession. The science of engineering is sustained through a diversity of ideas, discoveries, and partnerships that come from an inclusive and nondiscriminatory profession. Issues related to sustainability are covered more thoroughly in [Chap. 9](#).

6.2 National Society of Professional Engineers (www.nspe.org)

The National Society of Professional Engineers (NSPE) is currently headquartered in Alexandria, Virginia and has been in existence since September 3, 1934. Bridge engineer David Steinman (see [Fig. 6.3](#)) called together four engineering organizations—New Jersey, New York, Pennsylvania, and Connecticut—to explore the possibility of forming a single, nationally recognized professional engineering society. Steinman hoped to capture common interests and aspirations of all engineers in a way that would unite and strengthen all branches of the profession.



Figure 6.3 David Steinman, co-founder of the National Society of Professional Engineers, 1934. (Image used by permission of the National Society of Professional Engineers.)

In January 1935, the NSPE adopted *The American Engineer*, formerly a magazine of the New York State Society of Professional Engineers, to provide information that would enhance the work of engineers across the United States. The first reference to a common code of ethics for engineers was made in the May 1935 issue as a matter of

consideration. Eleven years later, the NSPE Board reviewed and approved a formal set of ethical canons prepared by a number of technical engineering societies, with publication in the January 1947 issue. Today, the NSPE code of ethics is one of the most complete sets of canons and principles available to professional engineers, with a host of resources to clarify intent and offer examples of practical applications. The Board of Ethical Review (NSPE BER) was created in 1954 to examine real and hypothetical situations that are faced by engineers and publish opinions on how ethics is involved in solving problems or addressing needs. These cases are available through the NSPE website, where you will also find sample examinations, reports, webinar materials, and even an ethics essay contest.

6.2.1 Overview

The overall introduction to the NSPE code of ethics is presented in two statements. One is the “Engineer’s Creed,” published in June 1954, and the other is the “Preamble” to the current code. The Engineer’s Creed reads: “As a Professional Engineer, I dedicate my professional knowledge and skill to the advancement and betterment of human welfare. I pledge (1) to give the utmost of performance, (2) to participate in none but honest enterprise, (3) to live and work according to the laws of man and the highest standards of professional conduct, and (4) to place service before profit, the honor and standing of the profession before personal advantage, and the public welfare above all other considerations. In humility and with need for Divine Guidance, I make this pledge.”

This creed emphasizes *service to humanity*, with recognition that society deserves the best of effort (“utmost performance,” “highest standards”) and the sincerest of motives (“service before profit,” “profession before personal

advantage,” “in humility”). A person is granted a license to practice engineering after demonstrating a minimum level of competence—the public *requires* this evidence and level of commitment, whereas the Engineer’s Creed encourages us to give the public our very best out of respect, thanksgiving, and humility. It should be an honor to practice engineering, not just viewed as an impersonal responsibility.

The Preamble to the modern code of ethics is similar to the former creed, as it also sets the tone of giving one’s best for the sake of humanity: “Engineering is an important and learned profession. As members of this profession, engineers are expected to exhibit the highest standards of honesty and integrity. Engineering has a direct and vital impact on the quality of life for all people. Accordingly, the services provided by engineers require honesty, impartiality, fairness, and equity, and must be dedicated to the protection of the public health, safety, and welfare. Engineers must perform under a standard of professional behavior that requires adherence to the highest principles of ethical conduct.” Personally, I like the Engineer’s Creed better. It reminds the engineer to be humble, which involves recognition that her ability to manipulate the mechanics of science to create new things that can improve the lives of millions of fellow human beings is truly a gift.

The code of ethics itself is set up into four categories: The Preamble, Fundamental Canons, Rules of Practice, and Professional Obligations. The Preamble (stated earlier in this chapter) identifies why it is critical for engineers to ascribe to a well-defined code of ethics. Primarily, it is because “engineering has a direct and vital impact on the quality of life for all people.” There are six fundamental canons that represent the primary topics of ethical conduct suitable to the engineering profession. These are summarized in [Fig. 6.4](#).

Engineers, in the fulfillment of their professional duties, shall:

1. Hold paramount the safety, health, and welfare of the public.
2. Perform services only in areas of their competence.
3. Issue public statements only in an objective and truthful manner.
4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

Figure 6.4 The Six Fundamental Canons of the NSPE Code of Ethics.

The Rules of Practice section identifies individual rules of conduct to illustrate adherence to the first five fundamental canons. For example, under the third canon (public statements), one of the rules of practice states, “Engineers may express publicly technical opinions that are founded upon knowledge of the facts and competence in the subject matter.” The NSPE BER published a sample opinion, Case No. 88-7, to illustrate this rule.¹¹

The sample opinion introduces a structural engineer who was hired by a large city newspaper to visit the site of a state bridge construction project, which has been the object of delay, cost increases, and litigation related to on-site accidents. The engineer performs a 1-day visual observation and issues a very general report that identifies potential problems and recommendations for additional testing. The newspaper takes this information and prints a number of articles alleging major safety issues, as well as misconduct and incompetence of the project engineers and contractors. When questioned by the state about her report, the engineer states that her report was limited in scope and was only intended to identify what she felt were potential

problems, but was not meant to be conclusive as to the overall safety of the bridge.

In their conclusions on this sample case, the NSPE BER noted that when an engineer is paid by a news agency to offer a professional opinion that concerns public safety, the engineer must act with particular care, integrity, and dignity and take whatever steps are necessary to improve the likelihood that her opinions will not be taken out of context. It was not unethical for this engineer to perform the limited investigation for the newspaper, but there was an obligation to require that the newspaper clearly state in any subsequent articles using her opinion that she was retained for a fee. I would also add that there should have been a clear understanding that anytime the engineer's conclusions or recommendations are noted, the instructions would be qualified as preliminary or based on a limited scope of review and investigation.

The Professional Obligations section offers practical illustrations of how engineers should conduct themselves in response to the sixth fundamental canon. In other words, how does an engineer act honorably, responsibly, ethically, and lawfully? This section includes nine basic subjects (a few related NSPE BER opinion numbers are shown in parentheses):

1. Maintain the highest standards of honesty and integrity (64-1, 88-2, 14-7)
2. Serve the public interest (76-12, 99-8, 18-9)
3. Do not deceive the public (81-5, 92-2, 01-10)
4. Maintain confidentiality (99-1, 05-11, 17-11)
5. Avoid conflicting interests (59-1, 93-1, 06-1)
6. Do not seek advancement by improper methods (62-13, 96-4, 15-10)

7. Do not maliciously injure the reputation of other engineers (81-1, 00-12, 11-14)
8. Accept personal responsibility (72-4, 90-2, 09-9)
9. Give credit where credit is due (69-9, 00-1, 18-6)

6.2.2 Honorable, Responsible, Ethical, and Lawful

The sixth fundamental canon nicely summarizes what we can call the primary message of the NSPE code: “Engineers, in the fulfillment of their professional duties, shall conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.” The engineering profession includes both public and private sectors of society, and duties within those sectors can be focused on only a few areas of responsibility or can include a very broad set of project types. The scope of tasks would be determined based on the function of the organization for which an engineer is employed, the level of competence achieved, and the range of clients or customers served. The duties of an engineer can include writing project proposals, reviewing designs submitted for code compliance, performing calculations to justify design decisions made based on professional judgment, field inspection, coordinating the specifications for land development, and much more.

If we were to label “fulfillment of professional duties” as *the what*, we would say *the how* is summarized as “honorably, responsibly, ethically, and lawfully.” One of the obligations an engineer has with respect to honorable behavior is to recognize the bigger picture beyond himself. Section III of the code states, “Engineers shall not promote their own interest at the expense of the *dignity and integrity* of the profession.” Promote their own interest, yes, but with

due regard to the interests of the profession—interests that include diversity of thought and identity, sustainability, and a positive reception by the public.

The works of Abraham Lincoln and Frederick Douglass bring to mind a unity of dignity, integrity, and diversity (see [Fig. 6.5](#)). Although the two did not meet face-to-face until after the *Emancipation Proclamation* was issued by Lincoln on January 1, 1863, they did correspond and share ideas through public addresses, letters, and newspapers. The *Emancipation Proclamation* was a heartfelt declaration shared by a president and a former slave, namely, that all persons held as slaves were considered to be free from that point onward. Legal and political barriers (among others) stood in the way of fulfillment, but Douglass remained committed to the abolition of slavery *legally*, through the existing political system. The two men disagreed on many things, but their overall contributions to the cause of abolition kept up a forward momentum, held alive by a commitment to integrity and the dignity that naturally accompanied them.

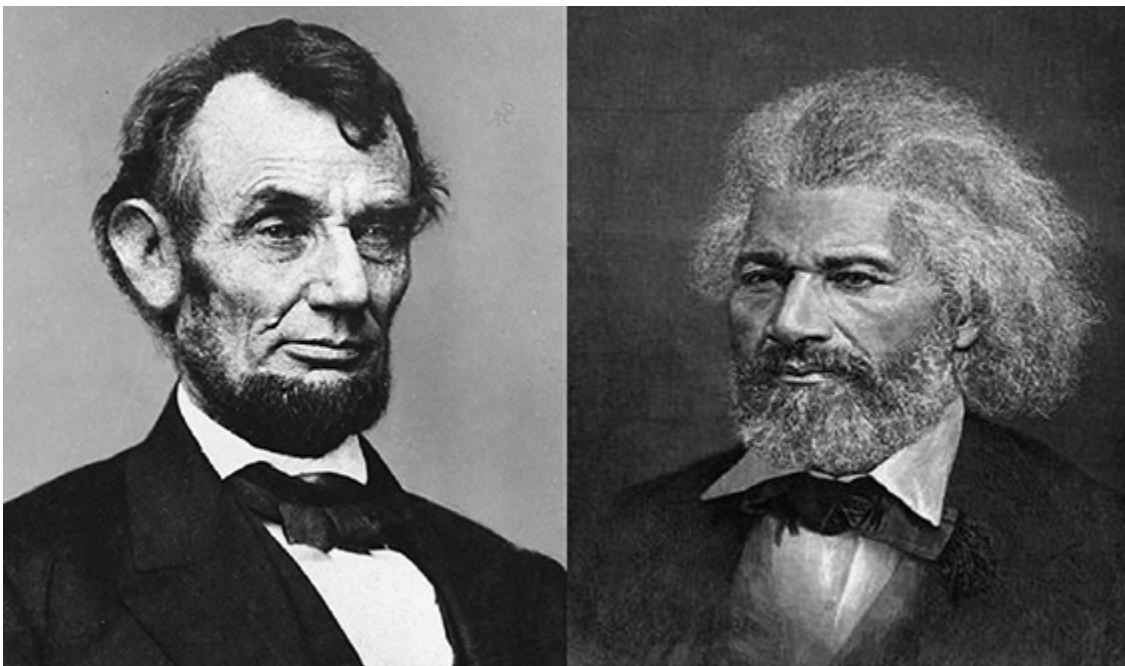


Figure 6.5 Abraham Lincoln and Frederick Douglass bring to mind a unity of dignity, integrity, and diversity.

There are three definitions for *dignity* that combine to create a well-rounded identity:

1. Dignity is the quality or state of being worthy, honored, or esteemed.¹²
2. Dignity is the importance and value that a person has, which makes other people respect them or causes them to respect themselves.¹³
3. Dignity is a seriousness, respectfulness, or formality in somebody's behavior and bearing.¹⁴

Donna Hicks, an associate at the Weatherford Center for International Affairs, Harvard University, published a descriptive piece entitled *The Declaration of Dignity*, encouraging people all over the world to commit to its principles.¹⁵ It is based on her observation that all human beings are unique and deserve to be treated well, but we also have an uncanny way of knowing how to attack and hurt one another, especially targeting one's sense of worth, or dignity. The declaration reminds people to treat one another as valued members of a world society and encourages us to believe that we are all worthy of having our identity accepted, of belonging and feeling included, of being safe and secure, of being understood, and more.

The dignity of the engineering profession is upheld by a serious regard for truth and by recognition that any person is capable of joining the profession, regardless of background, religion, ethnicity, gender identity, or other characteristic that we embrace or are born into as human beings. We encourage a diversity of opinions and thoughts because the profession is stronger for it, and the potential

for solving problems efficiently is dramatically improved by inclusion and respect.

Mark Halfon, Assistant Professor of Philosophy at Hunter College, City University of New York, examines issues related to integrity in his book *Integrity: A Philosophical Inquiry* and offers the following descriptions for a person of integrity¹⁶: “Persons of integrity embrace a moral point of view that urges them to be conceptually clear, logically consistent, apprised of relevant empirical evidence, and careful about acknowledging as well as weighing relevant moral considerations.” He adds, “Persons of integrity impose these restrictions on themselves since they are concerned, not simply with taking any moral position, but with pursuing a commitment to do what is best.”

The integrity of the engineering profession is not only upheld by how we interact with society, but also how we regulate activities and treat those within the profession. In 1975, the NSPE BER offered a sample ethical situation that speaks to this identification of integrity (NSPE BER Case No. 75-3).¹⁷ In that case, Engineer A was charged with, and found guilty of, having violated a section of the state society’s code of ethics. Subsequently, Engineer B intended to engage in a joint venture with the company of Engineer A, of which he is the president. The question being considered is whether it is ethical for Engineer B to work with the company that Engineer A is in charge of.

One of the points raised by the NSPE BER is consideration of pattern and severity. An extreme recommendation for punishment of an unethical engineer would be to shun him forever, regardless of whether that person was found guilty of a single infraction or exhibits a pattern of continual disregard for ethical practice, no matter how severe. It was decided that such a narrow and unyielding view is not consistent with the spirit of the law and of traditional concepts that redemption is a virtue that should be honored

where an individual can be restored to a status of acceptance. In summary, if Engineer A committed a serious offense, or has established a clear pattern of violations, then his position within that company is a material factor in the decision to be made by Engineer B. If the opposite is true, then it would indeed be ethical for Engineer B to engage in a business venture with the company of Engineer A, so long as careful scrutiny is maintained to ensure, to the extent possible, that additional unethical conduct will not develop.

6.3 Engineering Council of the United Kingdom (www.engc.org.uk)

The Engineering Council is the regulatory agency within the United Kingdom that sets and maintains standards of professional competence and awards titles for engineers and technicians. These titles include Engineering Technician, Incorporated Engineer, Chartered Engineer, and Information and Communications Technology Technician. To gain one of these titles, an applicant must first belong to a professional engineering institution licensed by the Engineering Council to assess their qualifications. The ICE and the Institution of Structural Engineers (IStructE) are two of these recognized groups.

The earliest formal association of engineers in the United Kingdom was developed in 1717 as the Corps of Engineers. A stronger recognition by society came in 1818 through the founding of ICE, which helped promote the works of civil engineering as instrumental to the development of the economy. More engineering societies were established as time progressed due to specialization (mechanical, electrical, etc.) and a strong demand arose in the 1950s for a central body to set standards for education and training in order to more cohesively represent the profession and enhance its image. The Joint Council of Engineering

Institutions was created in 1964, eventually turning into the Council of Engineering Institutions (CEI).

A Royal Commission was eventually brought on the scene to review the organization of engineering councils, and part of their recommendation was for the government to appoint an authority within CEI to coordinate the function and qualifications of engineers on a larger scale, and with an appropriate level of oversight. The Engineering Council, therefore, was created in 1981 from CEI and a detailed set of standards for licensure was published in 1985. In 2002, the Engineering Council was split into two groups: Engineering UK, which is responsible for the promotion of engineering, and the Engineering Council, which is responsible for professional registration standards.

6.3.1 Overview

A collection of ethical standards was made in 2005 by the Engineering Council and the Royal Academy of Engineering (RAE) as a result of consultation with engineering professionals and other professionals who specialize in ethics. The RAE was founded in June 1976 as the Fellowship of Engineering and was granted a royal title in March 1992, which also brought about the title change. The RAE focuses on policy, education, and research to improve the image of engineering and encourage excellence in all practitioners. It is one of four agencies that receive funding from the Department for Business, Energy, and Industrial Strategy in the UK government, since its activities support the improvement of public knowledge of science and engineering.

The latest edition of the *Statement of Ethical Principles* was published in July 2017 and is organized by four main principles: (1) Honesty and integrity, (2) respect for life, law, the environment, and the public good, (3) accuracy and

rigor, and (4) leadership and communication. The opening paragraph states, “Engineering professionals work to enhance the wellbeing of society. In doing so, they are required to maintain and promote high ethical standards and challenge unethical behavior.” The RAE reminds members that the statement is not a formal regulation or standard, and that it should be read with consideration to any requirements for licensure.

6.3.2 Respecting Competent Practice

A unifying theme that ties the ethical principles together is genuine respect for matters that are important to competent practice. The first principle emphasizes professional conduct, and a sincere effort made to understand and practice good behavior would be an adequate demonstration of respect. Characteristics of behavior include openness, fairness, honesty, and integrity, and these should be shown to others (employers, clients, colleagues) in equal measure and enthusiasm. The quality of being open alerts an engineer to the ways that other persons may be affected by her work, and the virtue of honesty will compel her to take steps to prevent or report corrupt practices or professional misconduct—respect for the profession is an important part of practicing with competence.

The second and third precepts involve recognition and honor for laws, facts, and respect for the wider public interest beyond the range of localized projects. Work should not only to be lawful but also justified. Engineers should competently discuss the scope of services needed for a project before entering into an agreement and include a provision for added services if the scope grows during the course of the project. A properly executed contract helps each party respect each other’s needs and elevates the

probability of success for everyone. Members are also exhorted to maximize the public good in the decision-making process and seek to minimize any potential harm to current and future populations. Wise use of knowledge and skill, with attention to accuracy and objectivity, is necessary to demonstrate a respect for competence to the public. Engineers are to present and review theory, evidence, and interpretation with honesty, accuracy, objectivity, and without bias ... considering the validity or applicability of reasoned alternate views or proposals.

The fourth ethical principle focuses on leadership within the profession and within society as a whole. High standards are set as the goal, which requires awareness of the issues that engineering and technology raise for society and an awareness of how the profession itself is being represented. Engineers must lead by example, demonstrating that diversity and equity are pillars to healthy growth in a problem-solving industry and communicating that these virtues also contribute to the well-being of society. Leadership involves making yourself available, which is difficult when the pressures of the job, and of life in general, demand time and resources that are often in short supply ... even a little bit helps. Awareness that shows respect for competence requires ambition to correct wrongs and to set things straight that have gotten skewed. Courage is needed to challenge statements made by another member of society or the profession that represent legitimate cause for concern, such as distorting the truth or unfairly maligning the character or reputation of another person.

6.4 Engineers Australia **(www.engineersaustralia.org.au)**

Prior to 1919, Australia was home to many small engineering advocacy organizations, until the increasing

demands of industry and infrastructure demonstrated a need for a more unified agency to promote the engineering profession. Engineers Australia (EA) was born out of this need and became incorporated as a not-for-profit company in 1926. A royal charter was granted by King George the Sixth in 1938. The purpose of the organization, as stated in the 2015 Royal Charter and By-Laws, is to advance the science and practice of engineering for the benefit of the community.

Figure 6.6 identifies three occupational categories of engineers recognized by EA. Each occupational category has four membership grades: fellow, member, graduate, and student. Outside the occupational categories, three other grades of membership include honorary fellow, companion, and affiliate. All of these classifications are important, as they represent a wide range of education and experience in order to allow the engineering field to reach as many as possible.

Professional: Holds an accredited or recognized 4-year professional engineering degree

Technologist: Holds an accredited or recognized 3-year engineering technology degree

Associate: Holds a recognized 2-year advanced diploma or associate degree of engineering

Figure 6.6 Occupational categories recognized by Engineers Australia.

The activities of members within EA to achieve their stated purpose include education, both members and the community; facilitating the exchange of ideas and information; encouraging the development of knowledge and competency; setting and maintaining high professional

standards for members; and informing community leaders and decision makers. EA is currently working through a 3-year plan for 2020–2023 with a strategy to deliver on their strategic goals across three areas of influence:

1. *The profession.* Engineers will be positioned for the future of work, and EA will serve as the voice to impact public policy for the benefit of the community.
2. *The membership.* Engineering professionals will aspire to be chartered, and they will see the value that EA has for the profession.
3. *The organization.* Services of EA will be streamlined for better simplicity, efficiency, and effectiveness, and to create an atmosphere where volunteers and employees will feel appreciated and valued.

6.4.1 Overview

The code of ethics published by EA is coupled with guidelines on professional conduct that provide a framework that members can refer to when using judgment in the practice of engineering. The opening paragraph in the November 2019 edition states, “As engineering practitioners, we use our knowledge and skills for the benefit of the community to create engineering solutions for a sustainable future. In doing so, we strive to serve the community ahead of other personal or sectional interests.” It is recognized that standards for acceptable conduct are not permanently fixed and may change over time, depending on the nature of relevant circumstances, but they will always represent the enduring ethical values and principles of the profession.

There are four principles of ethical conduct that summarize the duty of members:

1. *Demonstrate integrity* through honest practice, being well-informed, and respecting the dignity of all persons.
2. *Practice competently* by maintaining and developing knowledge and skills, with a sense of objectivity and adequate information for exercising judgment.
3. *Exercise leadership* by upholding the reputation of others and of the profession, supporting diversity, and communicating effectively.
4. *Promote sustainability* through responsible engagement of the community, by fostering the health and wellbeing of humans and the environment, and with a commitment to future generations.

6.4.2 Advocacy for the Profession

An overall sense of advocacy for the profession of engineering is weaved throughout the code of ethics and the general strategic position of EA. The four main ethical principles (see above) demonstrate a positive influence of engineering for members, clients, the public, and the environment, fostering a well-deserved sense of respect. The profession is not just another career—it is something that deeply influences the lives of others, even those who are not direct recipients of service, and the integrity of competent practitioners who communicate clearly by word and deed, is what holds the field of engineering in high esteem.

One of the guidelines for practice that advances the prestige of the profession states that engineers must act on the basis of a well-informed conscience. Society has no trouble recognizing the technical tools that engineers command as part of their training and practice, such as mathematics, physics, and chemistry. The fields of science

are integral with engineering practice. What really brings honor and respect to the profession is knowledge of this well-informed conscience. The public needs to see this, whether it is demonstrated by members to clients or to larger groups, such as high school students on career day. When an engineer shows discernment, impartiality, and objectivity in making the right decision, it shows the seriousness of her commitment to the profession and to ethical principles ... and thereby a seriousness to the well-being of the public.

The practice and relevance of engineering is promoted through clearly communicated policies and goals, which are made available to the public in many ways. The NSPE founded Engineers Week in 1951 as a way of increasing understanding of, and interest in, engineering and technology careers. The National Council of Structural Engineers Associations (NCSEA) supports numerous committees that focus on specific areas important for engineers and the public to understand, such as basic education, code advisory, continuing education, structural licensure, and more.

As of January 16, 2021, the American Society of Civil Engineers (ASCE) has developed 172 policy documents reflecting the Board of Direction actions related to major technical, professional, and educational issues of interest to engineers and to the public. Policy Statement No. 139, for example, was adopted by the Board on July 13, 2019 to communicate the importance of public involvement in the decision-making process. The issue recognized is the higher burden placed on natural resources and the environment due to rapid changes in technology and increasing demand for new infrastructure. Public awareness about the long-term effects of engineering projects and programs is critical to successful protection of health, safety, and welfare of individuals. In order to improve this awareness, civil

engineers are encouraged to participate in public meetings and social media information programs; give presentations and lead discussions of viable alternatives that address economic, social, and environmental impacts; and actively participate in elected or appointed legislative or regulating bodies of government, including the issuance of public comments during the meetings of governing councils.

6.5 Japan Society of Civil Engineers **(www.jsce-int.org)**

The Japan Society of Civil Engineers (JSCE) was established in 1914 with a goal of promoting the field of civil engineering, the expansion of civil engineering activities throughout the country, and the improvement of civil engineering skills in order to contribute to the advancement of scientific culture and the development of society. Some of the activities of the JSCE include conducting research, participating in international activities (such as emergency response and assistance after a major disaster), publishing periodicals and reports, meetings and educational ventures, promoting public relations, and disseminating materials to improve and advance the profession. Their principal office is located in Shinjuku-ku, Tokyo (see [Fig. 6.7](#)).

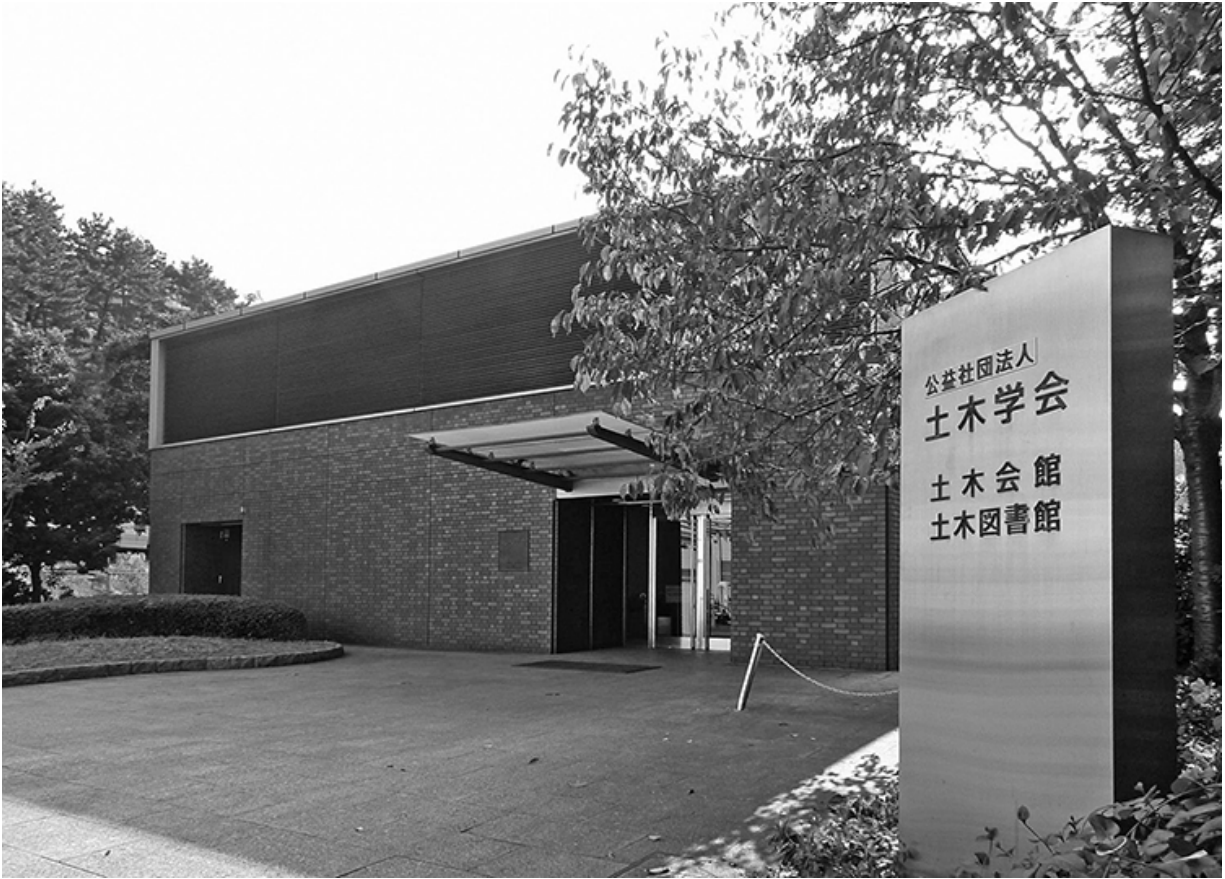


Figure 6.7 Office of the Japan Society of Civil Engineers.

On November 22, 2000, the Board of Directors issued a significant resolution entitled *Sendai Declaration 2000 on Infrastructure Development and Civil Engineering Technology* that can be downloaded from their website. It was produced in response to participation in the Third United Nations World Conference on Disaster Risk Reduction held in Sendai, Japan, on March 14–18, 2015. The declaration begins with an acknowledgment that infrastructure is the fundamental element to ensure public safety and welfare, and that civil engineering technology has made significant contributions to the expansion of economic activities and improvement of living standards throughout human history. The remainder of the document includes various principles and strategies to be adopted and

pursued by members of the profession toward the betterment, sustainability, and resilience of Japanese infrastructure.

6.5.1 Overview

The first ethical code for professional engineers in Japan was introduced in 1938 by the JSCE entitled *Beliefs and Principles of Practice for Civil Engineers*. This code was revised and republished in 1999 as *The Code of Ethics for Civil Engineers*, describing the integrity, honor, and dignity of the profession. The current edition, *The Civil Engineer's Code of Ethics*, was issued by the Board of Directors on May 9, 2014. The code includes a preamble and nine principles for ethical conduct. The Preamble, quite eloquently, states the following: “Ever cognizant of the profound interrelationship of their profession with both human society and Nature, civil engineers shall work for the development of technology; deepen and consolidate their knowledge; contribute by means of their wisdom, skills, and virtues to both the peace and prosperity of the people and the nation and to the welfare and sustainable development of humanity.”

The recognized relationship between humanity and nature is important since it serves as a reminder that the work of humanity has an unavoidable impact on nature. Consequences of land development may be good or bad, short- or long-term, depending on the activity, the area affected, and the experience of the design and construction teams. Some of these development activities include agriculture, diversion or water ways, extraction of materials, emission of heat and noxious gasses into the environment as a result of energy consumption or production, commercial forestry, and even genetic manipulation. The nine principles of conduct are clear and straightforward, and

each one includes an additional paragraph for further clarity:

1. Contribute to society
2. Respect both Nature and the fabric of civilization and culture
3. Ensure the security of society and mitigate disasters
4. Fulfill professional responsibilities
5. Guard integrity and avoid any conflicts of interest
6. Openly provide information and engage in public dialogue
7. Make known the results of research endeavors
8. Strive for self-improvement and human resource development
9. Comply with established norms

6.5.2 Social Infrastructure

The overall message of the code of ethics published by the JSCE can be summarized in the four goals that have been confirmed for all branches of the JSCE. These goals include the following, as identified on their website:

1. Propose an idea for social infrastructure development in the future from civil engineers' perspective
2. Acquire a steadfast relationship of mutual trust with society
3. Promote scientific and technological research/studies with a high degree of transparency
4. Evaluate public works from a neutral standpoint and reach a social consensus on those proper standards

One of the perspectives emphasized by these four points is a positive relationship with society, along with the understanding that this applies to both present and future societies. The term *social infrastructure* is part of urban and rural planning and covers a range of services and facilities that meet local and strategic needs of a society and contribute toward a good quality of life for all. These can include healthcare, education, transportation, recreation, faith-based facilities, and emergency facilities, as well as a responsible distribution and preservation of green or open spaces. The idea is to expand one's vision beyond the technological aspects of how a community functions to a more personal and humanistic emphasis. This sense of community is important, as it fosters trust and a respect of persons and property, and the activities of civil engineering are crucial to making it all work.

From a technological standpoint, civil infrastructure involves the design, analysis, and management of infrastructure necessary for human survival, such as electric power coupled with oil and gas extraction and distribution; water and wastewater treatment, collection, and distribution; communication systems, including public emergency and private enterprises; various systems to support means of transportation; and collections of buildings for urban and rural habitation and business. The concept of social infrastructure adds the importance of social, economic, political, and cultural context into the long-term planning process¹⁸ that also considers sustainability, maintenance and operations, and resilience from some form of disaster.

In his paper presented during the 1990 meeting of the National Academy of Engineering entitled, "The Social Function of Engineering: A Current Assessment," George Bugliarello offers five guiding principles for engineers to assess their work in light of social responsibility.

1. *Uphold the dignity of man.* Recognize the importance of individuality, privacy, diversity, and aesthetics instead of being limited by a stereotyped view of human beings.
2. *Avoid dangerous or uncontrolled side effects and by-products.* This requires a rigorous preliminary examination of how to solve a problem and achieve a given social purpose.
3. *Make provisions for consequence when technology fails.* Engineering systems can be complex, and sometimes there is great risk if failure occurs, and there should be some mechanism in place (redundancy, safety factors) to reduce that risk.
4. *Avoid buttressing social systems that perform poorly and should be replaced.* Oftentimes, the same design processes are used over and over again for the sake of economics, but it might be time to take a fresh look at a new system or design—one that makes better use of energy, respects the environment more completely, and has a better effect on the development of a region's economy rather than being narrowly focused.
5. *Participate in formulating the “why” of technology.* Engineers need to be guided by a clearer sense of the meaning and evolutionary role of technology. There is a philosophy to technology and engineering achievements that needs to be understood and communicated.

6.6 Review Questions

6.1. What were the Roman collegia?

6.2. What is the purpose of ethical codes?

6.3. What are some of the checks and balances for the content of engineering ethical codes?

6.4. How does the Illinois Architecture Practice Act define public health, safety, and welfare?

6.5. List four practical instructions related to the fundamental provision to hold paramount the safety, health, and welfare of the public.

6.6. What are some common elements of public health and welfare related to the well-being of individuals?

6.7. What is the *correspondence theory of truth* and why is it important to engineering?

6.8. List four practical instructions related to the fundamental provision to treat others with dignity, respect, and fairness.

6.9. How can professional engineers keep their knowledge and skills up to date?

6.10. How is *sustainable development* defined by the United Nations World Commission on Environment and Development?

6.11. How did the NSPE intend to use the publication *The American Engineer*?

6.12. What was the Engineer's Creed published by the NSPE in 1954?

6.13. According to the sixth canon in the NSPE code, why should engineers conduct themselves in an ethical manner?

6.14. What was one of the causes for a rise in the establishment of engineering societies in the United Kingdom during the 1950s?

6.15. What are the four main ethical principles promoted by the Royal Academy of Engineering?

6.16. What does the opening paragraph in the code of ethics (November 2019) published by Engineers Australia say about the work of engineers?

6.17. How can civil engineers help to improve public awareness about the long-term effects of engineering projects?

6.18. According to the Japan Society of Civil Engineers, what are some responsibilities of civil engineers in light of their understanding that there is a profound interrelationship between the profession, human society, and nature?

6.19. What is the definition of *social infrastructure* and what are four things it includes?

6.20. What are the five guiding principles presented by George Bugliarelo for engineers to assess their work in light of social responsibility?

6.7 Discussion Questions

6.1D. Discuss how society may view a professional engineer who *has not joined* some formal engineering society differently from one who has.

6.2D. The New Oxford American Dictionary defines *indoctrination* as “the process of teaching a person or group to accept a set of beliefs uncritically.” Do you think this describes codes of ethics published by engineering societies, such as NSPE or JSCE? Why or why not? Explain in terms of potential benefit or detriment to the profession.

6.3D. Obtain a copy of NSPE BER Case No. 19-10, *Observed Structural Defects and Inspection by County Building Official*, from the NSPE website (<https://www.nspe.org/resources/ethics/ethics->

[resources/board-ethical-review-cases/public-health-and-safety-observed](#)). Provide at least three alternative or additional actions that could be taken by Engineer A.

6.4D. The potential health hazard of fly ash in a concrete mixture was examined and determined to be controllable. Research and report on other potential health hazards with constituent materials of a concrete mixture and how that hazard has been addressed in the industry.

6.5D. Do you agree or disagree with some (or all) of the court's conclusions in the *Carvalho v. Toll Brothers Developers* case? Why or why not?

6.6D. Name five qualities or characteristics that can be reviewed by an engineer to make objective comparisons between competing products to be specified for a project.

6.7D. How can the character traits of kindness, generosity, and selflessness benefit a design team?

6.8D. Explain why it is important for engineers to understand and respect a diversity of cultures and civilizations. Begin by offering a definition for *culture* and for *civilization*.

6.9D. Add five pledges to the NSPE Engineer's Creed of 1954 that incorporate some of the tenets of the newest NSPE Code of Ethics for Engineers.

6.10D. In the discussion of NSPE BER sample opinion, Case No. 88-7, explain some of the problems with the message the newspaper communicated to the public on the design and construction of the bridge.

6.11D. Provide three examples of how the reputation of an engineer can be maliciously injured.

6.12D. Explain how the definitions for *dignity* describe a well-rounded engineer.

6.13D. Engineers Australia reminds engineers that standards for acceptable conduct may change over time. Explain why this happens. Present positive and negative aspects.

6.14D. An important principle of practice that advances the prestige of the engineering profession is that members must act on the basis of a well-informed conscience. Identify three characteristics of a well-informed conscience and why they are important to the profession.

6.15D. This chapter briefly explored several events and committees that serve to advance public knowledge of the engineering profession. Research and identify three other events that promote an understanding and appreciation for engineering. Identify the sponsoring agency, the target audience, and provide at least two examples of the effectiveness of each program.

¹“Professional Engineering Organizations,” Encyclopedia of Science, Technology, and Ethics, [Encyclopedia.com](https://www.encyclopedia.com/science/encyclopedias-almanacs-transcripts-and-maps/professional-engineering-organizations) (January 12, 2021),

<https://www.encyclopedia.com/science/encyclopedias-almanacs-transcripts-and-maps/professional-engineering-organizations>.

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⁴Dale P. Bentz et al., *Best Practices Guide for High-Volume Fly Ash Concretes: Assuring Properties and Performance*

[*NIST Technical Note 1812*] (Gaithersburg, MD: National Institute of Standards and Technology, 2013).

⁵Dirk M. Kestner et al., *Sustainability Guidelines for the Structural Engineer* (Reston, VA: American Society of Civil Engineers, 2010).

⁶*Carvalho v. Toll Bros. & Developers*, 675 A. 2d 209—NJ: Supreme Court 1996.

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⁸Louis L. Guy et al., *Final Report of the NSPE Task Force on Overruling Engineering Judgment to the NSPE Board of Directors* (Alexandria, VA: National Society of Professional Engineers, June 30, 2006).

⁹Aristotle and W. D. Ross, *Aristotle's Metaphysics* (Oxford, England: Clarendon Press, 1981).

¹⁰Gro Harlem Brundtland, *Report of the World Commission on Environment and Development: Our Common Future* (New York: United Nations, March 20, 1987), Section I.3.27.

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¹³*Cambridge Dictionary*, 2021.

<https://dictionary.cambridge.org/us/dictionary/english/dignity>.

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CHAPTER 7

Justification for Competent and Ethical Choices

Life is about making choices, and the field of ethics provides tools to help us make good choices. What qualifies as a *good choice* can certainly be defined differently, according to the parameters or goals set on making that choice. Simple goals for the chooser could include happiness, financial stability, physical or mental health, and contentment. A set of expanded goals for the chooser might include the well-being of others, protection of the environment, success of a company or other entity, and sustainability for future generations. There is always a goal (or goals) in mind when a person makes a choice.

Once a choice is made, it is important to be content with that choice. You do not have to believe it was the best possible choice, but simply be satisfied that you made a choice. Each choice should be analyzed in retrospect so that future choices can be better or can bring you closer to your goals. Analyzing choices involves matters of reason, proof, refutation, and correction (see [Fig. 7.1](#)). Since the

implementation of an ethical system is also a matter of making choices, it is important to understand how to reason through the process of deciding between competing choices and to maximize the level of commitment to, and confidence in, a selected choice.

1. *Reason is the power of comprehending, inferring, or thinking especially in orderly rational ways.* Reasoning allows us to categorize different choices and properly assess their value.
2. *Proof is the cogency of evidence that compels acceptance by the mind of a truth or a fact.* Once we have applied reason to sort through different choices, we must then look for some sort of proof to justify the position that reason appears to be pointing us to. Some of that reason may, in fact, be solidly based on proof to begin with.
3. *Refutation is the process of proving that a position is wrong by argument or evidence.* Sometimes it is not enough to rest on proof of one thing, but we need to further refute the other choices that were not selected.
4. *Correction is something substituted in place of what was wrong.* If we find from sufficient reason and proof that our original choice is not the right one, we need to be open to correction and switch to a choice that is better supported by the evidence.

Figure 7.1 Common definitions and applications for reason, proof, refutation, and correction. (*Merriam-Webster's Collegiate Dictionary, 10th Edition.*)

7.1 Defining an Ethical Foundation

Important distinctions must be made between definitions of terms and concepts of right versus wrong, good versus bad, or even deciding what is necessary under certain circumstances. The Murdough Center for Engineering Professionalism at Texas Tech University in Lubbock, Texas summarizes a structured way of approaching ethical problems and defining a foundation, in part by identifying distinctions that must be considered¹:

1. Conventional and reflective morality: is what we have always done what we ought to do?
2. Morality and law: just because it is legal, is it right?

3. Morality and economics: is the most economic decision the most moral decision?
4. Morality and obedience to authority: is following orders that are not proper a legal or a moral defense?
5. Morality or mere opinion: are you obligated to search further for a reason to justify actions than mere opinion?

Answers to these questions can offer a *starting point* to define our position, at least for now. Everyone has a position (even a claim to not have a position, or not to care, is a position). As human beings, we are prone to change, but that is not a bad thing. Sometimes our changes may bring us to a better place in our lives, or those around us will be happier because of those changes. To begin, perhaps we define our ethical foundation in response to the questions above as follows: (1) no response, (2) we will choose to obey the law, (3) we will choose to maintain a balanced budget, (4) no response, (5) no response. This is actually a good place to start: simple and direct. The only problem is ... no one lives their lives this way, free of moral conflict. There must be a more complex and useful foundation that can be constructed.

7.1.1 Conventional and Reflective Morality

The correct answer to the first question above is, "It depends." If I have always shouted at my mother as a teenager, for whatever reason, I should not continue doing that as an adult because it would be unacceptable to people around me (one of many reasons). If I have always brought my mother flowers for her birthday, I should continue doing that because it makes my mother happy. It also makes the

flower vendor happy because I am helping to support his business, and when others hear that I have brought my mother flowers, it will make them happy as well. One precept we can learn from this is that perhaps a good ethical foundation is one that increases happiness the most. This is still quite basic, but it does have some value. Another answer, perhaps, is through the action of a gentleman, who we learned from Confucius (551–479 BCE) in [Chap. 5](#) to always exhibit respectful manners. If what I have always done increases happiness and shows respect for myself and others, then I should continue doing those things.

If I were to examine this further, I should seek to expand on the idea of happiness if that is how I am building my foundation. The object of our happiness can change over time, and it can be something that is not beneficial, and even harmful, in the long run. Sometimes we have to do things that do not bring us immediate happiness, but we do those things because they improve our chances of having more happiness at a later time, or they will dramatically improve the condition of our future happiness. I am happy to be an engineer, so I will choose to abide by the ethical standards prescribed by my licensing board, such as not accepting bribes. If I do not make that choice, and I live in violation of those standards (such as accepting a bribe because it will increase my happiness for a period of time), I can be disciplined and possibly removed from the profession, which would reduce my happiness over the long term.

In [Chap. 5](#), we learned that Aristotle (384–322 BCE) declared a happy life to be a virtuous life, but the obtaining of virtues takes work. Virtue is obtained (and sustained) through habit, and we only receive them through education, training, and experience. Those things might not bring us immediate happiness, but we do them because they eventually will. In fact, with the right frame of mind, we can

find enjoyment in working simply because we know it will improve our chances of being happy. As Aristotle also noted, we do not typically choose happiness for the sake of something else, rather, we choose other things (contemplation, work, relaxation) for the sake of happiness.

7.1.2 Morality and Law

Obedience to the law is always a great place to start, which is initially recognized through the legislation of the country we call home (see [Fig. 7.2](#)). If we disobey the law, there should be consequences and society should deal with us accordingly. However, this is not really the question here. Just because something falls into the category of law does not automatically mean it has anything to do with morality or being “right.” Likewise, just because an act may appear to be ethical to one group of persons does not mean that action should then be legal for all of society, or even for that one instance. In [Chap. 5](#), we studied the Supreme Principle presented by Immanuel Kant (1724–1804 CE) as an admittedly simple test of morals, where we should accept moral rules as those that all of society should follow.



Figure 7.2 Until May 14, 1800, Philadelphia served as the capital of the United States of America, primarily through Independence Hall shown here.

For example, suppose a hungry child steals a loaf of bread to feed himself and his sister. Some would argue that this is acceptable and, in fact, ethical because he is helping to keep his sister from starving to death. However, that does not change the fact that he has broken the law, and breaking the law is *generally* unethical (someone else is almost always affected in some way). The person who was stolen from can grant complete absolution to the child, and may even decide to help by giving the child more food and making sure his family has some means of continual support. In this way, the shopkeeper has turned an illegal act into an opportunity for mercy and compassion ... that seems like a very ethical thing to do. Not every instance of thievery would end in this same way; however, so it cannot truly be a universal maxim. This may demonstrate a simple

exception, as there may always be exceptions with issues of morality, and part of defining an ethical foundation involves sorting through potential exceptions.

7.1.3 Morality and Economics

When considering one's family and financial responsibility, the most important thing is to make sure that expenditures do not exceed income. If this is reversed, there will be unpleasant consequences. Choosing to spend more than one brings in is unethical because such a person could no longer support himself or those who depend on his right actions, in this case to budget responsibly. Credit cards and mortgages allow us to make larger purchases when we do not have all of the money up front, but we must be willing and able to pay off the balance at a time that is mutually agreeable. It would be unethical to borrow money with no intention of ever paying it back.

Expanding on this topic (or any of these questions) may give us further insight and material to build an even stronger ethical foundation with a better capacity to choose when presented with a moral dilemma. What about charity? Most of the world's religions require members to give a portion of their income to their house of worship or congregation so that the money can be used for benevolent purposes, such as support of those who bring the religious message to others (missionaries) and providing for those in need. Even in this situation, when money is given, there is an expectation that the recipient will use it for the purposes intended. Our intent is not that a handout is used to purchase illegal drugs, but something that is more beneficial to a cause that we believe is important to sustain, such as the health of members of society or the spiritual well-being of persons around the world.

Apart from religious requirements, is it a good idea to give money away so that another person can benefit? Of course it is. Some would offer a counterargument that by giving money away you would have less for your own family, who may suffer as a result ... in response, it should be clear that no one should give away so much of their resources that their own family suffers. This recognizes a natural hierarchy in terms of helping others, but this has been (and should be) a strong foundation for a civil society for as long as they have existed. Families must care for one another, but it will always be possible for families on any income level to hold some money aside to give away.

7.1.4 Morality and Obedience to Authority

In a general sense, this subject is similar to dealing with morality and the law. Authority figures are put into position in some fashion, either by a vote of the members of society, through appointment of another authority figure, or perhaps by a supervisor who has elevated them to that position because of their hard work. Many of the world's religions believe that their God is responsible for putting them into positions of authority and subjects should respect them, if for no other reason than they were appointed by that god. People trust (or hope) that rulers will make good decisions on their behalf, but this brings us to the bigger question of "what is good?" If persons in authority consistently violate the trust of the people, there are legal remedies available, such as efforts to recall or pressure them to resign.

One of the subjects already discussed ([Chap. 1](#)) is that of civil disobedience. Martin Luther King, Jr. was part of a team that led fellow citizens in a peaceful boycott of the public transportation system in Montgomery, Alabama, where they broke the rules set by authorities of the time because those

rules were inequitable and unethical. How did they know this? The very founding documents of their country, which declared that all persons inherently had the same rights to life, liberty, and the pursuit of happiness. The honor of what Dr. King and the protesters did was further elevated by the intended goal: a beloved community, where no person would be judged by the color of their skin and all members of that community would be welcome through a lasting bond of friendship.

7.1.5 Morality or Mere Opinion

There are well-established methods of communicating ideas from a persuasive standpoint, as presented earlier, using reason, proof, refutation, and correction. Parents are usually the only ones allowed to say, “Because I told you so!” without justification—at least, not until the child reaches the teen years. At that point, the basis of that parent’s opinion on what the child should do takes a more meaningful form. Responses could still be fairly basic but more descriptive, such as, “We’ve always done it this way” (implying there has not been a problem yet, so why question it now). The foundational answer here is, “yes, you should offer reasons for your actions.” Inevitably, we usually have answers but are not always asked to articulate them. The study of logic is instrumental in understanding how to construct reasonable and persuasive arguments to validate opinions, which will be discussed briefly later in this chapter.

When the word “opinion” is brought up in dialogue, it can bring to mind an idea that what is being said has no real justification ... it is only what that person thinks on that specific subject and it really has no bearing on what is true or right. This brings up the idea that moral rules are subjective and cannot be thought to be universally true. Civilized societies exist through the interactions of residents

and visitors, and laws are written and enforced to assure that people are protected. Some crimes can truly be thought of as immoral, such as senseless, premeditated murder, or maliciously false testimony. Any culture that permits these two crimes will not survive.

7.1.6 A Sample Foundation

Choosing to live a life that honors what we perceive to be good moral behavior will always include checklists and cherry-picking to a degree. We need to build a foundation with clearly defined action items, not lofty goals without a clear path for attaining those goals. Actions should lead the way toward achieving goals, and whereas it would be best to take a deeply personal interest and joy in performing actions (because they are the right things to do), it is still reasonable to perform actions for the mere sake of achieving goals. My goal is to remain in the profession of engineering and, as stated earlier, I must hold to ethical principles dictated by others in order to keep this goal—it would be better if I practiced those ethical principles because they can be shown to benefit humanity, and this should make me happy, but I am also free to obey them simply as a matter of duty. In either case, it is also important to understand that human beings will never be consistent and mindful every moment of their lives—we will forget, we will break our own rules, and we will often need to refocus and start again.

1. As a child, I was brought up by religious standards, as best as my mother could manage (justification). I truly believe that my actions should be filtered through and evaluated by the Fruits of the Spirit as described in the Bible: love, joy, peace, patience, kindness, goodness, faithfulness, gentleness, and self-control (choice).

2. Because I am a citizen of the United States, and because society cannot truly function without law and order (justification), I will obey and take seriously prescribed laws (choice). If I do not believe certain laws to be “right” (justification), and I strongly desire to have them changed, I will use legal means to make my position known in as productive and persuasive a way as possible (choice). Due to the fact that I want to practice engineering, and society expects me to practice competently in both technical and ethical matters (justification), I will follow the rules, regulations, and standards of the profession to the best of my ability (choice).
3. Since I am grateful for the opportunities that human beings have to succeed and do well, and because sometimes members of society need help along the way to success and well-being (justification), I will give a portion of my resources to organizations that help others in various ways (choice).
4. If I have genuine and reasonable disagreements with my government, or administrators thereof, I will use legal, peaceful, and honorable means available to me to effect changes (choice) because I truly believe in the concept and pursuit of a beloved community spoken of by Dr. Martin Luther King, Jr. (justification). If I am ordered to commit an act that I have previously established to myself to be unethical or immoral (justification), I will refuse to do that act and offer suitable alternatives if possible (choice).
5. For the sake of truth and clarity, and in an effort to confirm objectivity and fairness (justification), I will do my best to offer sound, logical reasons for my opinions, not only on matters of morality but on issues of a technical nature (choice).

7.2 Truth and Rationality

A short dialogue is written in the Bible between Jesus and Pontius Pilate, Roman military governor based in Caesarea as well as Jerusalem (see [Fig. 7.3](#)), concerning the issue of truth.² When the Jewish leaders brought Jesus to Pilate on miscellaneous charges, especially that of claiming to be the King of the Jews, Pilate asks, “Are you a king, then?” Jesus replies, “You say rightly that I am a king. For this cause I was born, and for this cause I have come into the world, that I should bear witness to the truth. Everyone who is of the truth hears my voice.” In response, Pilate says and does something quite interesting. He says, “What is truth?,” but he does not wait for a response. Immediately afterward, he goes out to the Jews who brought Jesus to him and says, “I find no fault in him at all.” Pastor John MacArthur explains that the response from Pilate about truth was rhetorical cynicism, and that he was likely convinced that no answer existed to the question.



Figure 7.3 Pontius Pilate questions Jesus about truth.
(Source: St. Luke's United Methodist Church,
<https://stlukesokc.org/inspiration/st-lukes-blogs/daily-devotional/why-do-you-ask/>.)

Merriam-Webster identifies numerous definitions for truth: (a) fidelity, constancy, (b) sincerity in action, character, and utterance, (c) the state of being the case; fact, (d) the body of real things, events, or facts; actuality, (e) a judgment,

proposition, or idea that is true or accepted as true, (f) the property of being in accord with fact or reality, and (g) fidelity to an original or to a standard.³ If an engineer issues knowingly untrue statements about a work product or investigative report, there will always be some consequence, ranging from a hardening of the engineer's own heart and character toward moral virtue to even a loss of life. Somewhere in-between is the detriment caused to society, where not knowing a true fact can lead to incorrect conclusions and impractical or ineffective government regulation and may affect policies for generations. Aside from truth on technical matters, engineering codes of conduct include relatively consistent instructions, mostly related to representation, which have been discussed in more detail in [Chap. 6](#).

Michael Pritchard, director at the Center for the Study of Ethics in Society at Western Michigan University, assembled a number of example case studies to illustrate ethical issues that engineers may be faced with in their practice. One of these cases, *A Tourist Problem*, deals with the issue of truth, facts, perception, and truthful reporting.⁴ In this example, an environmental engineer who is tasked with monitoring the quality of water and air discharges from a manufacturing plant situated near a lake in a flourishing tourist area has just prepared a report that indicates the level of pollutant in the water discharge (which go into the lake) slightly exceeds the legal limitation. His research also indicates that there is little concern this higher concentration of pollutant poses any danger to people in the area—at worst, it will endanger a small number of fish. The cost to the plant in solving the problem will be excessive, including the potential loss of jobs. When the report is presented to his supervisor, the engineer is instructed to regard the excess as a mere technicality and to adjust the data to make it appear the plant is in compliance.

The use of the term *technicality* is an interesting one, and leads to pertinent questions: Would the engineer at the Department of Natural Resources who evaluates reports from local industry consider the excess as a technicality? Would the parents who allow their kids to swim in the lake consider the excess a technicality? What qualifications or authority does the supervisor have to allow him to declare the excess is a mere technicality? More importantly, as presented in the example, is the *principle of universalizability*, which is a deontological (duty-based) ethical test that invites us to imagine a world in which a proposed action is also adopted by everyone else. This principle has been presented and examined by Immanuel Kant as a *categorical imperative* (see [Chap. 5](#)).

The consequences of this principle are illustrated by two scenarios in this example. First, what if all manufacturing plants in this region decided to slightly exceed the legal amount of pollutants in their discharges? The combined excess would certainly cause more harm than that of a single plant. If the law were to allow for variance among a limited number of factories, who decides on the recipients of leniency? How is that fair and equitable treatment? Secondly, if all environmental engineers were allowed to make adjustments to their data in order to present a report of compliance that would certainly bring down the status of the engineering profession as one that cares little for the workings of science. If an engineer cannot justify a variance as something that falls squarely within the realm of statistics, which is a legitimate scientific method of analyzing the effect and relevance of variant measurements, then they can open a discussion with a governing authority for approval of that variance. The chances are high, however, that the Department of Natural Resources has already accounted for statistical variance when they set the original limits.

Different commentaries provided with this example agree that the engineer should not falsify his data. The supervisor in this case has essentially raised the issue of loyalty, which is also an important ethical consideration. For example, the Code of Ethics of the Peruvian Engineers Association⁵ states, “Engineers shall faithfully serve their employers and clients.” However, it also states, “Engineers shall be objective and truthful in their reports, statements, or professional testimonies. Engineers shall express opinions on engineering issues and facts only when they are based on a proper analysis and knowledge of facts based on technical competence and sincere conviction.” Further, “Engineers must realize that the health, safety, good, and welfare of the public, as well as the country technological development, depend on engineers’ judgements and decisions incorporated in devices, buildings, structures, machines, products, software, and processes. For no reason they will put their knowledge at the service of anything that affects peace and health.”

If we are to study this example case using the Peruvian Engineers Association’s ethical code as our standard, would we discover conflict? Perhaps not. The only precept noted above that requires interpretation is the issue of faithful (loyal) service. I would argue that the engineer would *not* be performing faithfully if he made the requested adjustments to the data, since his duty to the company is to truthfully generate reports based on his expertise, regardless of what conclusions the data leads to. If the supervisor thinks otherwise, and the engineer was not hired with this exception in mind, then he needs to reexamine his terms of employment and discuss the consequences of adjusting data when it cannot be justified by honest, statistical means. If the company cannot understand that truthfulness in all things will actually keep them out of hot water, in the short and long run, then the engineer should seek other

employment and should consult with legal counsel about the possibility of exposing that company to the public or appropriate governing authority.

7.2.1 What About Truth in Variance?

Variance or statistical range is an important part of how an engineer or a scientist manages and makes use of accepted scientific truths. It does not represent anomalous or outlying data, and it does not suggest that the subject is untrue.

Variance represents humanity. Philosopher Karl Popper (1902–1994 CE) notes that truth may be difficult to find from an objective manner, but that we cannot give up trying. He says, “How can we admit that our knowledge is a human—an all too human—affair, without at the same time implying that it is all individual whim and arbitrariness? ...

The solution lies in the realization that all of us may and often do err, singly and collectively, but that this very idea of error and human fallibility involves another one—the idea of objective truth; the standard which we may fall short of. Thus the doctrine of fallibility should not be regarded as part of a pessimistic epistemology. This doctrine implies that we may seek for truth, objective truth, though more often than not we may miss it by a wide margin. And it implies that if we respect truth, we must search for it by persistently searching for our errors: by indefatigable rational criticism, and self-criticism.”⁶

7.2.2 Rational Criticism

When we are discussing the sciences, evidence and data are always subject to scrutiny and criticism—that is, how experimentation works and how discoveries are made.

Scientists want to represent nature truthfully, and the process of discovering what is true is very detailed (through

the scientific method) with multiple checks and balances in an effort to maximize the value of the knowledge being produced. Rational criticism involves the examination of claims that may be made by persons to prove one thing or another, with a specific intent toward finding problems, untruths, or fallacious evidence. The goal is not typically a malicious one—it is simply an effort toward getting at the truth, but it does not work if the subject of study is based on emotion or something that cannot be supported by unbiased reason. Science uses past and present data, present theories and hypotheses, and reason to prove claims, and rational criticism is helpful to improve those claims or to build a stronger foundation. The same criticism can be applied to ethical dilemmas and choices that human beings make. The most direct form of criticism may be the use of logical arguments.

7.2.2.1 Basic Logical Argumentation

The basic elements of *logic* in philosophy were presented in [Chap. 5](#), but it would be helpful to expand on the subject further in this chapter. We have also spent time discussing reason—logic is all about reasoning, going from a set of premises to a conclusion. It is an analysis and appraisal of arguments that can deepen one's understanding of a subject or how parts of the subject can be explored in more detail. An argument consists of a set of premises (any number, but a typical argument includes two) and a conclusion that is intended to follow from the premises. An argument is said to be *valid* if it would be contradictory to have the premises true and the conclusion false, and it is *sound* if the construction is valid and the premises are, in fact, true. [Figure 7.4](#) provides examples of valid and invalid deductive logical arguments.

The conclusion of a valid argument must be true if the premises are true. If the premises are not true, the conclusion may or may not be true. If the premises are true and the argument is valid, then the argument is sound.

Sample form of a valid argument:

Major premise: If A, then B.

Minor premise: If B, then C.

Conclusion: Therefore, if A then C.

Sample form of an invalid argument:

Major premise: Some As are Bs.

Minor premise: Some Cs are Bs.

Conclusion: Therefore, some As are Cs.

Valid, sound argument:

Major premise: All men are mortal.

Minor premise: Tom is a man.

Conclusion: Therefore, Tom is mortal.

Invalid argument:

Major premise: Some cats have different colored eyes.

Minor premise: Some humans have different colored eyes.

Conclusion: Therefore, some humans are cats.

Valid, but unsound argument:

Major premise: All dogs are cows.

Minor premise: Mick Jagger (the actual singer) is a (physical) dog.

Conclusion: Therefore, Mick Jagger is a cow.

Figure 7.4 Examples of types of deductive logical arguments.

Deductive arguments reason from one statement to another by means of accepted rules, such that anyone who accepts the premises must also accept the conclusion. The argument cannot be used to prove the premises—they must stand on their own, and the one who builds the argument must be certain of each premise. The conclusion of a deductive argument never states more than what is described in the premises. For an inductive argument, the conclusion always states *more* than the premises, but it is not guaranteed to be true even if we know all of the observations or premises are true. There will always be a

possible counterargument with a better hypothesis (conclusion of an inductive argument).

When presented with an argument for a certain point, we need to first determine if we can agree that it is a sound argument or if it contains error. One of the ways to do this is through refutation, which is, in its most basic form, offering a set of truth conditions that make the premises all true and the conclusion false. Defense attorneys refute conclusions of prosecutors by constructing their own arguments using valid evidence, but showing that it does not establish their client's guilt. Refutation can begin by showing that certain premises lack certainty. In the world of engineering we rely on certainty, albeit within the boundaries of scientific language (variance, statistics), and some truths often turn out to be more certain than others. There are self-evident maxims that improve the strength of premises with certainty (stormwater will always flow downhill), other conditions that are evident through proof by acceptable scientific methods which are essentially certain, and there can be premises that can be formulated on reasonable interpretations of code prescriptions or inspection results.

For example, suppose I were to present the following argument to support my conclusion that a building needs to be torn down:

Major premise: This building has a crack.

Minor premise 1: All cracks are unsafe.

Minor premise 2: Unsafe buildings should be torn down.

Conclusion: This building should be torn down.

This is a valid argument since if all of the premises are true, then the conclusion certainly is true. However, it is an unsound argument because the premises are quite sloppy and at least one of them is not true. I can see something is not quite right, and I do not want to call for the demolition of

a building if it is not necessary, so I need to spend some time analyzing the argument. The major premise may be true, based on someone's observation in the field, but it is not descriptive enough. What size is the crack? Where is it located? What is the crack actually propagating through? Is it old or is it new and growing? What caused the crack? The first minor premise is simply not true: not all cracks are unsafe. The second minor premise assumes only one course of action is the only possible course, but this is also untrue. If a building is truly unsafe, it can be shored and repaired. Since there are serious problems with the premises, we have no assurances that the conclusion is true. It might be, but there is not enough evidence to support it.

7.2.2.2 Logical Fallacies

When constructing arguments or defending a position, it is important to recognize logical fallacies, or mistakes in deductive arguments. Fallacies often take the form of propositions offered as premises that *appear* to support the conclusion, but they do not support it at all. Recognizing when this happens will allow you to be clearer with your own arguments and to challenge those who have not taken the time to present their evidence soundly. Fallacies reject objectivity in one way or another, but they may not always be intentional. These types of arguments should be identified and scrutinized if the debating parties are genuinely concerned about seeking truthful conclusions.

For example, the fact that a position is strongly asserted, or that it is believed by a large group of people, does not mean it is valid or should be accepted—opinions require justification, not just “brute force” or “majority rule.” “Begging the question” is another fallacy that simply accepts as a premise what should be argued as a conclusion. As an argument for joining a particular religion,

for example, making reference to that religion's holy book is begging the question. It is also common to hear evidence for one religion or another by an "appeal to emotion," which is a hope that the listener will accept a conclusion based on how that person is made to feel (joy, anger, pity, guilt, etc.). The truth of a premise does not rely on my feelings.

"Ad hominem" arguments are also fallacies, where a personal, irrelevant attack is made on the opponent rather than on that person's position. A "red herring" fallacy is one where odd facts and irrelevant information are peppered throughout the discussion that deflects attention from the matter being discussed. This term apparently comes from a British magazine published in 1686 that proposed the idea of dragging around a dead cat to prolong a fox hunt by throwing off the scent of the dogs. The author suggested using a red (smoked) herring if a cat was not available.⁷ The fallacy of "dubious authority" arises when we appeal to some sort of authority who is actually not an authority in the subject for which they were chosen. Authority can also take the form of an internet page, a blog post, or a published periodical—there is an author behind the data, and we should be certain of their qualifications before accepting their conclusions for use in our arguments or proofs.

Other fallacies include the "straw man," which occurs when someone takes another person's argument, distorts or exaggerates it in some kind of extreme way, then attacks that distortion as if that really was the actual argument from the opponent. A "non-sequitur" argument is one in which the conclusion simply does not follow from the premises. In other words, the premises are not relevant to the conclusion, which can actually be said for many types of fallacies, such as the red herring or the straw man. The best way to learn how to recognize fallacies is to study them before entering into a debate, not during the heat of the moment. Learn not only to recognize and challenge them

when issued by your opponent, but also take them to heart so you do not commit them yourself.

7.3 The Art of Persuasion

Disputes can arise over any subject, for any reason, and among any types of people. Family arguments can introduce painful events from history that would rather be forgotten, but if they come up as a source of contention, they must be dealt with in a rational and patient manner. When business decisions are made within a company, opposing points of view can be on the table that require in-depth discussion to clarify the philosophy of how that company chooses to survive. Just being human and interacting with other humans presents the strong possibility of conflict that cannot simply be ignored or swept away. Ibn Miskawayh (932–1030 CE) taught that human beings naturally need one another, and happiness cannot be attained except through associations with other people (see [Chap. 5](#)). Therefore, we must learn how to deal with conflict in order to attain happiness.

Part of getting along with fellow human beings includes toleration for other points of view, beliefs, traditions, and opinions, but this does not mean that our responsibility is to have none of these for ourselves, or to keep them to ourselves. If there is a need to justify our position on matters—such as to defend an issue related to our exercise of engineering judgment, to persuade someone that our work is not negligent, or to instruct someone on our decision related to an ethical dilemma—we need to do so with truth, patience, and a diligent search for facts that will allow us to construct reasonable, logical arguments to convince others.

In resolving conflict, attempting to justify our own conclusions, or participating in disputes, there are two primary responsibilities of all parties involved: to listen

carefully, and to argue persuasively. The characteristics of a good listener are easy to recognize:

1. She avoids distractions and fully concentrates on what she is being told.
2. He resists the urge to interrupt. This can be difficult if the listener has trouble remembering things and wants to relay information the moment it pops up, but this does not give the speaker the time that they need to finish their own thought.
3. She asks relevant questions to get more information or to make sure she has heard the speaker correctly.
4. He makes a conscious decision to genuinely be interested in the conversation. It will be important to him, not for the sake of winning an argument, but for the purpose of learning something new or simply the joy of sharing the thoughts of another person.

Persuasion is another act entirely. Instead of listening, you are presenting your case. In a formal debate setting, participants will take turns to present their side, then there is a period for the opposition to rebut, then make their own presentation. This method of taking turns does not always apply to moments of discussion, whether it be over the morality of a certain action or providing justification that a design meets the intent of a complex construction code. In his book, *How to Argue and Win Every Time*,⁸ attorney Gerry Spence lays out four steps in constructing a persuasive argument.

1. Ask yourself, “What do I want?” and prepare reasons as to why you want it. What is the thesis?
2. Understand what the principal argument is that supports your conclusions or goals. There may be

supplemental arguments, but there is likely a main message.

3. Identify reasons and facts as to why you *should* win what you want.
4. Prepare to tell a story that incorporates all of the necessary information from the items above.

Adults still like stories, too (see [Fig. 7.5](#)), and the better we can engage the attention of the one we are trying to convince, the better will be the outcome for our case. A design decision can be justified through calculations, drawings, logical discussions and proofs, models, illustrations—a whole host of methods that can be used to drive the conclusion home. The most important elements, however, will be facts. Facts that can be agreed upon can be used as the anchor for convincing someone that the facts support our judgment or interpretation. Commentaries, legitimate scientific publications, projects that have been approved in the past, reports, case studies ... there is a lot of material that can be weaved together to tell a convincing story.



Figure 7.5 The most persuasive arguments are those which paint a story using a variety of methods and sources to hold the attention and interest of those we are trying to convince.

7.4 Steps in Making Ethical Decisions

The steps used in solving ethical challenges could be examined with similarities to the steps involved in a technical engineering design. The Accreditation Board for Engineering and Technology (ABET) provides a suitable summary of the engineering design process⁹:

1. Identify opportunities
2. Develop requirements
3. Perform analysis and synthesis
4. Generate multiple solutions

5. Evaluate solutions with regard to requirements
6. Consider risks
7. Consider a need to make trade-offs in order to obtain a high-quality solution under given circumstances

One can see a similar sequence of basic steps in evaluating potential solutions to ethical problems. The problem at hand needs to be clearly defined, which usually includes a rudimentary understanding of the risks encapsulated in potential solutions (Steps 1 and 6). Requirements can be found in civil laws, codes of conduct published by licensing boards, and in ethical codes published by engineering societies (Steps 2 and 7). The process of analyzing solutions may include research of sample cases in ethics published by universities or engineering societies, consultation with colleagues or attorneys, or a detailed review of the historical development of related terms or subjects (Steps 3, 4, and 5). Ethical problems with multiple solutions may include conflicts of interest, disclosure or acknowledgment of errors, presentation of facts or data, qualifications for work, making public statements, and issues of sustainability.

The Ethics in Employment Task Force of the National Society of Professional Engineers identified three principles that form a foundation for employees facing an ethical dilemma that involves their own workplace¹⁰:

1. When faced with an unethical business conduct or a legal question, the employee has a right and an obligation to seek advice and guidance as necessary to resolve the employee's concern or question.
2. The employee has an obligation and a responsibility to promptly bring to the company's attention any actions, situations, or conditions that the employee

believes are or may be violations of the company guidelines or the law.

3. As a licensed engineer, the employee has an obligation to protect the life, health, and property of the public.

It is also important to remember that you are not alone. Most engineering societies around the world include a special branch or department devoted to ethics and offer informal or unofficial opinions that can help to stimulate the development of conclusions or solutions to ethical dilemmas. Licensing agencies offer the same assistance. For example, administrative regulations for the State of Kentucky related to professional practice and conduct offer timely assistance in the review of potential ethical issues that a licensee may be troubling over. They state, “A licensee who is in doubt about the ethical propriety of any professional act or omission contemplated by that licensee may request an informal opinion from the executive director of the board.”¹¹ The request is to be submitted in writing and the executive director will likewise respond in writing. The regulations also state that; as long as the licensee’s request clearly, fairly, accurately, and completely states the contemplated professional act, and includes all relevant information; the licensee will not be disciplined for any professional act performed in compliance with the written advisory opinion furnished by the executive director.

7.5 Problem-Solving Strategies

Engineers solve problems. These can be issues that require immediate attention or allow for a more prolonged approach. There is always a question to be answered that involves the practical application of math and science (primarily). Stormwater must be diverted from roadways

through the principles of physics to solve the problem of potential flooding during a catastrophic event. A concrete mix design should incorporate constituents that do not produce carbon dioxide emissions in their extraction or processing using the principles of chemistry to solve the problem of global warming. Structural building systems require redundancy and robust connections that can be properly assessed through an accurate mathematical model to improve the resilience of a community in response to both frequent and uncommon environmental events.

In the book *Strategies for Creative Problem Solving*, Scott Folger and Steven LeBlanc illustrate the process of solving problems by taking the reader through the McMaster Five-Point Strategy heuristic, which includes the building blocks of define-generate-decide-implement-evaluate.¹² In order to arrive at a suitable solution, the real problem must be understood and well-defined. This is typically done by collecting and sorting through data, and sometimes discussing the problem with others who have dealt with similar issues. The next step is to generate potential solutions that are suitable for testing and evaluating—this can be done through brainstorming sessions or reviewing available solutions from related issues, such as typical construction details or specifications. This requires perseverance, patience, and objectivity.

Deciding upon one of the solutions to implement involves a careful analysis of the potential for meeting as many project goals as possible. This can be an iterative process, where certain tests involving logic and reason can help eliminate solutions that are less desirable. Part of the analysis process requires imagining potential drawbacks or problems that may occur after the solution has been implemented and to have something in mind to address these. For example, a construction detail can be put together clearly, meet requirements of economy and

consistency and other goals, yet potential problems could be related to physical constructability, the ability of the laborers to complete the work, material supply, changes required by the building department or requested by the contractor, and possibly due to obsolete means and methods that are necessary to finish the work.

One of the first steps in implementing a solution involves getting permission. Construction projects require permits from a whole host of agencies that assist the designers in assuring code compliance and that sustainability goals adopted by a community have been considered in the process. This involves processing and issuing documentation that justifies the selection, such as calculations, reports, or other data, and can also include interviews or meeting minutes from predesign conferences. The process of planning for implementation of the solution intensifies at this point, but it should have already begun during the stage of generating alternative solutions. During the construction phase, contractors may have questions about how to implement the solution, or wish to make changes, and these should be handled through careful review of the original design parameters and the intended goals.

Finally, the effectiveness of the solution requires evaluation to determine if it is a good fit for future projects and if it has, in fact, met the project goals. Other issues that required resolution may have surfaced during installation, and these should be reviewed to see if they could have been anticipated and controlled or eliminated by design, planning, additional research, or other means. Feedback can be helpful as well, not necessarily to repeat the same solution for another project but to implement changes in how any problem is to be approached in the future. It may turn out that a short phone conversation with a contractor familiar with the type of material used could have answered

questions unknown at the time and made the design even better. An honest evaluation may reveal a need for change in how the engineer initially approached the problem, or it may reveal some inadequacy in logic, reason, or base of knowledge that requires a dose of humility and a lot of courage to make corrections so that the whole process can be done better in the future.

7.5.1 Civil Engineering

Strategies that civil engineers use to solve problems often take a more general format so that they can apply equally to wide range of project types. The design of structures will be noted in the next section (structural engineering), but design tasks common to the field of civil engineering can also include site grading and drainage, best practices for control of site materials and pollutants in stormwater flow during construction, traffic management, water and wastewater treatment systems, integration of green spaces into the urban environment, and more. Following is a detailed summary of task categories that will apply to small and large projects alike.

1. Obtain a clear understanding of what the project goals are. What is the client actually trying to accomplish? Is there a method or procedure to get to those goals? This step includes obvious goals, such as economy, safety, and schedule, and may also include prioritization.
2. Understand the users of the final product. Is it private or will it be accessible to the public? Who retains ownership?
3. Help the owner define sustainability goals and identify a strategic combination of features that can achieve those goals.

4. Determine who will be responsible for performing a life cycle assessment and what the basis of parameters will be.
5. Identify all project participants and stakeholders who will be directly or indirectly affected by the project. Communicate your needs and intentions as clearly as possible, using sketches or other literature, to try to keep everyone on the same track.
6. Be familiar with all federal, state, and local regulations that are applicable and find out who is responsible for performing tests and inspections, attending meetings, making phone calls, preparing reports, and responding to building or engineering department reviews.
7. Carefully evaluate as-built information and topographic surveys. If anything appears incomplete or not adequate to the task, promptly request correction or replacement.
8. Keep accurate, written records of the schedule: meetings, deadlines, milestones, etc.
9. Reach out to governing officials as needed to clarify community requirements and project design parameters.
10. If possible, attend public review or comment meetings so that you can help answer questions and ask them yourself. This serves to enhance the image of the profession, and also leads to a more thorough understanding of the project goals.
11. Identify and visualize the design strategy that will meet as many of the client's goals as possible. Use innovative or unique solutions as the need arises.

12. Inspect and observe the construction at predefined intervals, keeping meticulous records of activity, weather, contractors/subcontractors present, any visitors (building officials, etc.), estimated percentage of completion, and punch list items requiring resolution.
13. When closing out a project, make sure you have completed all of your forms, calculations, etc. and made them available to any requesting agency and to the client.

As populations continue to grow, the needs of civil infrastructure become more dependent on innovative, reliable solutions. It is just as critical to manage existing systems as it is to develop new ways of supplying, storing, and delivering resources to urban and rural areas alike. Any solutions that are implemented in the present must not strain the dependence of future generations (as best as can be managed), and engineers must continue to diligently seek, consider, and develop better solutions to not only protect but also improve the condition of existing and proposed systems for the benefit of future communities.

7.5.2 Structural Engineering

The basic character of structural engineering involves loads, materials, and systems, and any problems to be solved will include one or more of these. Following a logical sequence of tasks can illuminate the right questions to ask or the correct avenue to research. During the design stage of a project, a structural engineer will perform numerous tasks that may require deeper thought or more concentrated attention than other tasks. It is helpful to label or categorize tasks for better efficiency in completing designs. Following

is a detailed summary of task categories that will apply to small and large projects alike.

1. Structural design is all about loads, analysis, reaction, and communication.
2. Understand the minimum load requirements per your jurisdiction and adopted code.
3. Understand the constraints imposed on the project by the architect/owner/developer, etc.
4. Recognize any physical constraints of the site and communicate any concerns or needs for testing, inspection, or other.
5. Determine and discuss sustainability options or requirements.
6. Perform some preliminary research, if necessary (similar structures, suitable products, new technologies, helpful design, or construction standards).
7. Understand the strengths, limitations, serviceability requirements, and behaviors of members and connections that support gravity loads.
8. Understand the strengths, limitations, serviceability requirements, and behaviors of building systems that resist lateral forces and provide stability.
9. Set up a reasonably accurate mathematical model of your structure.
10. Once analyzed, check some of the results by hand (if analysis was done by computer) to see if they make sense.
11. Complete clear and concise calculations, if necessary.

12. Determine whether the project requires written specifications.
13. Assemble construction drawings suitable for the level of detail required for each phase of work.
14. Maintain communication with all stakeholders as needed in a timely, clear, and helpful manner and provided documents as specified in the contract and schedule.

There is certainly overlap of problem-solving strategies or steps for civil and structural engineering, and these can be fairly common among other construction-related disciplines as well. That is why infrastructure projects are designed, constructed, and managed by members of a team, sharing the same desire for successful completion and satisfaction of all who may use the product. Team members learn from one another and respect different opinions or approaches to solving issues, and all are invested in truthful communication and reliable execution of duties. When one member of the team experiences stress or disillusionment due to any number of factors, that person is usually not alone and there should be some means available for expression (perhaps through a supervisor or human resources administrator). Problem solving is oftentimes a group effort, and communication is vital to a healthy and productive dynamic.

7.6 Review Questions

- 7.1.** What are some of the goals that a person has in mind when attempting to make a good choice?
- 7.2.** What four elements of evaluation are involved in making and analyzing choices?

- 7.3.** What are three of the questions asked by the Murdough Center for Engineering Professionalism that identify distinctions that must be considered when defining morality?
- 7.4.** What are three different definitions of *truth*?
- 7.5.** Identify the range of potential consequences if an engineer knowingly issues untrue statements.
- 7.6.** What is the principle of universalizability?
- 7.7.** What options (if any) are available to an engineer whose data shows noncompliance with a seemingly arbitrary limit imposed by a government agency?
- 7.8.** What is the doctrine of fallibility, according to Popper?
- 7.9.** According to Popper, how should we search for our own errors?
- 7.10.** What is the use of logical reasoning helpful for?
- 7.11.** Name and define three logical fallacies.
- 7.12.** How are the steps involved in making decisions for ethical problems similar to those used in engineering design problems? Refer to the summary of design steps offered by ABET.
- 7.13.** What are three ethical problems that may involve multiple solutions?
- 7.14.** What are the building blocks of the McMaster Five-Point Strategy heuristic?
- 7.15.** Name three of the civil engineering problem-solving task categories that could also be applied to the practice of structural engineering?

7.7 Discussion Questions

7.1D. Do you agree with Pontius Pilate, that perhaps there is no such thing as objective truth? Why or why not?

7.2D. Do you believe there could be any justification for “adjusting data” on account of a “mere technicality”? Why or why not?

7.3D. In the *Tourist Problem* case, would it have made a difference in the conclusions if there was, and would only ever be, a single plant that issues pollutants slightly in excess of the legal amount? Explain your answer.

7.4D. Evaluate the following logical argument and decide whether it is valid or invalid (with proof or refutation as applies)¹³:

Major premise: If you hold a moral belief and don't act on it, then you're inconsistent.

Minor premise: If you're inconsistent, then you're doing wrong.

Conclusion: If you hold a moral belief and act on it, then you aren't doing wrong.

7.5D. Reread the four characteristics of a good listener. Suppose you are speaking to a poor listener and assume that he violates each one of these characteristics. Offer two strategies you could use to bring the conversation back on track and reengage the listener for each one of the characteristics (a total of eight different strategies).

7.6D. For the design process summary provided by ABET, put the steps into order of most important to least important. Explain how you came up with that order.

7.7D. How should an engineer approach their licensing board to discuss potential ethical dilemmas?

7.8D. Identify three potential problems that could arise during implementation of the following three scenarios and determine solution to each of the problems. (1) A camping trip to the lake, (2) Transportation of a significant amount of a hazardous liquid from New York to San Diego by land, (3) Walking your timid dog through a neighborhood with ferocious alley cats.

7.9D. Take five of the civil engineering problem-solving task categories and place them in order of importance. Explain your reasoning.

7.10D. Take five of the structural engineering problem-solving task categories and place them in order of importance. Explain your reasoning.

¹Murdough Center for Engineering Professionalism. *A Structured Way to Approach Ethical Problems*. (Lubbock, TX: Texas Tech University, January 22, 2020).

¹John MacArthur, *The MacArthur Study Bible, NKJV*, John 18:37-38 (Nashville, TN: Word Publishing, 1997).

³*Merriam-Webster's Collegiate Dictionary, 10th Edition*, s.v. "truth."

⁴Michael S. Pritchard, ed. "A Tourist Problem," *1992 NSF Case Report: Teaching Engineering Ethics—A Case Study Approach* (Kalamazoo, MI: Center for the Study of Ethics in Society, 1992).

⁵Peruvian Engineers Association, *Code of Ethics* (Lima, Peru: Colegio de Ingenieros del Peru, April 4, 2018).

⁶Karl Popper, *Conjectures and Refutations—The Growth of Scientific Knowledge* (London, UK: Routledge Classics, 2002), p. 21.

⁷"Where Does the Expression 'Red Herring' Come From?" *The Old Farmer's Almanac*, accessed November 1, 2020,

<https://www.almanac.com/fact/where-does-the-expression-red-herring-come>.

⁸Gerry Spence, *How to Argue and Win Every Time* (New York: St. Martin's Press, 1995).

⁹ABET Engineering Accreditation Commission, *Criteria for Accrediting Engineering Programs, 2021-2022 Accreditation Cycle* (Baltimore, MD: ABET, 2020).

¹⁰Karen S. Pedersen et al., *Final Report of the NSPE Ethics in Employment Task Force* (Alexandria, VA: National Society of Professional Engineers).

¹¹State of Kentucky Administrative Regulations, Section 201 KAR 18:142(12).

¹²H. Scott Fogler and Steven E. LeBlanc, *Strategies for Creative Problem Solving* (Upper Saddle River, NJ: Prentice Hall, 1995), p. 18.

¹³Harry Gensler, *Introduction to Logic* (New York: Routledge, 2002), p. 82.

CHAPTER 8

Case Studies in Ethics and Standard of Care

Humanity benefits from a thoughtful analysis of history. We need to look back for examples of what went right (so we can repeat or continue) and what went wrong (so we can avoid doing again) in an effort to understand ourselves more deeply, to improve our characters, and to strengthen our grip on what works best. The study of applied ethics includes real, historical issues that provide lessons in moral decision making, critical thinking skills, and defending conclusions. Civil and structural engineers are very familiar with history—water always flows downhill, structures always impose a force onto the ground. Decisions for new designs are based in large part on understanding what has been done before, successfully or not.

Case studies in engineering mostly focus attention on failures due to the value placed on learning from someone else's actions or inactions that led to unexpected and undesired results. Some failures are extensively scrutinized by a judge and jury in a court of law, where expert

witnesses are called upon to define the standard of care and examine whether an applicable threshold was met. Other failures are settled out of court, and documentation to support conclusions one way or another may not be readily available for examination. In order to fill some of the gaps between available material, universities and engineering societies have created sample cases to illustrate findings and decisions in an effort to help students and practitioners develop skills in recognizing standard of care and elaborating on ethical considerations where applicable.

This chapter presents 5 cases where failure of an engineered structure affected designers, public officials, contractors, and the public in ways that were unexpected, but could have been avoided. There are ethical and technical lessons to learn from each case, but one of the most inclusive observations is that good communication and honest consideration of feedback or concerns expressed from others are vitally important to the success of any project. Case studies are easy to find, and the reader is encouraged to examine others that may be found in additional literature cited herein.

8.1 How to Study Case Examples

One of the benefits of a case study is it presents the reader with an image of what the world really looks like. Engineers see this real life during field visits of their own projects, but the obvious hope is that nothing ever goes wrong, property does not get damaged, and people do not lose their lives. Valuable lessons can be learned by studying things that “went wrong,” from a thorough presentation of predesign conditions, decisions that were made during the design process, steps contractors took to assure safety during construction, how something performed in actual service, and what phenomena caused and resulted from a collapse.

Cases are specific to a region and type of structure or system—findings may not be immediately relevant to other projects, but there are always common elements or concerns that will be illuminating.

According to Professors P.K. Raju and Chetan Sankar at Auburn University in Alabama, case studies should develop skills of teamwork, leadership, communication, and technical knowledge.¹ Case studies can involve real-world situations or something that is created from scratch that is based on a real occurrence, but either situation will promote learning of these skills. One important objective is to identify problem-solving criteria that may have made a difference in the situation studied. In other words, understand why certain decisions made were incorrect from a technical as well as an ethical standpoint. Each of these skills can be discovered and analyzed through those presented in a case study, and each can be worked on by students in a classroom setting. Students can work in groups that will give presentations to the rest of the class (teamwork), with one of them acting as the primary spokesperson (leadership). They can develop a report with their own conclusions, technical and ethical, and assign research pods as needed to create a defensible position to support their conclusions (communication and technical knowledge).

Although case studies in engineering focus mainly on technical issues and related lessons to be learned, it is also important to remember relevant principles of ethics, as emphasized earlier, that are found in codes of conduct published by various engineering organizations. Some of these ethical lessons that can be found in real-life case studies include:

1. “Civil engineers shall be fair and unbiased in all their interactions with the people, their clients, the organizations for which they work, as well as

themselves, faithfully and honestly discharging their duties and avoiding any conflicts of interest.” (Japan Society of Civil Engineers, *The Civil Engineer’s Code of Ethics*)²

Decisions and judgments made by engineers are based on an understanding of reality, which is made known by observation, testing, research, and instruction. Honest judgments, whether about oneself or some other entity, rely on truthful sources. Engineers should be expected to apply the principles of their trade through an honest expression of those truths. Case studies sometimes demonstrate potential consequences when a designer lacks appropriate respect for other members of the project team. Considerations of truth and rationality are discussed in [Chap. 3](#).

2. “Engineers continue professional development to enhance their technical and non-technical competencies.” (American Society of Civil Engineers, *ASCE Code of Ethics*)³

Since the fields of science form the backbone of engineering practice, it is easy to forget the human element. As human beings, we can become lazy, irritable, discouraged, or argumentative, and these nontechnical conditions can affect our performance and create an environment of hostility that causes other team members to avoid communicating with us, which leads to more problems. We need to continually develop and improve our ability to work and communicate with others, from all backgrounds, in a pleasant and productive manner. Poor communication on a project can quickly lead to some form of disaster.

3. “Every member of IER must use professional skills and experience when providing professional advice to a client or employer, and if such advice is not

accepted, inform such client or employer of any consequences which may be detrimental to the public health, safety, or interests.” (Institution of Engineers Rwanda, *Code of Professional Ethics for IER*)⁴

It takes courage to emphasize your conviction that some things are necessary and that alternatives may not only be insufficient, but they could also lead to a harmful outcome. When taking such a position, you must support your judgment with sound and unbiased scientific facts, data, or conclusions, and communicate clearly (and firmly) with kindness and appropriate humility. Some cases illustrate this point, where an engineer’s instructions or recommendations were not followed and a failure was the result—maybe not specifically related to the ignorance of what was requested, but the likelihood of a better result was definitely strong.

4. “Engineering professionals have a duty to obey all applicable laws and regulations and give due weight to facts, published standards and guidance, and the wider public interest.” (The Engineering Council and the Royal Academy of Engineering, United Kingdom, *Statement of Ethical Principles*)⁵

Engineers are not always familiar with every potential code, standard, or ordinance that may have relevance to a project—that is one of the reasons the agency that issues a permit for construction reviews the submittal documents and works with the design team to make sure they are aware of applicable regulations. Means and methods for construction are the responsibility of the contractor, but it is helpful for an engineer to have a basic idea of these standards, including requirements for jobsite safety. Some case studies involve failures as a result of insufficient protection of the construction while it is taking shape.

5. “The engineer will perform services or undertake responsibilities only where he or she is competent to do so.” (World Council of Civil Engineers, *WCCE Code of Conduct*)⁶

Competence changes with time and experience. A graduating engineering student will have a basic level of competence related to the mechanics of technical subjects but will likely have a limited grasp on how those subjects are applied to real-world problems. Mentorship with a licensed professional is key to understanding how this is done, usually in a well-defined manner. A company chooses to bring in specific types of projects, so a new graduate will gain experience and grow steadily in competence through these experiences.

6. “Registrants shall hold paramount the safety, health and welfare of the public and the protection of the environment and promote health and safety within the workplace.” (Engineers Canada, *Public Guideline on the Code of Ethics*)⁷

The practical applications of this canon have been discussed in [Chap. 6](#) of this book, but it bears repeating that the road to compliance is not always clear until something actually happens that requires an engineer to make a decision. It is easy to look back over reports and opinions on case studies and arrive at conclusions regarding what should have been done to uphold certain ethical principles, but sometimes the right choice doesn’t come so easily during the moment.

Suggested General References

1. Delatte, Norbert J. *Beyond Failure—Forensic Case Studies for Civil Engineers* (Reston, VA: ASCE Press,

2009).

2. Kaminetzky, Dov. *Design and Construction Failures—Lessons from Forensic Investigations* (New York: McGraw Hill, 1991).
3. Levy, Matthys and Mario Salvadori. *Why Buildings Fall Down—How Structures Fail* (New York: W.W. Norton & Company, 1987).

8.2 Skyline Plaza Apartments— Bailey’s Crossroads, Virginia (1973)

On March 2, 1973, a high-rise apartment building located near Bailey’s Crossroads in Fairfax County, Virginia, intended as part of a larger complex of structures, collapsed during construction, killing 14 workers and injuring 34 others. The resulting damage can be seen in [Fig. 8.1](#). Two apartment buildings had already been completed within the complex, as well as an adjoining lobby and parking structure. An inspection team from the Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, arrived at the site a few hours after the incident to begin an investigation. OSHA was assisted by the Center for Building Technology, National Bureau of Standards (NBS), to determine a cause and to offer an opinion as to whether any construction safety standards were violated.



Figure 8.1 Skyline Plaza Apartments, Bailey's Crossroads, Virginia. (Photo by H.S. Lew, NIST.)

The collapsed portion of the structure extended through the 24th floor, resulting in a 60-ft-wide gap from top to bottom. The report by NBS concluded that the mode of failure was shear in the floor slab at the 23rd level around one or more columns (punching shear) due to premature

removal of wooden formwork used to support concrete that had not yet attained the required strength specified on the structural drawings. The weight of falling debris resulted in additional slab failures that carried through to the bottom of the structure.

8.2.1 Design and Construction

The subject structure was a reinforced concrete flat plate building, supported on a 4-ft-thick concrete mat foundation. It was intended to have 26 stories of apartments with a penthouse and a multilevel basement—the roof slab of the basement coincided with the first floor of the occupied levels and was also to include landscaping. The governing structural code was the Fairfax County Building Code (adopted May 1956 with amendments to August 1971), which was based on the Building Officials and Code Administrators Building Code and referenced the 1963 edition of ACI 318 (American Concrete Institute, *Building Code Requirements for Reinforced Concrete*). Each floor slab was carried by regularly spaced reinforced concrete columns with a height of 9 ft, except the height of basement floors varied due to requirements for mechanical equipment. No column capitals or drop caps/panels were used to assist in carrying flexure and shear stresses. Reinforced concrete shear walls were included to resist lateral forces.

Normal-weight concrete columns were specified with a 28-day compressive strength of 5000 psi from the foundation mat to the 7th floor, 4000 psi from the 7th floor to the 17th floor, and 3000 psi for the remainder of the building's height. Light-weight concrete floor slabs (8" thick) were specified with a 28-day compressive strength of 3000 psi and were poured in four sections intended to be placed at a rate of one section per day, but this was not consistent.

The structural engineer of record required Grade 60 reinforcing bars in conformance with ASTM A-615.

Structural drawings included a note that required slabs being poured to be shored for two floors and backdropped at the center of the span, each way, and at the center of the bay on the next floor down. Architectural specifications also required two floors to be fully shored, but neither designer identified the minimum concrete strength required prior to removal of shores. At the time of construction, OSHA standards had the following requirements for formwork:

1. Braces and shores were to be designed to resist all foreseeable lateral loads at a minimum of 100 plf of floor edge or 2% of the total dead load, whichever is greater. Lateral bracing provided during construction was not strong enough to meet these minimum requirements.
2. A maximum deviation of shores from plumb was allowed at 1/8 in per 3 ft. Shores at the 23rd and 24th floors were found to have exceeded this limit.
3. Damaged or weakened shoring was to be removed from the site, but the investigation revealed that this was not done on the 23rd and 24th floors.
4. Unless specified by the structural engineer or architect, OSHA regulations provided basic curing times for concrete floors, which is one of the factors that influence the period of time that shores need to remain in place. Shores at the third section of the 22nd floor (extending to the floor above) were removed four days after placement of concrete on the 23rd floor, but they should have been left in place for a minimum of 10 days where ambient temperatures exceeded 50°F. Furthermore, the removal of these shores left only one

floor of shores above to support the freshly poured 24th floor.

5. Field-cured specimens of concrete were required to ensure that concrete has attained the necessary strength to support load prior to removal of formwork and shoring. No evidence was discovered that indicated specimens were prepared or tested.

8.2.2 Collapse and Investigation

At the time of the collapse, the only work being performed on the slab was that of concrete finishers. One of the laborers working nearby told investigators that he observed a large sag in the floor prior to the incident. There were differing statements from employees about the presence of shoring, as the amount and configurations would have been changing throughout the building on the day of the incident. Photographic evidence was also used by the investigating team to determine the most probable layout of formwork, and it was concluded that all formwork was in place for all poured sections of the 23rd and 24th floors, but all formwork in two sections atop the 22nd floor were removed and some formwork was in the process of being stripped from the third section.

The strength of the 22nd floor slab at the time of the collapse was estimated to be somewhere between 1310 psi and 1340 psi, taking into consideration quality and duration of curing, ambient temperature, and the presence of calcium chloride in the mix design. The actual strength of the 23rd floor slab was estimated to be somewhere between 1150 psi and 1200 psi, having cured for only 4 days. A three-dimensional finite element analysis was performed by the investigating team to determine internal forces in the slabs and columns based on expected shoring locations, and these results were compared with expected material

strength and resistance to load using elastic analysis methods and ACI 318.

8.2.3 Conclusions and Lessons Learned

Structural analysis and investigation concluded that the columns had the necessary strength to carry applied loads. Long-term deflection (creep) was ruled out as a contributing factor to failure because of the short period of time involved (about 4 hours) and due to the presence of compression reinforcement in the slabs. Flexural failure modes in the slabs were also examined and determined not to have precipitated the collapse.

Results of the analysis indicated that the punching shear capacity of the 23rd floor slab was exceeded at four column locations under unshored and partially shored conditions, and that this was a major contributing factor to the collapse. Concrete strengths that would have been required to resist shearing forces ranged between 1104 psi and 1920 psi. One of the resource studies cited in the NBS report stated that the shear capacity of a slab is significantly reduced when the supporting column has a narrow rectangular cross-section as compared to a square cross-section—one of the column locations in the failure zone would have experienced a 20% reduction in shear strength due to geometry alone (48" × 12").

One of the disabled workers sued the project architectural and engineering firms and was awarded a \$500,000 judgment after a jury found them to be negligent, which opened the doors to a number of other suits where damage claims were not covered by workman's compensation insurance.⁸ A representative of the American Institute of Architects issued a statement, describing the judgment as "frightening" and that it raised important questions about

the professional liability of architects. A spokesperson from a private group of citizens stated, “This decision holds, as we have held all along, that it was the faulty design and supervision of the Skyline Plaza building by the engineers and architects that brought on the collapse.”

Some of the lessons that apply to this case are summarized below.

1. Coordination of inspection responsibilities is critical. Check requirements with local ordinances, governing codes, and licensing boards.
2. Understand the extent of responsible charge expected of a licensed professional, on both a local level and as defined by national engineering societies. The act of responsible charge is discussed in more depth in [Chap. 3](#).
3. Being careful not to dictate a contractor’s means and methods for construction activities, be sure to include notes on the drawings or in the specifications that alert important activities, such as relevant design and construction standards.
4. Concrete and masonry construction require time to achieve target strength levels. Toward the beginning of construction, these members and systems are not generally supporting full design loads and may not require full strength prior to imposing some minimal amount of load. Confirm whether the contractor needs to impose load onto a partially cured structural member and include detailed specifications, testing, and inspection requirements on the project drawings to clearly inform the contractor of required strengths, minimum cure times, and more.
5. Progressive collapse is a very real phenomenon. Multi-storied structures should be detailed in such a

way that encourages redistribution of load in a ductile fashion, such as the provision of continuous reinforcement through supporting columns in a concrete slab building.

6. The architects and engineers were found to be negligent due to their lack of onsite inspection and coordination of responsibilities for oversight. Although the engineer's contract documents excluded field inspection responsibility, the governing code required supervision by a competent architect or engineer when requested by the building official. For a project of this magnitude, coordination of inspection responsibilities is critical and all parties need to understand pertinent roles, schedules, means of documentation, and required confirmation (testing).
7. Total responsibility for construction site safety, including means and methods, must lie with the contractor who sets up, administers, and inspects these operations. This includes all required bracing, shoring, or other temporary supports as necessary to maintain the stability of a structure before it reaches design strength.

Suggested References

1. ACI Committee E703. *The Contractor's Guide to Quality Concrete Construction (ACI/ASCC Manual)*, 4th ed. (Farmington Hills, Michigan: American Concrete Institute (ACI) and American Society of Concrete Contractors (ASCC), 2018).
2. Ellingwood, Bruce R. et al. "Best Practices for Reducing the Potential for Progressive Collapse in Buildings (NISTIR 7396)." U.S. Department of Commerce, National Institute

of Standards and Technology, Washington, DC: February 2007.

3. Leyendecker, E. V. and S. G. Fattal. "Investigation of the Skyline Plaza Collapse in Fairfax County, Virginia (NBS Building Science Series 94)." U.S. Department of Commerce, National Bureau of Standards, Washington, DC: February 1977.

8.3 Teton Dam—Newdale, Idaho (1976)

On the morning of June 5, 1976, a 305-ft-high, central-core-zoned earthfill dam failed, draining close to 240,000 acre-ft of water from the reservoir associated with the Teton River over a period of 6 hours. Filling of the reservoir began on October 3, 1975. Between January 1, 1976 and April 5, 1976, filling continued at a rate of about 0.3 ft per day, which increased to between 1.9 ft and 2.3 ft per day. The dam failed when the water level of these initial filling operations reached an elevation that was 30.3 ft below the crest, causing 11 deaths and an estimated \$400 million to \$1 billion in damage.⁹ Construction of the dam is shown in [Fig. 8.2](#). Immediately following the incident, the U.S. Department of the Interior ordered an investigation and established a highly qualified independent panel to prepare a report on the planning, design, construction, and operation of the dam and reservoir, as well as a thorough study of the failure.



Figure 8.2 Downstream view during construction of the Teton Dam, Newdale, Idaho. (Image from “Lessons Learned from Dam Incidents and Failures,” Association of State Dam Safety Officials.)

The Teton Dam and reservoir were part of the Teton Basin Project, designed by the Bureau of Reclamation to control flooding and provide a source for power generation, irrigation, and drinking water. Complete failure of the dam occurred shortly before noon, releasing a wall of water through an enlarged hole caused by collapse of the embankment crest. Flow of water had nearly stabilized by about 8:00 P.M., resulting in a loss of 40% of the embankment and submersion of several structures associated with the operation of the dam.

The investigation panel concluded that the response of the Bureau of Reclamation to the incident was prompt and

complete. Site selection and initial geologic studies were appropriate and design followed practices current at the time, though those practices did not sufficiently consider the effects of differing geological conditions that were present at the dam site. The fundamental cause of the failure included a combination of geological conditions and decisions made during the design process that contributed to poor performance. These conditions included the existence of numerous open joints and cracking in abutment rocks, highly erodible windblown silt as embankment core material, and problematic deep key foundation trenches, as well as inadequate provision for collection and safe discharge of seepage or leakage.

8.3.1 Design and Construction

Consideration of the Teton River as a resource for water was made as early as 1904. More detailed studies of the area began in 1932, but mostly on sites far upstream from the location eventually selected for construction. Inspections of the eventual canyon site began in 1956 through the U.S. Corps of Engineers, the U.S. Geological Survey, and the U.S. Bureau of Reclamation. A special report was prepared in March 1962 that included basic elements of the dam that would eventually be constructed. Reconnaissance estimated that sufficient quantities of impervious materials were available within one mile of the site, and construction materials (sand, gravel, volcanic rock) could also be obtained nearby.

A core drilling program at the location of the dam and reservoir began in July 1961 and continued through 1970. Percolation tests showed relative impermeability of many sections, but individual cracks or joints of random orientation that could be problematic were also observed. Rock types were found to be primarily basalt and rhyolite.

Basalt, the most common type of rock under the surface of the Earth, is a dark-colored, fine-grained igneous rock that most commonly forms as a product of lava flow. Rhyolite is an extrusive igneous rock with a very high silica content and is pink or gray in color with very fine grains. It typically forms from granitic magma that has partially cooled in the subsurface. Tuff also comprised some of the site geology, which is an igneous rock formed from the products of an explosive volcanic eruption.

Final design of the dam was completed in early 1971 and construction began in February 1972, continuing through November 1975. The seepage barrier for the central part of the dam included a wide, impervious zone of low-plastic to nonplastic silty material (ML type soil as defined by the Unified Soil Classification System) and a grout curtain in the foundation rock base. The abutments included a grout curtain and silty material in a key trench approximately 70 ft deep through heavily jointed rock. A transition zone of sand and gravel was constructed upstream of the seepage barrier in the embankment, but not the key trenches. Specifications required grouting for any discovered faults, joints, shear zones, springs, or other defects.

8.3.2 Collapse and Investigation

On June 3, 1976, clear-water springs were observed at distances of 1300 and 1500 ft downstream, coming from joints in the rock of the right bank. After 7:00 A.M. on June 5, a number of leaks were noticed, including a flow of muddy water and some turbid water from the right abutment that increased dramatically over the next 3 hours. At 10:30 A.M., a loud noise was heard and a large leak appeared on the face of the embankment that appeared to emerge from a tunnel about 6 ft in diameter, eventually developing into an erosion gully.

Later in the day, a vortex was formed in the reservoir above the upstream slope of the embankment and a small sinkhole appeared ahead of the gully that was developing on the downstream slope. At 11:55 A.M., the crest of the dam began to collapse at a point between the vortex and the gully and continued to enlarge with the flow of discharging water. Peak failure occurred at about 12:30 P.M. and the Teton Reservoir was essentially empty by about 6:00 P.M.

Floodwaters were contained within the 1200-ft-wide Teton Canyon for about 5 miles from the dam at which point they exited the canyon and spread out, affecting five counties located downstream. The counties of Fremont and Madison took the worst effects of the flood (all six drownings occurred in Fremont County), where 1950 farms and buildings were destroyed, 59,600 acres were damaged, and 14,900 heads of livestock were lost.¹⁰ Overall, it took about 36 hours for the floodwaters to reach the American Falls Reservoir, which was 155.9 miles from the dam.

An independent panel of experts, well-known in the fields of civil and geotechnical engineering, was commissioned in mid-June 1976 by the Secretary of the United States Department of the Interior and the Governor of the State of Idaho to study the planning, design, construction, and failure of the dam to determine a cause and to recommend measures that should be implemented for future safe dam design. Sworn testimonies of 37 eyewitnesses were reviewed in addition to photographs, supplemental motion pictures, and information gathered from public hearings in Idaho Falls on July 21, 1976. Detailed studies were made of design procedures and construction documentation, testing was performed and analyzed, and various other organizations were consulted for special studies. The panel issued its findings on December 31, 1976.

8.3.3 Conclusions and Lessons Learned

The investigating panel issued the following conclusions related to the cause of failure of the dam:

1. The pilot grouting program carried out in 1969, as well as additional predesign studies, identified unusually difficult geological conditions that would be encountered in completing the foundation grout curtain. These difficulties were not well-covered by existing dam design practices.
2. Volcanic rocks at the damsite were highly permeable and moderately to intensely jointed which allowed water to move freely and rapidly to the foundation during filling, except where joints were effectively grouted.
3. Wind-deposited clayey silts used for the core of the dam and key trench fill were highly erodible and use of this material adjacent to the permeable and jointed rock at the abutments was a significant contributing factor to failure of the dam.
4. The layer of rock directly below the foundation grout cap was not adequately sealed and provided an avenue for piping in the key trench fill, which led to an erosion tunnel across the base of the fill. The steep-sided geometry of the key trenches contributed to transverse arching at the base of the trenches, which allowed for the development of cracks that opened channels through the core material.
5. The specific cause of failure could not be pinned down with complete certainty, partly because the failed section of the dam was carried away by the flood and could not be analyzed. However, two aspects

undoubtedly contributed to the failure, including imperfect grouting of the rock below the grout cap and cracking in the key trench fill material. The design depended too much on the adequacy of the key trenches and grout curtain and other measures should have been developed and implemented to control seepage.

Recommendations proposed by the panel and other investigations and research included not only design and construction procedures, but also the processes in place to warn citizens of impending danger. During the early stages of observed seepage, the Bureau of Reclamation decided it was not necessary to alert nearby residents because an emergency situation did not appear imminent, and the Project Construction Engineer did not want to cause a panic. This decision was made at about 9:30 A.M. The sheriff's offices in Fremont and Madison Counties were notified at about 10:43 A.M. to alert residences to potential flooding and prepare to evacuate should it become necessary. A complete evacuation of all low-lying areas was eventually called for between 11:00 A.M. and 11:30 A.M.

Some of the lessons that apply to this case are summarized below.

1. Adequate mechanisms for safe collection and discharge of seepage and leakage should be built into the design and given a priority in the construction schedule.
2. Sufficient instrumentation needs to be present to inform of changing conditions in the dam and foundation so that inspectors and operators can properly judge the safety of any given situation.
3. A detailed warning and emergency plan must be developed with the contribution of government

agencies, emergency response organizations, and related citizen groups. Inspectors and operators must be fully informed of procedures and lines of communication.

The scope of work of a design professional on a construction project is usually complete when occupancy is granted, or the facility is brought online. However, the interests of public safety also require involvement of technical professionals in the development of emergency plans in the event of failure of critical elements of infrastructure and the design team's scope of involvement should be prolonged accordingly. One of the ethical tenets adopted by Engineers Ireland states, "At all times in their relations with the public, Members shall apply their skill and experience to the common good and the advancement of human welfare with proper regard for the safety, health, and welfare of the public."¹¹

4. When unusual or complicated geological conditions exist, detailed studies and evaluations should be performed in order to identify the most fatal combination of circumstances and to design an adequate defense system. Difficult or unusual designs should be peer reviewed prior to completion of construction documents.

Suggested References

1. Graham, Wayne J. "The Teton Dam Failure—An Effective Warning and Evacuation." 25th Anniversary Conference of the Association of State Dam Safety Officials, Indian Wells, California: September 2008.
2. Independent Panel to Review Cause of Teton Dam Failure. "Report to U.S. Department of the Interior and

State of Idaho on Failure of Teton Dam.” U.S. Government Printing Office, Washington, DC: December 1976.

3. U.S. Army Corps of Engineers. “General Design and Construction Considerations for Earth- and Rock-Fill Dams (EM 1110-2-2300).” Department of the Army, Washington, DC: July 2004.

8.4 Hartford Civic Center Stadium— Hartford, Connecticut (1978)

Shortly after 4:00 A.M. on January 18, 1978, the steel-framed roof of an innovative, 10,000 seat coliseum in Hartford, Connecticut collapsed during a freezing rainstorm after a period of snowfall. Fortunately the structure was unoccupied, so no one was hurt or killed in the event. The roof structure was a triangular lattice steel space frame system, covering an area of 300 ft × 360 ft, which was introduced by the structural engineering firm as a cost-saving and innovative feature. An important characteristic of the design process was the use of a state-of-the-art computer analysis program, but this turned out to present a false sense of security to the engineers when they were questioned numerous times about the adequacy of the construction. [Figure 8.3](#) shows the collapsed roof of the civic center stadium.



Figure 8.3 Hartford Civic Center Stadium in Hartford, Connecticut, after the roof collapsed on January 18th, 1978. (Photo courtesy of the Connecticut Historical Society.)

The total load carried by the roof structure when the collapse occurred was estimated to be about 66–73 psf, but the structure should have been able to carry 140 psf.¹² After the collapse, the City of Hartford hired Lev Zetlin Associates, Inc. (LZA) to determine the cause of the collapse and to recommend a procedure for demolition. In 1980, consulting engineers Robert and Richard Loomis published a paper in a journal issued by ASCE after their study and analysis of torsional buckling as a mode of collapse. LZA discovered that the roof began failing as soon as it was built due to

deficiencies in the design, including an 852% overstress of the top truss layer's compression members, underestimation of the actual dead load by 20%, and interior compression members being overloaded by 72%.

LZA concluded that the collapse was likely initiated by lateral buckling of the top chord compression members, whereas Loomis and Loomis believed that torsional buckling of compression members was the initial mode of failure (torsional buckling is a twisting of a member about its shear center). Exterior members were supposed to be braced at 15-ft intervals, but the design configuration of bracing at midpoints only provided resistance in one direction, thus leaving these members laterally unbraced for a length of 30 ft. Loomis and Loomis discovered that top chord truss members, as well as diagonal compression struts near the four support columns, were near their critical buckling load before any snow load was added to the roof.

8.4.1 Design and Construction

Structural design began in 1971 and construction began in 1972. The space truss system included a series of interconnected 30-ft × 30-ft inverted pyramids with a depth of 21.2 ft to the center of gravity of the top and bottom chords. Horizontal and diagonal members framed into the midpoints of the main diagonals and top chord members of each pyramid in an apparent attempt to reduce the laterally unbraced length from 30 ft to 15 ft. The structural system was supported by four 7-ft square concrete columns spaced on a grid measuring 240 ft × 240 ft such that the top chords cantilevered out 45 ft and the bottom chords extended 30 ft beyond the supports. The main truss members were fabricated as cruciform shapes of four angles bolted to connector plates, intermediate braces were single angle shapes, and the bottom chord members were W-shapes. In

order to create a drainage system for the roof, the deck was supported by a separate system of beams elevated above the space trusses by short posts (the top chord members were not laterally braced by the deck). This decision further complicated the design, as alternative mechanisms for bracing needed to be considered and carefully included in the computer analysis.

In his book, *Beyond Failure—Case Studies for Civil Engineers* (referenced earlier in this chapter), Norbert Delatte summarizes five ways in which the design of the roof system deviated from the standard method for these types of structures, contributing to the weaknesses that led to the collapse:

1. The cross-sectional configuration of the four steel angles making up each truss member did not provide good resistance to buckling due to the cross-shaped built-up section, which has a smaller radius of gyration than a more common shape.
2. Top horizontal members intersected at different points than diagonal members, therefore the diagonal members did not brace the top members against buckling.
3. Roofing panels were not directly supported by the top layer of the steel framing system.
4. The four support columns were positioned inside the edges of the roof instead of along the boundaries.
5. The space frame was not cambered to help control deflections.

These features were considered innovative and projected to save the owner a fair amount of money in construction. The engineers used a state-of-the-art computer analysis program to assist in the design process and verify the

adequacy of these unusual arrangements. The use of computers at this time was still relatively new, and it was important (as it is today) for engineers to understand the limitations and to interpret results in light of the expectations of experience and judgment. When designs incorporate features that have not been tested before or do not follow conventional methods that have been understood for years, it is difficult to predict and judge the results of computer analysis.

Oversight during construction by a qualified structural engineer was requested by the architect but denied by the construction manager. The roof structure was assembled on the ground, lifted once completed, and secured into place on January 16, 1973. Excessive deflections were observed in the space truss system at numerous times during construction and were reported to the structural engineers of record, but no corrections were investigated or completed. Unfortunately, the engineers who designed the structure trusted a new technology over physical signs of distress. Excessive or unanticipated deflections should be investigated to determine the cause, to understand how and why the actual performance deviated from what was expected, and to evaluate corrective solutions. Some of these instances included:

1. While the completed system still sat on the ground, the inspection agency reported excessive deflections at some of the truss joints.
2. Once the space frame system was hoisted into the final position on the four pylons (before the roof deck was placed), deflections were measured to be twice those predicted by computer analysis. When notified, the engineers explained that such discrepancies between actual and theoretical measurements should be expected.

3. When a subcontractor was fitting supports for fascia panels, he ran into extreme difficulties due to the excessive deflections. The project manager instructed the installer to make it work, so materials were modified and refabricated.
4. About a year after the roof was completed, a citizen expressed concern over the noticeable downward deflection, but the engineers and contractor were not concerned.

8.4.2 Collapse and Investigation

The roof collapse brought 1400 tons of steel down to the ground in an empty coliseum with no injuries or loss of life. Excessive deflections that were observed during construction and shortly after opening were signs of impending failure that should have been taken more seriously. LZA identified numerous design errors and a lack of appropriate judgment and oversight led to the collapse. Forensic analysis completed by Loomis and Loomis revealed that more than 70 members would have buckled in torsion when the full roof dead load was placed. When the weight of snow was added to the system, members that were already right at their capacities buckled, causing forces acting on the lower layer of framing members to change from tension to compression, resulting in more buckled members and a sequence of progressive failure.

Torsional buckling of members in an ordinary structure is an uncommon mode of failure and is sometimes not reviewed by choice or is overlooked entirely. This, however, was no ordinary structure and forensic analysis quickly identified conditions of stability that were not properly checked in the original computer analysis, nor were properly understood by the engineers of record. Investigators pointed out that the City of Harford did not require a peer

review of the design during the permitting process, though such reviews were customarily required for projects of this magnitude.¹³ An adequate peer review may have revealed the limitations of the computer analysis or potential failure modes that were not adequately considered in the design.

8.4.3 Conclusions and Lessons Learned

Soon after the collapse and investigation, a new roof was designed, fabricated, and set atop the original four columns, and the civic center was able to reopen in 1980. All parties settled out of court in 1984. Some lessons that can be learned from this event are provided below.

1. An engineer needs to seriously investigate warning signs that are observed in a structure. Inspectors and contractors are qualified to recognize conditions that deviate from ordinary structural behavior, such as excessive deflections or cracking, and their concerns will often indicate that there truly is a problem. By closely examining any reports of concern, an engineer fulfills a common rule of ethics: to hold paramount the safety, health, and welfare of the public.
2. Ethical codes commonly include a reminder that engineers are to only work in areas of their competence. In order for this canon to be followed, an engineer needs to be honest with herself. She may be quite familiar with structural steel, but the arrangement of members into a specific system can elevate the level of complexity to where load paths and reactions are not clearly evident. Computer analysis is only part of the solution. The results of the analysis need to be scrutinized by a professional who

knows what to expect, or at least by a second set of trained eyes.

3. Computer programs cannot replace sound engineering judgment based on knowledge, experience, and independent analysis or verification. A computer is a tool and should be treated as any other tool—with a proper understanding of how it works, sufficient knowledge of how to use it (input), and a reasonable expectation of the finished work (output). Engineers and Geoscientists BC, for example, state “Registrants should make efforts to keep up with technological advancements and use new technology where appropriate. However, where Registrants render services that involve analysis, calculations, or other engineering or geoscience services that are supported by the use of computer programs, they should do so only after taking steps to thoroughly understand the programs, their underlying assumptions, and their limitations.”¹⁴
4. Even considering safety factors, it is not always the best approach to design structural members to be so close to their structural capacities that there is little room for human error.
5. Unusual or complicated structures can introduce uncertainty that escapes a contractor’s understanding, elevating the potential for mistakes and misinterpretations of the design intent. Simplify the arrangement of members as best as possible and adequately detail the assembly. Seek input from contractors during the design process.

Suggested References

1. Lev Zetlin Associates. "Report of the Engineering Investigation Concerning the Causes if the Collapse of the Hartford Coliseum Space Truss Roof on January 18, 1978." City of Hartford, Connecticut: June 12, 1978.
2. Loomis, Robert S. and Raymond H. Loomis. "Torsional Buckling Study of Hartford Coliseum." *ASCE Journal of the Structural Division, Proceedings of the American Society of Civil Engineers*, Vol. 106, No. ST1: January 1980.
3. Ramaswamy, G. S. et al. *Analysis, Design, and Construction of Steel Space Frames* (London, UK: ICE Publishing, Default Book Series, January 2002).
4. Ziemian, Ronald D., Ed. *Guide to Stability Design Criteria for Metal Structures*, 6th ed. (New York: John Wiley & Sons, 2010).

8.5 Minneapolis I-35W Bridge— Minneapolis, Minnesota (2007)

In the early evening of August 1, 2007, the eight-lane I-35 highway bridge over the Mississippi River in Minneapolis, Minnesota suffered a significant failure in the main span of the deck truss, causing 1000 ft of the length to collapse, with close to half of that falling into the river. 111 vehicles, including construction equipment and materials, were sitting on the bridge portion that collapsed at the time, and 17 were recovered from the water. In total, 13 people lost their lives and another 145 were injured. On that day, four of the eight traffic lanes were closed due to deck overlay construction work. [Figure 8.4](#) shows one of the collapsed areas of the bridge.



Figure 8.4 I-35 Bridge collapse, Minneapolis, Minnesota.
(Photo by U.S. Coast Guard.)

The National Transportation Safety Board (NTSB) was called in to investigate and determine the cause of the collapse and to make recommendations to other government agencies for future work. An investigation report was also completed by the engineering firm Wiss, Janney, Elstner Associates, Inc. (WJE) at the request of the Minnesota Department of Transportation (MDOT) and the Governor of Minnesota. The NTSB concluded the probable cause of the collapse to be a design error that created insufficient load carrying capacity in one of the steel gusset plates. Failure occurred under a combination of substantial increases in the weight of the bridge due to previous modifications, along with the weight of traffic and concentrated construction loads. WJE also discovered that

several gusset plates at different nodes were originally designed to carry roughly half of the loading that was required by the governing design code at the time.

8.5.1 Design and Construction

Structural drawings for the foundation system of the bridge were approved in 1964 and final design plans of the superstructure were approved in June of 1965. The structure included fourteen spans with welded built-up steel beams for girders and trusses and connections of rivets and bolts. Thermal expansion was accounted for by a combination of fixed and sliding bearings on abutments and piers. The original deck consisted of two 6.5-in-thick reinforced concrete slabs separated by about 6 in. Two parallel, three-span continuous Warren-type steel trusses were used as the main structural system with welded box sections for top and bottom chords, as were diagonal and vertical members designed as compression members, with a total length of 1064 ft. Tension members were H-shapes welded to web plates. Each node included two gusset plates riveted to the side plates of the box members and to the flanges of the H-shaped members. Floor trusses were designed with wide flange shapes welded to gusset plates at node points, spanning about 72 ft between the centerline of the deck trusses at each node, and supporting 14 wide flange-shaped stringers.

Construction began in 1965 and was essentially completed by November 1967. It was classified as nonredundant and consideration as a fracture-critical structure was required for inspection. Beginning in 1994, in-depth fracture critical inspections were performed annually due to recent bridge failures.

8.5.2 Collapse and Investigation

On the day of the collapse, work in several lanes of traffic was being conducted and the bridge was supporting the additional weight of construction equipment and roadway materials, including sand and gravel to make concrete that would be poured later in the evening. A motion-activated camera captured the collapse, showing the center span separating from the rest of the bridge and falling into the river. Within a half-hour of the collapse, the Minneapolis Fire Department and Police Department were on the scene to begin search and rescue operations and put out fires.¹⁵ Nearby citizens and construction personnel were already attempting to rescue vehicle occupants and render aid as best as they could.

Failure of the bridge began with substantial inelastic deformation of the improperly designed gusset plates, then followed to other plates and eventually the rest of the structure was not able to carry the redistributed loads. Interestingly enough, the most heavily loaded gusset plate that failed first had not experienced significant section loss due to corrosion whereas other parts of the structure did not fare as well. A fatigue research report was completed in March 2001 and, although that investigation identified many poor fatigue details in the main truss and floor system, replacement on account of potential fatigue cracking was not recommended due to a variety of other factors.¹⁶

Through the process of investigation, the NTSB found that three major renovations and modifications of the bridge took place since the time it opened in 1967. The first project occurred in 1977 where the existing deck was milled to a depth of $\frac{1}{4}$ in and topped with a 2-in-thick wearing course of concrete. The finished work increased the dead load of the bridge by 13.4%. In 1998, additional work done on the bridge involved replacement of the median barrier, upgrade of concrete traffic rails, improvement of drainage,

miscellaneous repairs and replacements, and installation of an anti-icing system. Permanent changes to the median barrier system increased the dead load by another 6.1%. The third project included deck resurfacing work that was being completed on the day of the collapse.

Over the course of operation, several load rating reports were produced for the bridge. The first report discovered was completed in September 1979, which was likely performed in conjunction with the bridge overlay project in 1977. An additional report was produced in December 1995 in accordance with adopted specifications at that time, but an evaluation of gusset plate capacities would not have been required. The governing limit state to dictate the load rating was tension stress in the bottom flange due to flexure of the structure. In 1997, the load rating of the bridge was downgraded due to dead load increases, though documentation of the analysis revealed minor errors, some discrepancies in determining dead loads, and an incomplete consideration of the effect of section losses due to corrosion. A final load rating inspection was completed in June 2006, wherein the superstructure was labeled as *structurally deficient*, though the factors that caused this assignment did not cause or contribute to the collapse.

8.5.3 Conclusions and Lessons Learned

The NTSB concluded that the initiating event was a lateral shifting instability of one of the diagonal members and subsequent failure of the gusset plate connection on the center portion of the deck truss, leading to collapse in part because of a lack of redundancy. This failure was attributed to design errors by the bridge engineering firm, some of which included an incomplete evaluation of plate capacities. The company's design review process was inadequate and

standard practice for review by federal and state agencies did not require evaluation of gusset plate design, partially due to the fact that these connections are generally understood to be designed more conservatively than individual members. Additionally, these investigations identified a need to have clear specifications and guidelines for stockpiling construction materials on the deck during renovations or other activities.

On September 18, 2008, a new concrete bridge to replace the one that collapsed was opened to traffic. The MDOT began discussions with other agencies right after the collapse to begin planning for a replacement. The new bridge is a high-performance concrete box girder bridge that accommodates ten lanes of traffic and is designed to carry future traffic with a minimum design life of 100 years.¹⁷ The new bridge incorporates several sustainable design elements, including the use of recycled construction materials and recycled glass to create mosaics, LED highway lighting, and a self-contained bridge drainage system.

Some of the lessons that apply to this case are summarized below.

1. When assessing the strength and stability of an existing structural system, it is important to check both members and connections. Material data should be collected from reliable sources, or onsite samples can be extracted and tested. The capability of members and connections to resist load should be determined using current codes, standards, and research. Expected section losses due to corrosion or other physical damage should also be included in the analysis. Furthermore, it is important to accurately account for all dead loads carried by the structure and anticipated live or construction loads based on current codes.

2. Prior to allowing the stockpiling of materials, it is important to first have an understanding of the load carrying capacity of the subject structure. Code requirements for live loading in design are supposed to cover these temporary, added loads, but a structure may have undergone modifications or be in a state of disrepair to where the capability of carrying load is already diminished. This may be difficult for an engineer of record to communicate clearly and timely, but predesign investigation and appropriate notes in the drawings and specifications can be important tools. The activity should also be discussed during preconstruction meetings.
3. Highway departments must carefully consider and manage lane closures when work is being done on a supporting structure, especially when the structure carries load that has not been properly evaluated or documented as to safe placement.

Suggested References

1. Hill Howard J. et al. "I-35W Bridge Over the Mississippi River: Collapse Investigation (Bridge No. 9340)." Wiss, Janney, Elstner Associates, Inc., Northbrook, Illinois: November 2008.
2. National Transportation Safety Board. "Collapse of I-35 Highway Bridge, Minneapolis, Minnesota, August 1, 2007." Highway Accident Report NTSB/HAR-08/03, Washington, DC: November 2008.
3. Parsons Brinckerhoff and Louis G. Silano, eds. *Bridge Inspection and Rehabilitation—A Practical Guide* (New York: John Wiley & Sons 1993).

8.6 Eighth Street Pedestrian Bridge—Miami, Florida (2018)

At about 1:46 P.M. on Thursday, March 15, 2018, a pedestrian bridge on the campus of the Florida International University campus in Miami, Florida, still under construction, came crashing down onto an eight-lane roadway (SW 8th Street). The main structural system of the bridge was a single concrete truss that supported a deck and a roof canopy—a rare design for a trussed bridge, which are more commonly constructed of steel. Only the first span had been completed, with a length of 174 ft and an approximate weight of 930 tons. Six lanes of traffic were open at the time and eight vehicles were fully or partially crushed. One bridge worker and five vehicle occupants were killed and 10 other people were injured. The collapse is shown in [Fig. 8.5](#).



Figure 8.5 Eighth Street pedestrian bridge collapse, Miami, Florida. (Image from U.S. Department of Labor/OSHA Report prepared by Mohammad Ayub, July 2019.)

Just prior to the collapse, posttensioned rods within one of the diagonal members at the end of the truss was in the process of being retensioned—this was a recommended measure by the bridge engineers when cracking was reported after two diagonal members were de-tensioned (as required) during one of the stages of construction. This detensioning was specified during an intermediate stage of construction, where the main span of the truss would be set atop support piers prior to finishing the back span truss section and an intermediate support (Fig. 8.6 shows the intended final configuration). Cracking was first heard and observed after shores were removed from under the truss structure in the casting yard a little more than 2 weeks prior to the collapse.

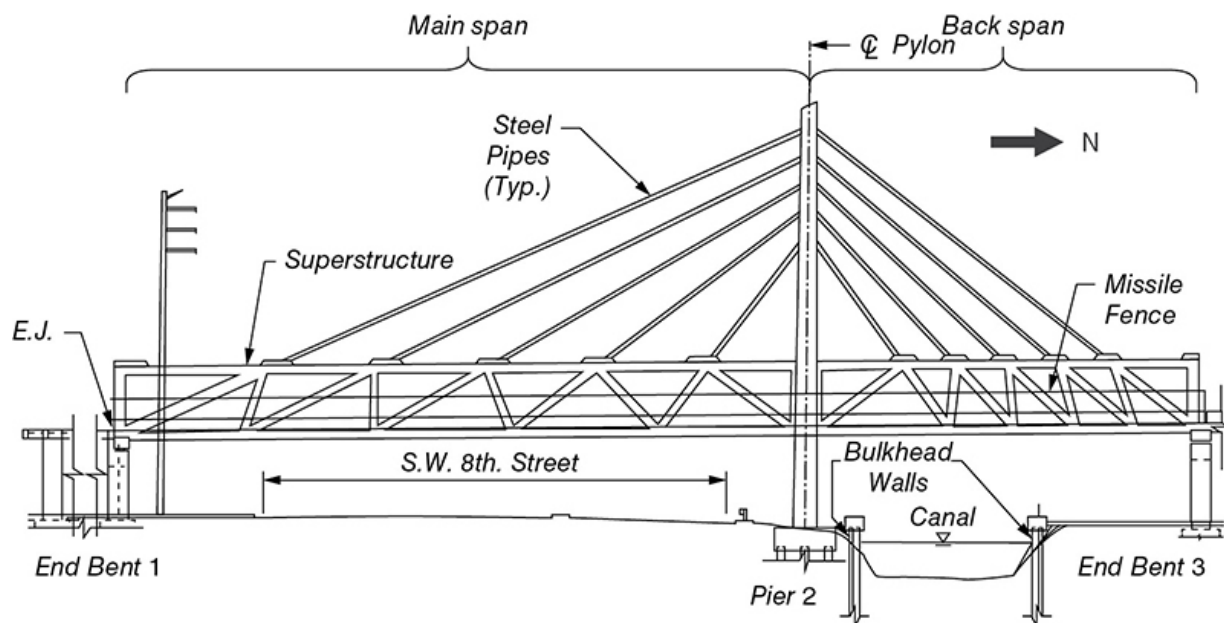


Figure 8.6 The intended final layout of the Eighth Street pedestrian bridge. (Image from U.S. Department of Labor/OSHA Report prepared by Mohammad Ayub, July 2019.)

The NTSB conducted an investigation that spanned a period of 19 months, concluding that failure of the nodal region where the diagonal member was being retensioned, including the connection to the deck, was the event that triggered the collapse. The structural failure modes included an inadequate interface shear connection between the failed diagonal member and the deck, punching shear surrounding the base of the vertical member connecting at the same node as the diagonal member and the deck, and weak flexural resistance of the same vertical member as the nodal region attempted to detach from the deck. The main cause of the failure was attributed to load and capacity calculation errors made by the design engineers, and inadequate peer review was noted to be a contributing factor. Furthermore, the engineer of record failed to understand the significance of the structural cracking observed in this node before the truss even left the manufacturing plant. The company who performed the peer review should also have been notified of the cracking for their opinion and recommendations.

8.6.1 Design and Construction

The pedestrian bridge was designed in two spans that would cross the travel lanes of SW Eighth Street and the Tamaimi Canal as part of the University City Prosperity Project, intended to improve the infrastructure on the campus of the Florida International University in Miami. The main section was to span a distance of 174 ft from the south pier to an interior pylon pier, and the second span (back span) was to extend a distance of 99 ft from the interior pylon pier to the north pier. The walking deck would be elevated 18.5 ft above the roadway.

The main structural feature was a single concrete truss with diagonal members designed to a different angle and

length, aligned with 10 steel pipe stays extending down from the upper pylon, or mast, to replicate the aesthetics of a cable-stayed bridge. The 32-ft-wide concrete deck, posttensioned in the longitudinal and transverse directions, acted as the truss bottom chord and a concrete canopy, posttensioned in the longitudinal direction, acted as the top chord. Six of the main span web members were to be permanently posttensioned, four members were not to be tensioned at all, and two members (the outermost diagonal members at each end) were to be temporarily posttensioned to address temporary construction conditions. All members also included conventional deformed reinforcing bars.

Construction was to proceed in eight stages:

Stage 1: Cast the substructure.

Stage 2: Cast the main span truss in a nearby yard with all of the posttensioning of the deck, canopy, and diagonals.

Stage 3: Transport the main truss and place it over the south pier and north pylon, set into a simply supported condition until the back span could be secured. The incident occurred at this stage.

Stage 4: Casting and setting of the back span truss.

Stage 5: Adding continuity tendons and casting of the upper pylon.

Stage 6: Installation of the upper pipe members and supports between the upper pylon and the deck.

Stage 7: Installation of bridge components.

Stage 8: Installation of landings.

8.6.2 Collapse and Investigation

Distress of the main span structure began during the removal of formwork at the casting yard on February 24,

2018, when construction workers heard a loud, distinct popping sound. Upon inspection, cracks were found in the outermost lower nodal regions (the first main diagonal member and first vertical member connections at the deck). Photographs were taken and information was forwarded to the bridge engineers on February 28 for review and comment. The engineers responded on March 7, expressing no structural concerns but advising the contractor to seal the cracks in accordance with the Florida Department of Transportation (FDOT) standard specifications.

On March 10, the main span truss was moved into position and set onto the supporting piers at about 12:30 P.M. and two diagonal members were detensioned as required by the project documents immediately thereafter. During this time, cracks began to appear at multiple locations but more prominently around one of the nodes that had already cracked. The contractor sent an email to the design engineers with photographs and an indication of strong concern on March 12—no additional communication took place between March 10 and 12. The engineers responded to the email at 9:45 A.M. on March 13, commenting that the additional cracking was not a safety concern and that the contractor should install shims underneath the deck diaphragm at the bridge centerline. General testimony agrees that cracks did, in fact, progress significantly after detensioning the second diagonal member. After other discussions and considerations, at 5:18 P.M. on March 13, the design engineers phoned and emailed the contractor to direct them to retension the second diagonal member.

In the morning of March 15, at about 8:00 A.M., representatives from the design engineering office visited the site to observe the cracks in advance of a 9:00 A.M. meeting with the owner and contractors to discuss the damage. During that presentation, the engineers again

reiterated that they were not concerned with the safety of the span suspended over the road. Restressing of the diagonal member was in progress at 1:46 P.M. on that same day when the bridge ultimately collapsed onto the road below.

The primary investigation by the NTSB found the main cause of the event to be errors by the bridge engineers, where the failed node was underdesigned because of two things. First, the demand on the node was underestimated by almost a factor of 2. A postcollapse analysis by the Federal Highway Administration (FHWA) found similar miscalculations of demand at other nodes, one being 10 times lower than it should have been. Second, the capability of the node to resist horizontal shearing forces along the deck was overestimated. The drawings did not consistently state required conditions for intentionally roughening concrete surfaces to be mated together, although the common bridge specifications by the American Association of State Highway and Transportation Officials (AASHTO) included general instructions for this work. The NTSB also concluded that the peer review done during the design phase was not adequate and should have included all significant stages of construction. When questioned about the scope of their work, the peer review agency stated that they were only hired to review the design of the structure in its final installed state. It was also found that the reviewers did not evaluate the node connections of the truss to the canopy or deck—they stated that these considerations were excluded due to a lack of fee and time. The overall qualifications of the reviewing agency to perform such work were also found to be deficient.

8.6.3 Conclusions and Lessons Learned

As a result of their investigation, the NTSB made safety recommendations to the FHWA, FDOT, AASHTO, and to the engineering company who performed the original design. These recommendations included prequalification of peer review engineering companies, complete shoring and traffic lane closure immediately after detection of structural cracks, and enhancement of design procedures for concrete bridge structures. The bridge design engineers hired an independent forensic investigation agency to conduct their own research, which included tests on full-scale replicas. The cause of collapse was reported through this additional investigation to be failure by the contractor to roughen the concrete surface beneath the diagonal member identified in the NTSB report.¹⁸ These findings were used in part by the bridge engineering company to convince a federal judge to lift a suspension imposed by the FHWA and to block a proposed 10-year debarment. The suspension and recommendation for debarment were issued on July 14, 2020, which would exclude the company from participating in any federally funded projects.

Some lessons that can be learned from this event are provided below.

1. Cracking that occurs in concrete are classified as occurring either in plastic concrete or hardened concrete.¹⁹ Plastic concrete may generally crack due to plastic shrinkage or settlement of the mixture. Hardened concrete may crack as a result of drying shrinkage, thermal stresses, a chemical reaction, weathering, corrosion of reinforcement, poor construction practices (adding water, inadequate curing, etc.), construction overloads, errors in design and detailing, or externally applied loads. Although some cracks in reinforced and pre- or posttensioned concrete structures are normal, the size and extent of cracking are controlled by good design and detailing

practices. Observed cracks should be studied, monitored, and evaluated as to the likely cause and whether repairs are needed. Opinions of other professionals who are familiar with concrete construction should be carefully considered during the evaluation process.

2. In his book, *Design and Construction Failures—Lessons from Forensic Investigations* (referenced earlier in this chapter), Dov Kaminetzky explains that the degree of damage observed through cracking needs to be considered with regard to the location of the cracks in the structure. Classifying the severity of cracking by measuring width, length, and frequency is helpful, but it should not be the only criterion for assessing damage.
3. Concrete truss bridges are rare, especially those which lack sufficient redundancy and are asymmetric (the NTSB recommended that current bridge design standards need to enhance redundancy guidelines for concrete truss bridges). A typical truss bridge design includes two parallel steel trusses with evenly spaced and similarly shaped triangular sections, connected together with lateral supports and bracing. When introducing an unusually configured structure, it is important to make sure a suitable structural model is created for design purposes and the results of the analysis are checked using means that can be easily understood. Furthermore, peer review of the design at all significant stages of loading and support must be completed by a qualified structural engineer.

Suggested References

1. Ayub, Mohammad. "Investigation of March 15, 2018 Pedestrian Bridge Collapse at Florida International University, Miami, Florida." U.S. Department of Labor, Occupational Safety and Health Administration, Washington, DC: July 2019.
2. National Transportation Safety Board. "Pedestrian Bridge Collapse over SW 8th Street, Miami, Florida, March 15, 2018." Highway Accident Report NTSB/HAR-19/02, Washington, DC: October 2019.

8.7 Review Questions

- 8.1.** What are some of the benefits derived from a thoughtful analysis of historical events?
- 8.2.** Explain the necessary foundation (or basis) for making engineering judgments or decisions.
- 8.3.** What are four nontechnical conditions of humanity that can negatively affect our performance?
- 8.4.** How should an engineer conduct herself when she is taking a position that an alternative design proposed for a project will be harmful?
- 8.5.** What did the NBS report conclude as the mode of failure in the Skyline Plaza apartment building collapse?
- 8.6.** What were three OSHA standards that were not met during the construction of the Skyline Plaza apartment building that collapsed?
- 8.7.** Identify four lessons learned from the Skyline Plaza apartment building collapse.
- 8.8.** What did the core drilling program in the site evaluation for the Teton Dam reveal that was reported as potentially problematic?

8.9. What was the problem with volcanic rock, which was noted to be one of the causes for the failure of the Teton Dam?

8.10. What was an important characteristic of the design process for the roof of the Hartford Civic Center Stadium roof that wound up being a problem in the end?

8.11. In the Hartford Civic Center Stadium roof collapse, what were the different initial modes of failure reported by LZA and by Loomis and Loomis?

8.12. What were three of the ways Norbert Delatte noted that the design of the roof trusses at the Hartford Civic Center Stadium deviated from the standard method of design for similar structures?

8.13. What happened during the fitting of supports for the fascia panels at the Hartford Civic Center Stadium?

8.14. In the interest of holding public safety as a paramount ethical obligation, what should an engineer do when notified of warning signs in a structure?

8.15. According to the NTSB, what was the probable cause of collapse of the I-35 bridge in Minneapolis?

8.16. In addition to using current codes and standards to assess the strength of a bridge, what else should be accounted for when assessing the physical quality of members?

8.17. During which stage of construction did the pedestrian bridge at the Florida International University collapse?

8.18. According to the NTSB, in what two ways was the pedestrian bridge at the Florida International University under-designed?

8.19. What problems were discovered with the peer review that was done for the design of the pedestrian bridge at the Florida International University?

8.20. What are some of the reasons why hardened concrete may crack?

8.8 Discussion Questions

8.1D. Discuss some of the consequences that could result when members of the design team have a lack of respect for one another.

8.2D. Why is it important for a permitting agency to work with the designers as members of a team instead of taking an adversarial role?

8.3D. On a project as large as the apartment buildings at Skyline Plaza, why is it important to sample and test concrete specimens?

8.4D. In the early stages of seepage observed at the Teton Dam, the project construction engineer did not alert nearby residents because he did not want to cause a panic. Do you believe this was a reasonable exercise of judgment? Why or why not?

8.5D. When unusual or complicated geotechnical conditions are discovered during the predesign stages of a dam (or other work involving excavation or soil mechanics), who are four groups, persons, or agencies that should be contacted for assistance and why?

8.6D. List three additional lessons (beyond those stated in this case study) that could be learned from the Teton Dam failure. Be sure to cite any references used and carefully explain the importance of these lessons.

8.7D. What are the structural differences between lateral buckling and torsional buckling of a structural member (in reference to the Hartford Civic Center Stadium roof collapse mechanism)?

8.8D. Why is it important for an engineer to understand and verify computer analysis programs? What types of things would be involved?

8.9D. One sign of structural distress is a noticeable downward deflection. Identify four other signs of distress that might be observed in a structure (include sources from your research).

8.10D. What are five recommendations you would give an engineer who is about to design a structure that is somewhat out-of-the-ordinary?

8.11D. When construction workers heard a loud, distinct popping sound during the removal of formwork at the casting yard for the pedestrian bridge that was to be placed at the Florida International University, what types of things could (or should) have the design engineers done to examine the situation?

8.12D. Name five things that an engineer can do to evaluate the condition and origin of observed cracks in concrete.

¹P.K. Raju and Chetan S. Sankar, "Strategies for Using Case Studies in Engineering Classrooms," *SEATEC Forum* at Auburn University, Auburn, AL: March 1999.

²Japan Society of Civil Engineers (JSCE), *The Civil Engineer's Code of Ethics* (Tokyo, Japan: JSCE, May 9, 2014).

³American Society of Civil Engineers (ASCE), *Code of Ethics* (Reston, VA: ASCE, October 26, 2020).

⁴Institution of Engineers Rwanda (IER), *Code of Professional Ethics for IER*, accessed March 1, 2020, www.engineersrwanda.rw.

⁵Engineering Council/Royal Academy of Engineering (EC/RAE), *Statement of Ethical Principles* (London, UK: EC/RAE, July 2017).

⁶World Council of Civil Engineers (WCCE), *WCCE Code of Conduct*, accessed March 1, 2020, www.wcce.biz.

⁷Engineers Canada, *Public Guideline on the Code of Ethics* (Ottawa, Ontario, Canada: Engineers Canada, 2021).

⁸Ben A. Franklin, "\$500,000 Awarded in Building Collapse," *New York Times*, January 14, 1975.

⁹U.S. House Committee on the Judiciary, *Teton Dam Disaster Assistance Act of 1976*, 94th Cong., 2d Session, 1976, Rept. 94-1423.

¹⁰*Ibid.*

¹¹Engineers Ireland, *Code of Ethics* (Ballsbridge, Dublin, Ireland: Engineers Ireland, 2018).

¹²Rachel Martin and Norbert J. Delatte, "Another Look at Hartford Civic Center Coliseum Collapse," *ASCE Journal of Constructed Facilities*, Vol. 15, No. 1: February 2001.

¹³*Ibid.*

¹⁴Engineers and Geoscientists BC, *Guide to the Code of Ethics* (Burnaby, British Columbia, Canada: Engineers and Geoscientists BC, 2021).

¹⁵Hollis Stambaugh and Harold Cohen, *I-35 Bridge Collapse and Response, Minneapolis, Minnesota, August 1, 2007 (Report 166)* (Washington, DC: U.S. Fire Administration, Federal Emergency Management Agency, August 2007).

¹⁶Heather M. O'Connell and Robert J. Dexter, *Fatigue Evaluation of the Deck Truss of Bridge 9340* (St. Paul, MN: University of Minnesota Department of Civil Engineering, Minnesota Department of Transportation, March 2001).

¹⁷Alan R. Phipps and Kevin MacDonald, "Sustainability Leads to Durability in the New I-35W Bridge," *Concrete International*, American Concrete Institute: February 2009.

¹⁸Kim Slowey, "Judge Denies Figg's Request to Lift Highway Administration Suspension," *Construction Dive*, August 18, 2020, <https://www.constructiondive.com/news/figg-sues-feds-asks-court-to-lift-suspension/583354/>

¹⁹American Concrete Institute Committee 224, *Causes, Evaluation, and Repair of Cracks in Concrete Structures (ACI 224.1R)* (Farmington Hills, MI: American Concrete Institute, 2007).

CHAPTER 9

The Globally Conscious Engineer

Civil and structural engineers need to pay close attention to constraints and potential challenges for each project site. Physical and legal boundaries set the focus area, allowing engineers to concentrate design effort into reasonable chunks that are defined by specific needs and resources. Local data is obtained from a variety of sources, including geotechnical reports, environmental impact reports, zoning regulations, existing land development patterns, and political bodies, such as city councils and county legislative boards. This data is crucial to developing code-compliant products of construction. [Figure 9.1](#) shows a bridge supporting a critical transportation route, demonstrating how manmade objects can fit beautifully into their own local environment.



Figure 9.1 Bridge at Niagara Falls, New York, United States.

Even on a local level, it is clear to see how the constructed environment affects the surrounding population: water drainage patterns must be maintained, sensitive pockets of land must be protected, and the diversity of life that exists within the boundaries of development must be respected. People, animals, and vegetation all share the same, important environmental resources, and there must be a thoughtful process of making changes to the landscape. Change is inevitable, but a healthy, symbiotic relationship is mandatory. There are legitimate differences of opinion as to how this relationship can best be managed, but everyone can agree that some level of protection is required for the benefit of future

generations. Mutualism is the goal, where all affected entities or species benefit from change, but commensalism may also be acceptable where one (or several) entities or species benefit and the others are not negatively affected. Parasitism is where one group of participants benefits, and the remaining entities are harmed—this is a condition that should be avoided as completely as possible.

The natural progression of this thinking leads one to the understanding that what humans do on a local level can easily have more broad, long-lasting effects. As problem solvers, engineers need to be trained to think beyond the local project level and adopt a mindset toward needs on a global scale, where specialized education and training can be used to benefit a more extensive, diverse group of clients and fellow human beings.

The term *global consciousness* brings to mind a parapsychological experiment that began in 1998 as an attempt to detect a relationship between a common mindset and emotional connection among human beings and the behavior of physical systems in the surrounding environment. For our purposes, however, we will identify the *globally conscious engineer* as one who exhibits the qualities and dispositions identified in [Fig. 9.2](#). These characteristics are necessary for the development of a system of ethics that is truly tolerant and genuinely selfless. The consistent practice of sound ethics takes diligent and attentive work and may not get any easier with the passage of time, but it is important to keep moving forward and fight the temptation to give up.

Characteristics of a Globally Conscious Engineer:

1. Understands the cross-cultural interconnection of systems, institutions, and actions
2. Acknowledges the value of all cultures
3. Demonstrates open-mindedness toward a diversity of nonnative belief and activity
4. Recognizes the implication of engineering decisions beyond the local level
5. Predisposed to act in an informed way that benefits society beyond self
6. Able to identify ethical issues and critically examine multiple solutions or outcomes
7. Elevates the importance of sustainable and environmentally friendly solutions
8. Practices a willingness to help those who may be disadvantaged due to income or position

Figure 9.2 Characteristics of a globally conscious engineer.

9.1 A Global Reality

Codes of ethics developed by engineering societies universally recognize the impact of engineers on a global scale, for present and future generations. The American Society of Civil Engineers (ASCE), for example, states that engineers “utilize their knowledge and skills to enhance the quality of life for humanity.”¹ Engineers Australia (EA) recognizes that engineers promote sustainability by balancing the needs of the present with the needs of future generations through the identification of options that have economic, environmental, and societal consequences.² The code of ethics published by the World Federation of Engineering Organizations (WFEO) emphasizes that engineers are to “be aware that the principles of eco-system interdependence, diversity maintenance, resource recovery and inter-relational harmony form the basis of humankind’s continued existence.”³ In the most basic of terms, the global perspective emphasizes continued human existence and improvement of harmony, though harmony is best understood on a smaller, more personal scale.

The term *harmony* refers to an inner or shared peace or tranquility among persons—an accord or agreement, not in all things, but enough to foster mutual respect of a basic

coexistence. Those who make use of local structures, waterways, green spaces, or other community gathering places expect a level of harmony in order to complete the purpose for which they have entered the area. Whether for relaxation or work-related activity, the mind and body are best suited to completing tasks when there is minimal threat or discomfort: the more harmonious the environment, the more easily a task can be completed. As human beings spread a good perception of harmony beyond local borders, outlying communities will be encouraged to embrace that same sense.

9.2 Rules and Responsibilities

Professor Angela Bielefeldt (University of Colorado, Boulder) identifies two distinct perspectives for engineering ethical frameworks associated with responsibility for the environment and sustainable practices.⁴ The first is anthropocentric, where the engineer believes that preservation of the environment is ultimately self-preservation for human life. Even with an admittedly narrow association, engineers can still grasp the importance of sustainability for all persons, regardless of physical characteristics or country of origin. One of the aspects of the environment that may be lost in an anthropocentric position is simply the value of beauty and other interests. Nature offers the opportunity to study and examine scientific principles and provides invaluable means for recreation and relaxation, all of which contribute to human development and welfare.

The second perspective described by Professor Bielefeldt is biocentric, where the engineer believes preservation of the environment is part of human responsibility due to the intrinsic right to life of all organisms on the planet. This perspective recognizes intrinsic value in the environment

and ecology beyond the value of sustaining human existence. Both perspectives emphasize responsibility. Albert Schweitzer argued that the most fundamental feature of humanity is not our intellect, but rather our will to live—both to survive and to grow, which naturally lends to a common respect for all life. He believed that a reverence for life is one of the most important qualities of character, and that this reverence leads to a healthy dose of empathy for the struggle of all living things to survive and develop. [Figure 9.3](#) lists key elements of sustainability that demonstrate a need for awareness, honesty, and creativity.

Elements of sustainability:
1. Longevity of natural resources
2. Effective waste management
3. Protection of environmental quality
4. Social equity for all generations
5. Economic growth without exploitation
6. Resilience of human systems to natural disasters
7. Reliable clean energy

Figure 9.3 Elements of sustainability.

9.2.1 Green Construction Codes and Standards

In the United States, the *Constitution* grants states the authority to regulate construction within their respective boundaries, except for federal buildings. This process was described in more detail in [Chap. 4](#). The most widely published codes related to numerous fields in the construction industry are those produced by the International Code Council (ICC), which are assembled by numerous committees and subject to public input and scrutiny before hitting the shelves as model code documents. They do not take legal effect until a governmental agency adopts them into their own civil code,

oftentimes making locally based revisions or additions. If your project requires some type of green feature or system, there is a good possibility the regulation came from a document originally published by the ICC.

9.2.1.1 International Green Construction Code (IgCC)

In May 2009, the ICC Board of Directors voted to create a Sustainable Building Technology Committee to work on the first draft of the IgCC. The committee included professionals with expertise in critical disciplines and was supported by numerous agencies and sponsors, including the American Institute of Architects, ASTM International, ASHRAE, the U.S. Green Building Council, the Illuminating Engineering Society, and others. Public comment hearings on the first draft were held in August 2010, a subsequent draft was produced for further comment and revision in November 2010, and final provisions were completed in October 2011 that led to publication of the 2012 Edition of the IgCC and is currently on a 3-year cycle.

The code provides minimum requirements for siting, design, construction, and operational plans for high-performance green buildings (primarily commercial occupancies) and covers new buildings, new portions of existing buildings, new systems installed within existing buildings, and relocated existing buildings. Goals of the publishers are to provide for health, life, and safety in construction; increase economic and resource efficiency; reduce effects of climate change through more resilient buildings, communities, and cities; and provide quality today without compromising the needs of future generations. The writers also make it clear that legal occupancy of existing buildings may remain essentially unchanged unless the local authority considers changes

necessary for the general safety and welfare of building occupants and the public. It includes both prescriptive- and performance-based options, as well as an appendix chapter for residential construction.

One of the key components to the IgCC (consistent throughout the I-codes, actually) is consideration of alternatives. Other materials, methods of construction, designs, systems, or published standards may be considered for a construction project as long as the governing jurisdiction allows and approves of them as meeting the intent of the IgCC and other existing laws or ordinances. The publishers recognize the innovative nature of green technologies and understand that change can occur rapidly. Additionally, the code is not intended to promote the use of one product over another and building officials should have the authority to carefully review the ideas and strategies of component manufacturers or licensed professionals to achieve sustainability goals by a variety of means. In fact, Section 105.4 of the IgCC stipulates that where the building official does not approve an alternative, the reasons for such rejection shall be provided to the applicant in writing.⁵

9.2.1.2 National Green Building Standard (ICC 700)

Appendix J of the IgCC requires that detached one- and two-family dwellings and multiple family townhomes, not more than three stories in height, plus accessory buildings and the sites themselves, comply with the provisions of the National Green Building Standard (NGBS), which is currently published by the National Association of Home Builders of the United States (NAHB) as a voluntary consensus document for residential occupancies suitable for adoption and modification as a governing jurisdiction may decide.

The 2020 edition of the standard was approved by ANSI as an American National Standard in January 2020 and is managed by Home Innovation Research Labs, which is an accredited standards developer. The full standard applies to design, construction, and modification of all residential buildings, residential portions of mixed-use buildings, and complete mixed-use buildings where the residential portion exceeds 50% of the gross floor area.

The intent of the NGBS is to establish criteria for rating the environmental impact of design and construction to achieve conformance with performance levels of residential structures, sites, and subdivisions related to green uses and effects.⁶ Rating levels include a combination of mandatory regulations plus accumulated points awarded for different practices identified in the standard. Section 4, for example, identifies points related to site design and development. Certain types of sites that are selected to minimize environmental impact are awarded special points, including infill, grayfield, and brownfield sites. Infill sites include vacant or underutilized land with at least one boundary adjacent to existing development. A grayfield site is one that has been previously developed and may include a small amount of contamination. Brownfield sites are known or suspected to contain hazardous materials, pollutants, or other contaminants, which can be defined by local statute or Public Law 107-118, January 11, 2002 (H.R. 2869).

9.2.1.3 Federal Laws

Federal environmental statutes and programs typically set the bar for the development, interpretation, and enforcement of regulations throughout the country regardless of whether a project is federally funded or managed. Although numerous federal agencies regulate environmental impact by different means, the primary

responsibility lies with the Environmental Protection Agency. Policies are set by the main office in Washington, DC and regional offices implement requirements and work with state and local governments on enforcement and permitting. Some of the federal statutes administered by the EPA include the National Environmental Policy Act of 1969 (introduces the Environmental Impact Statement and Environmental Assessment project requirements), the Clean Air Act (introduced in 1963), the Clean Water Act (introduced in 1972), the Endangered Species Act of 1973, and the Toxic Substances Control Act of 1976. Where states have their own programs, enforcement activity of the EPA is relatively limited.

The U.S. Army Corps of Engineers (Corps) plans, designs, builds, operates, and maintains navigable waterways, flood control and hurricane protection systems and facilities, and other infrastructure. The Corps has been tasked with more environmental responsibility since passage of the National Environmental Policy Act. Different branches of the Corps include project management, economic and social analysis, environmental planning and compliance, coastal management, and an operations division. The National Oceanic and Atmospheric Administration (NOAA), a division within the U.S. Department of Commerce, serves as an important resource on information related to climate change, general weather conditions, and other issues affecting oceans and coasts. It is also tasked with the conservation and management of coastal and marine ecosystems and resources. Other environmental protection duties are carried by the U.S. Department of the Interior, the U.S. Department of Agriculture, and even the U.S. Coast Guard.

9.2.1.4 Miscellaneous Rules and Regulations

State legislatures may create new environmental laws related to construction activity that civil and structural engineers should be aware of. Since the engineering team is not usually responsible for starting a project or determining how to develop a plot of land, they might not be immediately aware of effective regulations beyond codes, standards, and ordinances that are commonly enforced. Federal and state projects are usually the first ones to be affected by legislative change, since the government intends to lead by example, and they are responsible for protecting public assets.

The State of Maryland, for example, published the Greenhouse Gas Emissions Reduction Act in 2009 and the Maryland Climate Change Commission Act in 2015 to establish legislative goals for achieving certain predefined milestones, employing a combination of regulatory, market-based, and voluntary programs. An interim executive order was signed by the Governor in December 2012, directing all state agencies to consider the risk of coastal flooding and sea level rise when they design capital budget projects, and charging the Department of General services with updating its architectural and engineering guidelines to require new and rebuilt state structures be elevated 2 or more feet above the 100-year base flood levels.

Local permitting jurisdictions will also need to keep abreast of new regulations that affect land development or services provided. Responses to the effects of climate change are still relatively new, and there is something of a trial-and-error approach being taken by most of the world's governments to address a rather complex set of issues. For example, on May 4, 2021, the French Parliament passed a climate change bill by a vote margin of 332 to 77, which

was drafted to include feedback from 150 members of a public citizens consultation group. At the time of this writing, the bill still needs to be passed by the Senate before a final vote in the lower house. If passed, the bill will prohibit the construction of new airports or expanding the capacity of existing airports and will ban domestic flights on routes that are served by a train ride of under 2.5 hours. Community services and land development will be affected by these restrictions, which require engineers to be attentive.

The design process for a project that requires judgment for projected environmental situations or conditions, based on statistical models and politically charged research, can be difficult, especially when the area of development is only partially controlled by regulations. An advisory opinion to analyze the ethics behind these difficult situations was published by the National Society of Professional Engineers Board of Ethical Review (NSPE BER), Case No. 18-9, on January 22, 2019.⁷ The advisory opinion involved an engineer in private practice who was hired to perform hydrodynamic modeling and coastal risk assessment connected to climate change and future sea level rise for a residential development project. There was no adopted code in the region of work that mandated action, so the owner would have some legal latitude in selecting the path forward.

Based on the latest models and historic weather data, the engineer recommends the project should be built to withstand a 100-year storm surge elevation change. This recommendation is based on a reasonable and objective belief that a less stringent design standard would place future residents at risk and potentially cause significant property and environmental damage. However, the owner chooses not to pursue this course of action due to cost. The NSPE BER asks, “What are the engineer’s obligations under

the circumstances?” There are numerous principles within the code of ethics that apply to this case, including:

1. Hold paramount the safety, health, and welfare of the public.
2. If an engineer’s judgment is overruled, he should notify his employer or client and appropriate authority.
3. Approve only those documents that are in conformity with applicable standards.
4. Advise clients when it is believed that a project will not be successful.
5. Engineers are encouraged to adhere to the principles of sustainable development.

The NSPE BER concluded that the engineer has an ethical obligation to continue to pursue discussions with the client and emphasize the danger that exists to persons, property, and the environment if his recommendations are not followed. This may require a detailed presentation of known facts and projected expectations in an effort to demonstrate to the client that there is no political agenda, the truth has been sought in an objective manner (following accepted scientific protocols), and a future dangerous condition can be reasonably assumed. If the client continues to object, the engineer may want to bring in another engineering company to offer a second opinion, or he may need to withdraw from the project.

9.2.2 Professional Responsibility and Discretion

The advisory opinion described above illustrates an example where an engineer should consider working with local

government officials toward adopting a suitable land development code or standard that encourages sustainability and requires certain activities to implement solutions at a reasonable pace. Regional codes and land use policies often lag behind new research and discoveries that reveal better, and even critically important, changes in how resources should be managed, and sometimes policy makers simply are not aware of these developments. Engineers are expected to stay current in the areas of knowledge affecting those who ultimately use the products of their designs and they have a responsibility to share information, or to correct misinformation, when it may contribute to a more suitable outcome for a project. Beyond the letter of the law or adopted standards, government officials (generally those who are not elected to position) are free to exercise administrative discretion in the development, interpretation, and application of policy and they depend on the expertise of qualified professionals to assist in making the right decisions.

Responsibility to adopted laws and standards is a given. Principle 3 in the code of ethics published by Engineers and Geoscientists BC reminds registrants to “have regard for the common law and any applicable enactments, federal enactments, or enactments of another province.”⁸ A reference guide published by the organization provides further details on the types of effective laws. They are to be considered with due care and registrants are to apply their professional judgment to determine whether the principles contained in nonbinding types of laws are applicable to a given situation. These laws can be related to professional ethics, or they can apply to a broader field of individuals and projects. Communication is key to working through areas that are in need of improvement, and both public and private sector engineers need to share their knowledge and experience when a project calls for collective discretion.

Engineers who are employed by governmental agencies, and are in a position to grant construction permits, are often granted latitude in their analysis and ultimate decisions where activity may have a foreseeable negative effect on the environment. One such case occurred over a dredging/filling permit for a proposed trailer park in Boca Ciega Bay near St. Petersburg, Florida.⁹ The land being considered was located about 1 mi from the Intracoastal Waterway, being riparian to the Bay with some portion underlying the water. It is a navigable waterway of the United States and an arm of the Gulf of Mexico (see [Fig. 9.4](#)), which requires local government approvals as well as a permit from the Army Corps of Engineers.

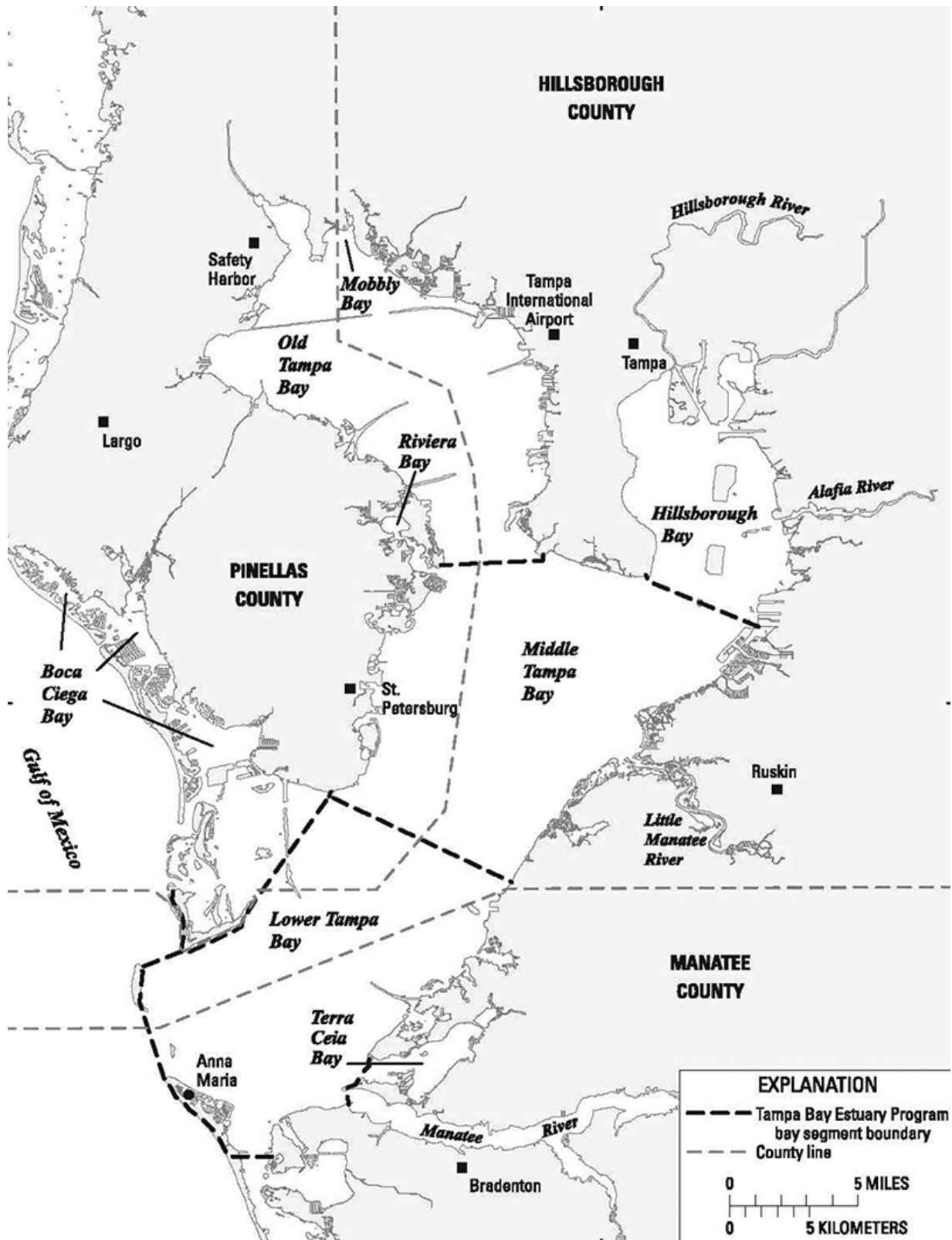


Figure 9.4 Interconnected lagoons and bays of Tampa Bay, Florida. (Image from U.S. Geological Survey Circular 1348, *Integrating Science and Resource Management in Tampa Bay, Florida*, 2011.)

Before filing an application with the Corps, the owners obtained a permit (pursuant to a state court order) from the Pinellas County Water and Navigation Control Authority, although they continued to oppose the work, as did the Board of County Commissioners of Pinellas County and about 700 individuals who filed protests. The U.S. Fish and Wildlife Service, Department of the Interior, also opposed the project due to their belief that it would cause measurable harm to fish and wildlife resources of the Bay. Although there was evidence showing that the construction would both aid and obstruct navigation, and the District Engineer decided that the project would ultimately have no material adverse effect on navigation, he nonetheless recommended that the application be denied on December 30, 1966, stating: "The virtually unanimous opposition to the proposed work as expressed in the protests which were received and as exhaustively presented at the public hearing have convinced me that approval of the application would not be in the public interest. The continued opposition of the U.S. Fish and Wildlife Service, despite efforts on the part of the applicants to reduce the extent of damage, leads me to the conclusion that approval of the work would not be consistent with the intent of Congress as expressed in the Fish and Wildlife Coordination Act, as amended, 12 August 1958. Further, the opposition of the State of Florida and of county authorities ... gives additional support to my conclusion that the work should not be authorized."

The Secretary of the Army formally denied the application on February 28, 1967, which led to a lawsuit filed by the landowners to compel the Secretary to issue a permit on the

grounds that the Secretary had no authority to refuse the permit on any grounds other than navigation, flood control, or the production of power in accordance with the Rivers and Harbors Act of March 3, 1899. The government and other defendants answered the suit by arguing that the Court did not have the power to compel a discretionary act by the Secretary of the Army. The District Court disagreed, held that the Fish and Wildlife Coordination Act was not authority for denying the permit, and granted a summary judgment for the landowners on February 17, 1969. A stay of execution of judgment was also granted until an appeal could be heard and decided. The District Court concluded, "The taking, control, or limitation in the use of private property interests by an exercise of the police power of the government or the public interest or general welfare should be authorized by legislation which clearly outlines procedure which comports to all constitutional standards. This is not the case here. As this opinion is being prepared, the Congress is in session. Advocates of conservation are both able and effective. The way is open to obtain a remedy for future situations like this one if one is needed and can be legally granted by the Congress."

While the case was under review by the U.S. Court of Appeals, Fifth Circuit, the Corps revised its regulations to state that in considering a permit application to fill, dredge, discharge, or deposit materials in such a way that navigable waterways are affected, engineers will evaluate all relevant factors, including the effect of the work on fish and wildlife, conservation, pollution, esthetics, ecology, and the public interest. In a report on March 17, 1970, the House Committee on Government Operations recommended that the Corps should consider that conservation will be endangered by every dredge and fill project unless the applicant can prove otherwise.

On July 16, 1970, the District Court's ruling was reversed, and the Corps' denial of the application was upheld. Part of the decision was based on the landowners' acknowledgment that there was sufficient evidence to justify the findings of an administrative agency that the fill operations would do damage to the ecology or marine life on the bottom of the bay, and even though they incorporated design changes to minimize the effect, the U.S. Fish and Wildlife Service still opposed the project. The U.S. Court of Appeals decided that system ecology does, in fact, have an effect on interstate commerce, which would allow the Fish and Wildlife Act of 1958 to be used for assessing projects in navigable waterways. The Court concluded,

When the House Report [*Our Waters and Wetlands: How the Corps of Engineers Can Help Prevent Their Destruction and Pollution*, H. Rept. No. 91-917, 91st. Cong. 2d Sess. (1970)] and the National Environmental Policy Act of 1969 are considered together with the Fish and Wildlife Coordination Act and its interpretations, there is no doubt that the Secretary can refuse on conservation grounds to grant a permit under the Rivers and Harbors Act.

At first glance, the effort of the Court of Appeals to determine a legal basis for allowing the Corps of Engineers discretionary powers seems as though it opens the doors to arbitrary governmental interference with the right of landowners to develop private property. The decision, however, was arrived at by a thorough consideration of the evidence and arguments presented by both sides and included a detailed evaluation of the powers of Congress and inherent responsibilities for protecting wildlife and resources for future generations. Design and construction considerations do not operate in a vacuum, and since no human being possesses perfect knowledge or

understanding, it is wise to integrate findings and solutions from a variety of resources into a search for resolution to multifaceted problems.

9.2.3 A Rational Position

Aside from legally mandated codes and standards previously discussed, licensing boards and codes of conduct published by engineering societies include a combination of requirements and encouragements—mostly encouragements, however, because there can be significant complication with the adoption of environmental design strategies, such as the IgCC (discussed earlier in this chapter), by building departments as mandatory. Stuart Kaplow, an attorney who specializes in environmental law in Cockeysville, Maryland, discusses the difficulties of mandatory environmental building codes, in particular the 2018 edition of the IgCC, on his company's website.¹⁰ He writes, "The 2018 IgCC is ideally suited to be edited and revised for use as a voluntary compliance code promoting sustainability and energy efficiency, for specifications in contract documents, for college and professional school textbooks and curricula, and the like, but it is not ideal for use in a regulatory setting for the compulsory certification of green buildings and construction related materials." He goes on to describe his observations on the current environmental focus in society. "Many believe that a voluntary, non-mandatory approach to environmental sustainability is the best hope for stewardship of our planet ... but even without any significant market penetration of the existing IgCC or other mandatory green laws, the marketplace shift in the U.S. to green building has been dramatic ... green building will soon be the norm and anything else will be substandard."

Licensing agencies and engineering societies often use the same, nonbinding language to describe a general sense of awareness and acceptance (I have added some emphasis within the following citations). The Texas Administrative Code states, “Engineers *should* strive to adequately examine the environmental impact of their actions and projects, including the prudent use and conservation of resources and energy, in order to make informed recommendations and decisions.”¹¹ The *Code of Ethical Conduct* published by Engineering New Zealand tells registrants, “You must, in the course of your engineering activities, *have regard* to reasonably foreseeable effects on the environment from those activities, and *have regard* to the need for sustainable management of the environment.”¹² The ASCE Code of Ethics states, “Engineers *consider* and balance societal, environmental, and economic impacts, along with opportunities for improvement, in their work.” The key sentiment is to *consider* the effects of one’s work on the environment, especially when there may not be a specific mandate applicable to the work.

In [Chap. 2](#), we discussed the measure of minimal competence that a licensed engineer is expected to maintain. In [Chap. 6](#), we discussed how a licensed engineer is expected to continue learning and growing in their career. Part of that growth requires knowledge of engineering-related news and technological developments, especially as it relates to the future of the profession. Sustainability and environmental responsibility are important features that we have adopted as being critical to a long, healthy, and successful future, and society recognizes the importance of civil and structural engineering in achieving numerous development goals. Consulting engineers do not always work on projects that require compliance with environmental sensitivity standards, but there are still steps that can be taken to incorporate sensitivity and positive

action (in other words, *to consider*) with a large range of project types. We will discuss specific strategies later in this chapter but at the moment, there are three different approaches that a civil or structural engineer can take with projects in giving consideration to environmental impacts and communicating that consideration.

The first approach would be more *passive* by nature. An ethical engineer in this group would be aware of current events and trends in sustainable development, be aware of general ways sustainability can be implemented, be aware of mandates or other legal requirements, and be able to evaluate optional sustainability measures when recommended or requested. This basic approach or position does not stem from ignorance or apathy. In fact, it requires an ongoing desire to expand and improve upon knowledge and a continual effort to develop awareness of opportunities.

The second approach to projects would be *slightly proactive*. Engineers would have the same qualities as those in the passive category but would also take particular note of how developing trends could be incorporated into their projects—this takes a more personal and effective route. They would also be keenly aware of specific goals and trends that can be applied to the needs of a region, not just a single project. This would include direct knowledge of available products, their benefits, and their limitations. Open dialogue about such products or procedures would be encouraged, but not necessarily demanded. Slightly proactive engineers can evaluate and promote the use of alternative designs that will better meet sustainability goals, even though they might not be the most economical solutions in the short-term.

A more *proactive* approach to project management requires a deeper and more robust knowledge base that goes beyond the basic news story, project advertisement, or

case study. Engineers in this category actively seek sustainable design features in the majority of their projects and promote this course of action, even if it is not requested. Optional measures of compliance derived from public ordinances or voluntary codes are considered mandatory, and an engineer understands the steps it would take to incorporate these measures into a relevant project and to defend that decision before the owner, architect, building official, or other stakeholder. The proactive engineer also participates in the development or promotion of a region's sustainability goals. To carry the momentum forward, these engineers actively mentor others to have the same philosophy, they obtain relevant certifications, produce educational presentations or papers to inform the profession, and even serve in public office.

Whatever pathway, method, or approach an engineer decides will be appropriate to their needs at that time—and the approach can change with each project or change completely at a future period of time. The issue at hand is to *give due consideration* to these needs and conditions of design, whatever they may be, and not to ignore or relegate such things as unimportant.

9.3 Social Sustainability

There are three primary areas of focus when it comes to sustainability: environmental, economic, and social. In each case, the principle is simply well-being for current and future generations. A healthy environment is necessary for strong development of all life forms, and a vibrant economy is crucial to securing freedoms and lifestyles. Andrea Colantonio, London School of Economics and Political Sciences, and Tim Dixon, Oxford Institute of Sustainable Development, describe the concept of social sustainability: “Concerning how individuals, communities, and societies

live with each other and set out to achieve the objectives of development models which they have chosen for themselves, also taking into account the physical boundaries of their places and planet earth as a whole. At a more operational level, social sustainability stems from actions in key thematic areas, encompassing the social realm of individuals and societies, which ranges from capacity building and skills development to environmental and spatial inequalities.”¹³

Key elements of social sustainability from a business perspective involve recognition of the impact that a corporation or business entity has on individuals and society, and these are identified in [Fig. 9.5](#). These elements emphasize the very human aspect of running a business, where the goal is not simply acquisition of wealth (which can be used for different purposes) but development of a social structure. People spend much of their time at work, where they interact with a select number of individuals frequently (coworkers), a larger group less frequently (repeat clients or customers), and an even larger group on a sporadic basis (less frequent clients, colleagues, customers, or the public). These interactions should be managed in a way that promotes harmony and forwards momentum. Two important qualities to be managed are *equity* and *diversity*. We are not all equal in knowledge and experience, and those in positions of leadership are responsible for training others in order to increase overall competence within the workplace, and thereby within society. Inequities in skills are part of how society develops and how people interact and grow ... to teach and learn from one another, and thereby form strong bonds of unity in purpose.

1. Human rights
2. Fair labor practices
3. Living [working] conditions
4. Health, safety, wellness
5. Diversity and equity
6. Work-life balance
7. Empowerment
8. Community engagement
9. Philanthropy and volunteerism

Figure 9.5 Key elements of social sustainability in business. (Source: ADEC Innovations, *What is Social Sustainability?* <https://www.esg.adec-innovations.com/about-us/faqs/what-is-socialsustainability/>).

9.4 Sustainable and Resilient Development

Sustainability in development of physical structures and systems is partially based on an understanding that natural resources are finite, and we want to make sure there is enough to go around for many generations to come, but it is also based on the idea that human beings must not cause measurable damage to environmental systems and functions. ASCE defines sustainability for civil engineering as “a set of economic, environmental, and social conditions in which all of society has the capacity and opportunity to maintain and improve its quality of life indefinitely without degrading the quantity, quality, or the availability of economic, environmental, and social resources.”¹⁴ Individual elements or smaller systems of a larger civil engineering project can be evaluated and designed with sustainability in mind, but an overall systems perspective must also be applied in order to understand the wider economic, environmental, and social context. Social elements of

sustainability were discussed earlier in this chapter and are also covered throughout this book in different ways.

The Federal Government of the United States has outlined its intent toward sustainable facilities since 2002 through a combination of executive orders, statutes, and official publications and research. Six guiding principles¹⁵ were established to assist agencies in meeting statutory requirements for high-performance sustainable buildings, which include employment of integrated design principles, optimization of energy performance, protection and conservation of water, enhancement of the indoor environment, reduction of the environmental impact of materials, and assessment and consideration of building resilience. Executive Order 13834, issued on May 17, 2018, repeated the intent behind these goals are to increase efficiency, optimize performance, eliminate the unnecessary use of resources, and protect the environment. These principles, as related to the practice of civil and structural engineering, will be discussed later in this chapter.

The term *resilience* is used to describe the capacity to recover quickly from difficulties or disaster. Psychologists have studied resilience in people for a long time. Some factors that contribute to resilience, such as genetics, early life experiences, and luck, cannot be modified and are unpredictable. Other factors that contribute to favorable resilience include healthy habits, healthy relationships, an ability to accept a mixture of wins and losses in life, and an ability to live with and learn from mistakes.¹⁶ The more resilient a person is to negative events in her life, the better suited she is to handle future events and to experience a deeper joy of life.

In physical terms, resilience is important in structures, services, and the well-being of those who use these physical elements in relation to the systems that have been disrupted. The term *community resilience* describes the

social, cultural, economic, and human needs of any region, large or small, along with the built environment. It involves an ability to prepare for and adapt to changing conditions and to withstand and recover rapidly from disruptions, which can include terrorist attacks, accidents, or natural disasters.¹⁷ Natural hazards can include earthquakes, floods, hurricanes, tornadoes, wildfires, and more.

To protect the public, buildings should not collapse or scatter debris that makes it impossible for people to escape in case of emergency, and routes of travel should be reasonably preserved to allow for movement of emergency vehicles, supply chains, or a means of evacuation. Lifelines and services should be protected against interruption or pollution, residents should not be displaced in unmanageable numbers, and places of business should be somewhat functional to keep the economy running. This is called *interdependency*, which identifies the multiple-level reliance between systems that is required for each to be functional or provide services. Even without the unfortunate event of a disruptive disaster, these systems are limited in function due to age, complexity, and sometimes a lack of adequate planning. It is described well by Charlie Edwards in his publication, *Resilient Nation*:¹⁸

“We live in a brittle society. Our just-in-time lifestyles provide most of us with a seemingly infinite number of goods and services. This is made possible by greater social and economic interdependencies and mass communication. Over 80% of Britons live in urban areas relying on dense networks of public and private sector organizations to provide them with food, water, electricity, communications, and transport. For much of the time this lifestyle poses us few challenges, but it relies on an infrastructure that is outmoded and

archaic, and which increasingly lacks the capacity to support our complicated lives.”

Sustainability and resilience require planning, partially to address the current needs of society based on the age, quality, and distribution of structures and services, but also to address the needs of future generations. Parents help their children to succeed on their own by training and by giving them tools to assist in their growth and development, but they also participate by doing their part in making sure their kids have a world in which to grow and develop. Parents vote for politicians who they believe will benefit the growth of their region (or country) in a positive way, not only for their own sustenance, but that of their children as well. Parents participate on committees to help enhance their children’s educational network, they encourage healthy associations with other groups, and they do their best to contribute in other ways to protect the needs of future generations. In fact, it is not only parents but members of any community contribute to healthy, long-term development by going to work, obeying laws, helping others who are less fortunate, and by supporting good, positive relationships with other members of their community.

9.4.1 The UN Sustainable Development Goals

Sustainability is usually measured by a series of goals, whether mandated by local planning or building jurisdictions or recommended by organizations with a variety of different agendas. The United Nations (UN), for example, published a set of 17 sustainable development goals that were adopted by all member states in 2015 as part of the 2030 Agenda for Sustainable Development

(www.un.org/sustainabledevelopment/). Realizing that time is short, the Secretary General and other organizers have called upon world leaders to redouble their efforts and attention to achieving these goals, including efforts related to inspiration of local action and innovation, strengthening data systems and institutions, rebalancing the relationship between people and nature, and unlocking more financing that can be directed toward sustainable development.

These goals can be placed into four categories, the *first* of which is related to basic human needs and include the elimination of poverty (Goal 1), the elimination of hunger (Goal 2), eradicating disease and conquering persistent health issues (Goal 3), increased access to education and school enrollment (Goal 4), and provision of clean water and reliable sanitation (Goal 6). A *second* category of goals are related to basic human rights, including gender equality (Goal 5), reducing general inequalities related to income, social status, and perceived differences with regard to religion or culture (Goal 10), improving the administration of justice and protection of peace and freedom (Goal 16), and promotion of inclusive partnerships that will work together in moving closer to achieving sustainability goals (Goal 17).

A *third* category of goals is related to the environment. These include addressing climate change (Goal 13), effective management of marine biodiversity (Goal 14), and effective management of land-based biodiversity (Goal 15). The *fourth* grouping of goals is related to the benefit of human livelihood for generations to come, and includes clean, sustainable energy (Goal 7), strong economic growth and availability of jobs (Goal 8), reliable infrastructure with innovative industry (Goal 9), resilient cities and communities (Goal 11), and responsible consumption and disposal of resources or waste (Goal 12).

9.4.1.1 Basic Human Needs (Goals 1-4 and 6)

The survival of a population relies on a functioning infrastructure that can deliver clean water, remove waste, and connect people to one another. At the very least, there must be a provision for safe travel between regions within and beyond a community, a means of collecting and sanitizing a basic supply of water for different purposes, garbage and human waste collection and disposal, food growth or production and distribution regions, energy production and delivery, and means of communication. These elements provide for sustained living and must be operational for the longterm, which means reliability and cost-effectiveness will be important qualities to consider in the engineering of this infrastructure.

Other basic human needs include available and affordable housing, a healthy economic structure that produces sustainable employment and allows for a reasonable profit for goods and services, emergency facilities, and public safety. Civil engineering plays a crucial role in developing innovative and economic solutions to bring these basic systems to societies that are stricken with poverty, but it takes a lot of coordination with governments and other organizations formed for the purpose of addressing the needs of the public. Employment opportunities in engineering fields can boost a region's economy and provide local knowledge and experience to the development of solutions, which is one of the quickest ways to achievement of these goals. Partnerships need to be formed between engineering organizations around the world to provide for greater mobility of resources and professionals, and some of this can be accomplished through government grants and public donations. Universities need to have an established presence close to (or within) poverty-stricken

regions with effective liaisons, facilities, and funding to attract and train new students to prepare for an engineering education. Professional engineers need to be aware of the problem and do what they can to help with design, brainstorming solutions, advancing awareness of the value of the profession in addressing these issues, and offer their services and resources toward improving the conditions of infrastructure and education, close to home and around the world.

There are a number of engineering organizations that focus on delivery of resources and practical assistance to communities that are suffering from a lack of basic needs and the infrastructure that would support those needs. Engineers Against Poverty was established in 1998 by the Royal Academy of Engineering in London, United Kingdom and currently specializes in enhancing the systems used to deliver infrastructure for the purposes of improving life, reducing poverty, and mitigating the impact of climate change. Another charitable organization is Engineering for Change, which was founded in 2009 by the American Society of Mechanical Engineers and the Institute of Electrical and Electronics Engineers. Their mission is to prepare, educate, and activate the international engineering workforce to improve the quality of life of underserved communities around the world.

Engineers Without Borders International (EWB-I) is an association that serves as a unified platform for independent and autonomous member organizations that are based in more than 60 countries with a single vision of a world in which every community has the capacity to sustainably meet their basic human needs. The early EWB-USA organization, for example, designed and installed the first clean water system to the Mayan Indians in the heart of a jungle in San Pablo, Belize, that was supplied and powered by a nearby waterfall. At that time in mid-2000, the work

was done by Dr. Bernard Amadei, professor of civil engineering at the University of Colorado, Boulder, and fourteen of his students ... not yet known as EWB-USA, which was officially founded by Dr. Amadei in 2002.

In fact, there is an entire field of study known as *Humanitarian Engineering* with degrees offered by well-known universities and colleges, such as Purdue University (West Lafayette, Indiana), Colorado School of Mines (Golden, Colorado), University of Warwick (Coventry, United Kingdom), and Penn State University (University Park, Pennsylvania). These programs focus attention on environmental engineering, geological engineering or geophysics, civil infrastructure engineering, and the social sciences to prepare students to apply knowledge and training in promotion of more sustainable and equitable uses of water, energy, and other resources as well as to mitigate potential hazards.

9.4.1.2 Basic Human Rights (Goals 5, 10, 16, and 17)

Most ethical codes published by engineering societies include numerous principles related to human equality and opportunity. There is close to universal recognition that inclusion of all types of persons is necessary for the sustainability of the engineering profession. The code of ethics published by ASCE states this principle nicely: “Treat all persons with respect, dignity, and fairness in a manner that fosters equitable participation without regard to personal identity.”¹⁹ The promotion of equitable treatment is also described by Engineers Canada: “Registrants should treat all people equitably and with dignity. Registrants must also respect evolving human rights legislation and the prohibited grounds of discrimination such as race, national or ethnic origin, color, religion, age, sex, sexual orientation,

gender identification, marital status, family status, disability, and conviction for an offense for which a pardon has been granted or in respect of which a record suspension has been ordered or any other grounds.”²⁰

The reduction of human inequalities around the world is an ongoing and laborious process, usually yielding results at a slower pace than other areas in part due to the difficulty in securing agreement among the nations. Perceptions of inequality are deeply rooted in history, cultural development, and religion to a point where the unfair treatment of another becomes part of one’s character. This is difficult to change. Inequality can be found in the form of socioeconomic status, distribution of physical resources, employment or opportunity on the basis of gender or gender preference, mobility offered to persons with disabilities, quality of treatment of others due to race or national origin, and positions of power and influence. One of the most influential goals to address global inequality is to ensure that developing countries are better represented in decision making on global issues so that solutions can be more effective and accountable. Richer countries should be able to understand this need, as they, too, include sectors where inequality prevents citizens from experiencing the benefits of economic growth and personal fulfillment.

At the sustainability summit, Achim Steiner, Administrator of the UN Development Program, stressed to participants, “To realize the promise of the 2030 Agenda—and its core pledge to leave no one behind—it is essential that all peoples, particularly those facing discrimination and exclusion, have access and voice and can participate equally in every aspect of life.” He explained that the UN was taking extra steps to better address disabilities in all settings to ensure that persons with disabilities are given equal access and voice in society, so they can realize their fullest possible potential. Children with disabilities not only

have to struggle with psychological discrimination, but the added hindrance of inadequate physical access to the same educational facilities as others. Disabled girls have a double disadvantage, as do those living through conditions of conflict or disaster, as resources are often siphoned off to address different needs. These are basic human rights that need to be addressed in order to assure delivery and provision of basic human needs. Some organizations assisting with the effort to address human rights include (by no means an exhaustive or preferential list):

1. The Global Partnership for Assistive Technology was launched in 2018 with a goal of reaching 500 million disabled individuals around the world with life-changing technology, including wheelchairs, eyeglasses, hearing aids, and even prostheses.
2. Plan International is a humanitarian organization reaching 75 countries around the world that advances children's rights and equality for girls. Founded in 1937, the group advocates that every girl and boy have the right to be healthy, educated, protected, valued, and respected in their own communities and beyond.
3. In July 2013, the Office of the United Nations High Commissioner for Human Rights launched the UN Free & Equal campaign aimed at promoting equal rights and fair treatment of lesbian, gay, bisexual, transgender, and intersex people everywhere. Activities include promotion of safe and loving home environments for children, fostering visibility by activities and celebrations, and dissemination of multimedia materials.
4. The International Fund for Agricultural Development, established in 1978, is a financial institution and

specialized UN agency that provides financial assistance through grants and low-interest loans for agriculture in rural areas of developing countries. Their work not only addresses worldwide hunger, but also has an effect on poverty and some equalization of opportunities for those who lack resources. The organization helps rural farmers expand their business, build resilience, and take charge of their own development.

9.4.1.3 The Environment (Goals 13-15)

Goals representing the environment are divided into three areas: conditions in the air (climate change), life on land, and life below water. The issue of addressing climate change is primarily defined in the Paris Agreement, an international treaty on climate change with 196 participating nations that entered into force on November 4, 2016. The primary goal of the treaty is to limit future global warming of the planet to no more than 1.5 degrees Celsius compared to preindustrial levels. Member countries commit to taking action for reducing greenhouse gas emissions and building resilience to adapt to the impacts of rising temperatures in the future. Zero-carbon solutions are already proving to be economically competitive, most notably in the energy and transportation sectors. Civil and structural engineering solutions being explored and implemented to address climate change will be discussed later in this chapter.

Ocean conservation, for example, is ultimately human conservation. In early science classes, we learn that our rainwater, drinking water, weather, climate, coastlines, much of our food, and even the oxygen we breathe are ultimately provided and regulated by the oceans (see [Fig.](#)

9.6). There are five recognized ocean basins—the Atlantic, Pacific, Indian, Arctic, and Southern (Antarctic)—which cover 71% of the Earth and produce 50% to 80% of available oxygen, mostly through plankton, drifting plants, algae, and some bacteria.²¹ Carbon is continually exchanged between the ocean's surface waters and the atmosphere, and is also stored for long periods of time in the ocean depths. Sea grasses, mangroves, marshes, and other systems along the world's coasts absorb and store carbon at a much faster rate than other places, like forests, and when disrupted by human (or other) activity, emit large amounts of carbon back into the atmosphere, contributing to climate change. Land development involving waterways, seas, and oceans requires careful attention and responsible modeling to determine potential long-term effects and provide data to judge alternatives.



Figure 9.6 The Earth's surface is covered by oceans, which produce 50-80% of our oxygen and exchange carbon with the atmosphere. (Source: National Oceanic and Atmospheric Administration.)

9.4.1.4 Benefit of Future Human Livelihood (Goals 7-9, 11, and 12)

Construction and sustenance of infrastructure, industry, cities, and communities represent the bread and butter of civil and structural engineering practice. As the world's population increases, more urbanization takes place and a larger strain is put on freshwater supplies, control of sewage, air quality, availability of shelter, energy consumption, and public health. The term *human settlement* was first used at the United Nations conference in Vancouver, British Columbia, Canada in 1976 to describe the union and organization of physical elements, social services, and infrastructure.²² Physical shelters are built for privacy, security, and protection against the weather, and are formed using locally available building materials and assembled by community labor forces. These structures should be arranged in a way that makes the most efficient use of available land and keeps them close to needed services or supplies.

Social services within human settlements include provisions for education, business, health and welfare, leisure and recreation, green spaces, and government. The proper function and sustainability of these services require physical structures, land use planning and organization, energy, and a vibrant economic structure. Management of resources and services does not only rest with government or business, but it is also the responsibility of all inhabitants to respect the presence and needs of others and to contribute for mutual benefit. Engineers play an important

role in the long-term development of structures and spaces necessary to support life within the community.

Sustainable and maintainable infrastructure is key to the function of any settlement. It is the complex network that moves people, products, and energy, as well as facilitating communication and connectivity to people within and outside the community. All of these features require collective management, not just a random scattering of structures and services. Strategic, multistakeholder partnerships can be instrumental to the sustainability of human settlements in developing countries, as well as impoverished regions in more economically stable countries. These partnerships would share knowledge, expertise, technology, and financial resources and build on existing initiatives to develop measurements of progress for targeted, long-term growth and self-sufficiency. As human settlements grow beyond basic sustenance, they should be welcomed as part of the growing global economy and provided with resources, personal and physical, to help them maintain a permanent place.

9.4.2 Promotion and Support

Sustainable and resilient requirements that are legally mandated for a project need to be clearly understood by all affected participants. However, there may be additional goals that an owner, developer, community advocacy group, or local governmental agency would like to have considered, and may even offer incentives for implementing solutions toward achieving some of these goals. These should be identified and discussed during a project's design team kick-off meeting, if not sooner. Environmental, economic, and social goals may include a number of stakeholders who can contribute to a better understanding of intent and best practices toward achieving success. Support for project

managers responsible for overseeing the implementation of sustainable and resilient strategies is critical, as many of these approaches deviate from conventional practices and may be eclipsed by other project needs, such as schedule and cost.

Governmental strategies to promote and support sustainability and resilience in a community, as proposed by Charlie Edwards in his book *Resilient Nation*, require engagement, education, empowerment, and encouragement.²³ Rather than issue impersonal communication, authorities, officers, and public health ministers need to engage with people by listening to individual and community concerns and focus on helping to shape or influence appropriate decisions. Preparedness meetings should be encouraged, involving councils, clubs, societies, emergency planning officers, with the help of social media as may apply. The most effective type of education is that which is subtly embedded in the daily lives of community members, reflecting the context and demographics of each location.

Empowerment makes use of natural abilities and talents of residents to strengthen and repair the region in which they live. They must be given the tools and training needed to assist governmental agencies, and others they are familiar with in daily life, as part of the unity needed for a happy and healthy society. As people are empowered to help, they feel less vulnerable and alone when a disaster strikes, which adds to the overall strength and resilience of the people themselves and contributes to the quicker assessment and repair of damaged infrastructure, buildings, or services. Empowerment goes together with encouragement. Governmental agencies that are responsible for functions within a community need to trust inhabitants and express this through encouraging and

instructive communication, explaining expectations and benefits of helping one another.

The National Institute of Standards and Technology introduced six steps, taking a high-level perspective, that need to be followed in planning for a more resilient community.²⁴ The first step involves the formation of a collaborative planning team of relevant stakeholders and those who are instrumental in defining and achieving goals. Secondly, before any work can begin, the situation within the community needs to be understood through an analysis of social functions and dependencies and identifying clusters and key components of the built environment. The third step includes development of long-term community and infrastructure performance goals, where hazards are also identified and considered.

The fourth step includes development of specific plans to identify solutions and measures for meeting goals and present strategies for implementation. After this, plans need to go through a proper circuit of review and approval by public committees, members and societies of the community, emergency response agencies, and permitting departments. The final phase, of course, is implementation. A successful program will include continual evaluation and modification as needed, whether conditions change or not. Strategies should be flexible enough to allow for adjustments and should be specific enough to allow for reasonable discussion and debate. Long-term goals should not be subject to change when political administrations change, but this is difficult to control.

9.5 Civil Engineering Solutions

On April 30, 2021, the ASCE Board of Direction adopted Policy Statement 418, *The Role of the Civil Engineer in Sustainable Development* (quoted earlier in this chapter),

identifying the importance of maintaining and improving the quality of life indefinitely without degrading the quantity, quality, or the availability of economic, environmental, and social resources. The policy presents two simple principles of development: do the right project and do the project right. A project's effect on a community must be understood by all stakeholders before any formal design is made. Once all are committed, sustainability goals must be addressed holistically, from start to finish, rather than sticking sustainable features into the project here and there. Communication and accessible, transparent discussion and decision making are critical to success.

The policy statement reminds us that civil engineers have a leading role in design, planning, documenting, advocating, and managing the construction of infrastructure that is critical to a healthy, functional society. Complex problems require a multitude of viewpoints and specialties to envision potential solution alternatives. Civil engineers need to work with ecologists, biologists, economists, sociologists, and elected officials and oftentimes need to represent a number of disciplines within civil engineering, such as urban planning (which includes strong elements of architecture), structural engineering, environmental engineering, surveying, construction managing, geotechnical fields, transportation, and more.

During the process of setting sustainability goals, the civil engineer will need to understand and present tools that can be integrated into the whole project as a pathway toward achieving those goals. Life cycle assessment may also be performed as part of a civil engineer's scope of work or it may be completed by a different member of the design team, and it will include consideration of the long-term environmental effects of construction materials, including extraction and processing of raw materials, manufacture and transportation of the final product, any effects that

product will create during its use (occupying formerly green spaces, diverting storm water, etc.), and ultimate recycling or disposal. These assessments require research and iterative review over the course of the project and software programs are an important part of categorizing, storing, and presenting data to assist in making suitable choices.

9.5.1 Green Highway and Hardscape Construction Materials

The building and use of roads produce the highest level of greenhouse gases in the world, through energy produced by fossil fuels for mining, transportation, and paving works and through vehicle emissions. Quite simply, a green highway system is one in which the impact on the environment is minimized by an optimal combination of strategies and solutions, ranging from mineral extraction to ongoing maintenance and eventual replacement. Some of these strategies include more responsible production of asphalt; using recycled and renewable materials; minimizing the amount of pollutants from vehicles used during manufacture, transportation, and construction; new technologies for lighting and signage.

One of the technologies used in European countries (only to a minimal extent in the United States) is the production of warm mix asphalt (WMA), which reduces temperatures used in production and resulting carbon emissions. Innovative additives cause the reduction in viscosity of the asphalt binder at these lower temperatures, allowing aggregate to be fully coated as required for performance. Sustainable aggregate production includes the reduction of acquisition and processing of virgin material and its transportation, which can be achieved through the use of recycled aggregate, specification of more durable local materials, reducing the use of water and energy during mining and

processing stages, and maximizing the use of rail or marine vehicles for material transportation. A special type of asphalt using recycled rubber tires in the mix design will be discussed later in this chapter. Innovations in the production, design, and use of concrete will also be discussed later in this chapter.

Pervious concrete (see [Fig. 9.7](#)) is an excellent example of an innovative way to meet the needs of hardscape infrastructure while respecting natural routes of drainage. It is a type of concrete with a high porosity that allows water from precipitation and other sources to filter directly through, thereby reducing runoff, filtering pollutants, recharging the natural groundwater supply, and reducing the amount of urban flooding. Some of the benefits of this paving system is the reduction or elimination of stormwater retention ponds and swales, which can reduce the cost of construction. Since pervious concrete mixes contain very little fine aggregate, the resulting product typically contains between 15% and 35% of interconnected voids that allows water to pass through at rates between 3 and 5 gallons per minute per square foot of surface area. Quality assurance and acceptance criteria are found primarily in ASTM C-1688, *Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete* and ACI 522.1, *Specification for Pervious Concrete Pavement*. Since the strength of pervious concrete is limited, it is generally specified for a different set of performance goals.



Figure 9.7 A sample of pervious concrete.

9.5.2 Sustainable and Resilient Urban Drainage Systems

Resilience and reliability would be categorized as operational goals, while sustainability can be classified as a strategic goal of civil engineering systems. In the context of urban wastewater or stormwater systems, emerging

technologies are providing solutions, but the amount of historic performance data is lacking. Long-term functionality may still be questionable, especially when needs change over time, but the problems that are addressed have a consensus of approval and understanding that approaches used to achieve goals are still effective, and the probability of good, long-term performance is high. Best management practices require drainage designs to cope with the full spectrum of flood flows, mitigate issues such as pollution and runoff, and balance the watershed characteristics that will be changed as a result of development.

Historical stormwater detention areas are designed and situated to control flooding and reduce runoff, and innovative improvements have included geomembrane filtering fabrics to remove solids and control the amount and toxicity of pollutants that may be present. Another solution to urban drainage is the installation of on-site stormwater capture, retention, and local distribution, usually for purposes of irrigation, erosion, and flooding control. These are incorporated as sustainable elements for traditional *gray infrastructure* that also includes storm drains, paving, and piping. These underground detention systems control the volume and discharge of runoff in a way that complements changes made to the landscape, and they allow for continued use of the site above for buildings, roadways, paved and green spaces.

The layout of paving and landscaped areas is decided upon by numerous members of the design team, in coordination with the owners, developers, and local ordinances, but the civil engineer can provide valuable input and support for a sustainable direction. *Green infrastructure* is a term used to identify natural water management elements and systems, including plantings, vegetated rooftops, and absorbent gardens that can capture, filter, and divert stormwater. The amount of runoff is reduced, and it

controls the level of pollutants that may be present in direct rainwater or surface flows. These green spaces are also instrumental in providing a livable atmosphere within densely urban areas, as they advance social sustainability through a sense of community and common ground. Urban stormwater runoff is one of the main reasons that lakes or coastal waters oftentimes fail to meet national water quality standards, and green infrastructure is a powerful means of control.

Parking lots can create a special challenge, especially when they occupy (or are close to) sensitive areas of vegetation or wildlife. They change how the land originally moved stormwater around the area and pollutants were minimized compared to that produced by new occupants. In 2018, the ASCE Foundation began working on a sustainable solution for a large parking lot at the ASCE headquarters in Reston, Virginia that was badly in need of repairs.²⁵ The final design included permeable pavement, stormwater filtration systems, and other means of keeping more than half of the site's potentially contaminated stormwater runoff out of the nearby watershed. This important function is accomplished by a biofilter which captures and treats stormwater that enters through precast porous concrete panels and soils above (see [Fig. 9.8](#)).



Figure 9.8 Courtyard area in the parking lot at ASCE headquarters in Reston, Virginia, with precast porous concrete panels and a biofilter for storm water treatment. (Courtesy ASCE Foundation.)

A bundle of parking spaces near the front of the building was rebuilt with permeable interlocking concrete pavement sections, which cause flowing water to drop to a reservoir base made of stone. This base can store and infiltrate flows from a 100-year storm event, which is a common sustainability model target. Vertical check dams detain and infiltrate stored water rather than allowing it to run downhill on the subgrade. The remainder of the parking lot (almost 105,000 square feet) was repaved with an asphalt product made with roughly 722 recycled tires. The tires are used in an additive known as “engineered crumb rubber,” making up 11 pounds for each ton of asphalt, which not only diverts waste from landfills, but helps to stiffen the mix and reduce the potential for rut and crack formation by making it more strain-tolerant. Because it requires less material and

maintenance, the life cycle cost is generally cheaper than hot-mix asphalt roads.

9.5.3 Optimization and Resilience of Transportation Systems

Long-term strategies for sustainable transportation include reviews of the demand for vehicles, the consumption and production of fuel, needs for low-income individuals and families, infrastructure master planning, prediction of emissions, and changing needs of society. Resilience also plays an important part of securing a community's economic vibrance and the consistent flow of goods, services, and interaction. It must be viewed not only with regard to physical systems, but also according to human needs for efficiency and safety. Those needs will be known by policy decisions and through observation of behavior patterns. Civil design, therefore, will be dictated by a variety of agencies and committees.

One form of optimization that is receiving a great deal of attention is the concept of a New Mobility HUB, intended to address transportation issues from start to finish, where users of a transit route may experience a lack of options or costs related to inconvenient availabilities or layouts over the course of a trip. These networks connect a variety of sustainable transportation options and services through physical locations (mobile points) throughout a region that are linked electronically and physically to develop door-to-door sustainability, as much as can be practically attained. A feasibility report was prepared for a network of hubs in Toronto, Ontario, Canada in 2006, and the first small-scale transportation HUB was launched in April of that same year. Ontario's Metrolinx has developed a 25-year transportation plan that includes development of 51 Mobility HUBS located throughout the Greater Toronto and Hamilton areas to

include the integration of rapid and local transit, specialized transit, cycling and accessible pedestrian networks.

An interdisciplinary organization that actively studies and promotes urban transportation resilience is Sustainable Mobility and Accessibility Research and Transformation (SMART) at the University of Michigan. The initiative started by a group of individuals to address the challenge of sustainable mobility with a goal of ensuring that future generations have access to adequate mobility resources to meet their needs while maintaining the health, integrity, and resilience of supporting environmental and social systems.²⁶ SMART collaborates research and promotion of systems, approaches, and frameworks that serve to support accessibility, livable cities, environmental sustainability, and social equity. The group currently focuses on five main areas: systems integration, accessibility, innovative solutions and industries, the sociocultural context of urban transportation, and forming lasting multidisciplinary partnerships.

9.5.4 Principles of Climate Change Adaptation

Over the past 50 years, scientists have observed a rise in the temperature around the globe, increased frequency and duration of extreme weather events, a rise in the level of the sea on much of the coast of the United States, and a noticeable disappearance of sea ice.²⁷ There is close to universal agreement that *something* must be done to both mitigate and counter the effects of climate change, and equal agreement that any solutions cannot be worse than the actual problem. The world still requires a functioning financial system, basic human needs, opportunities, and essential liberties. Questions that need to be explored include “What short-term actions can be taken to make a

meaningful difference?,” “What long-term strategies can be reasonably pursued, given our current technological and social structure?,” “What technological advances need to take place in order to pursue more aggressive and effective long-term strategies?,” and “What impediments are there (social, economic, practical, technological, ethical, political) that need to be addressed in order to effectively respond to the problem?”

Strategies that come from civil engineering will be based mostly on a more refined focus on land development and protection of infrastructure. In response to anticipated sea level rise, for example, future public works projects should take projections into account for flood protection and existing facilities may require additional flood-proofing or enhancements in the site drainage design. Changes in weather patterns, such as increased precipitation, will require updated pollution prevention plans for construction sites and improvements in stormwater management systems, such as drainage of land and collection or storage system capacities.

9.5.5 Engineering with Nature

In October 2020, the U.S. Army Corps of Engineers entered into a partnership with the University of Georgia to establish the Network for Engineering with Nature with the goal of accelerating the delivery of nature-based solutions and natural infrastructure in the public and private sectors. The Engineering with Nature initiative was begun in 2010 as a way to highlight good examples of practice from earlier projects and to advance future capabilities to integrate nature’s value into engineering projects. It primarily deals with water resources that include waterway transportation, flood risk management, ecosystem restoration, coastline preservation and maintenance, and others. A civil

engineering approach is crucial, involving knowledge of hydrology, water supply and treatment systems, environmental and geological management, management of waste and runoff, and responsible use and implementation of building products and construction methods. Following are some of the relevant projects highlighted by the program.²⁸

1. *Dangote Sandbar Breakwater in Lekki, Lagos State, Nigeria (2018)*. Due to continual erosion and loss of natural habitat along this coastal region, and recognition that a conventional rubble-mound breakwater solution would only be marginally effective, engineers developed a sandbar breakwater system concept using mostly natural sands and maintaining the natural aesthetics, habitats, and function of the harbor. The project team used state-of-the-art mathematical modeling tools to determine the optimal placement, angle, and sand volume to assure dynamic stability. The use of offshore sand eliminated the need for rocks or concrete, which substantially reduced construction time and cost.
2. *Pierce Marsh in Hitchcock, Texas, United States (2016)*. Subsidence, freshwater intrusion, and erosion led to habitat degradation of coastal prairie into intertidal marsh or open water (see [Fig. 9.9](#)). This project used 150,000 cubic meters of unconsolidated fine material (silts and soft clays) from routine maintenance dredging, a plentiful resource, to reduce erosion and raise the marsh to its target elevation. Sediment was contained in target areas by engineered berms and grade control markers and previously restored sections of the marsh were properly avoided. Collaboration on the project was extensive, including partners such as the National Oceanic and

Atmospheric Administration, the Department of the Interior, the Natural Resources Conservation Service, the Texas Commission on Environmental Quality, Ducks Unlimited, and the Galveston Bay Foundation.



Figure 9.9 A small levee constructed in Pierce Marsh in Hitchcock, Texas. (Photo by National Oceanic and Atmospheric Administration.)

3. *Marker Wadden in Lake Marken, Flevoland, the Netherlands (2018)*. Conditions of the lake became very poor for support of a natural ecology when transformation projects were abandoned in the 1990s. An innovative engineering approach using the same fine sediments that caused the problems in the first place included the creation of small islands as

mudflats, marshland vegetation, creeks, and shallow isolated pools. These form gradual transitions from land to water that trap sediment and trigger biochemical processes, stimulating both nitrification and denitrification. Many opportunities and pathways for visiting the new islands were provided, and wildlife began returning to the site as soon as construction started.

4. *Jackson Park in Chicago, Illinois, United States (2019)*. The landscape that holds the park was originally designed in 1890 as home to the 1893 World's Columbian Exposition. In recent times, the park suffered from invasive species, impaired geomorphology, and a lack of native species richness. Fifteen restorative measures were implemented, including the expansion of open spaces, invasive tree removals, creation of a submerged wetland shelf, fringe marshes, curvilinear walking paths, and more. New elements were introduced to mirror the patterns of the original designer in order to maintain the original historical significance of the area.

Additional Resources

1. U.S. Army Corps of Engineers, *Civil Works Sustainable Infrastructure Practices Guidebook* (Washington, DC: USACE, December 1, 2019).
2. Gro Harlem Brundtland, *Our Common Future—Report of the World Commission on Environment and Development* (New York: United Nations, March 20, 1987).
3. Robby Caspeelee, Luc Taerwe, and Dan M. Frangopol, eds. "Life Cycle Analysis and Assessment in Civil Engineering: Towards an Integrated Vision," *Proceedings of the Sixth International Symposium on Life-Cycle Civil Engineering* (Boca Raton, FL: CRC Press, 2019).

9.6 Structural Engineering Solutions

Once the urban planning and architecture teams, owners, the public, and community officials have settled on the form and function of a building or facility, the structural engineer needs to *continue* assessing and discussing sustainable features and how they can help the overall project achieve sustainability goals. A life cycle assessment can be produced to help make decisions on materials and other strategies using the principles of ASTM E-2921, *Standard Practice of Minimum Criteria for Comparing Whole Building Life Cycle Cost Assessments for Use with Building Codes and Rating Systems*. Oftentimes, the structural engineer is not included in meetings where sustainability goals are discussed and decided, and this is unfortunate. This lack of representation may be attributed to numerous factors, including a general ignorance of how sustainability can be greatly enhanced through manipulation of materials and a more responsible use of existing facilities and systems.

9.6.1 Construction Materials

When structural engineers design building systems, a material is usually selected based on requirements for aesthetics, open space, fire resistance, durability, resilience, economics, local labor forces, availability, and even personal preference. It is not just a matter of comparing the engineering properties of physical materials (wood, steel, masonry, concrete, composites, etc.) or judging the merits of a sustainable project solely through the advantages or disadvantages of materials alone. A building system includes structural materials, finishes, connections, and other components that may influence choice as well. The right product must be chosen under the right circumstances and in the right context.

9.6.1.1 Concrete and Masonry

Concrete mix designs present a multitude of avenues toward better sustainability, as the formula includes aggregates, water, additives, cementitious materials, and reinforcement, all of which can be optimized and even partially replaced with recycled constituents. Furthermore, the thermal mass of concrete structures can be used advantageously as insulation and other energy conservation applications. In fact, buildings constructed of concrete use less energy for heating and cooling when compared with those constructed of lighter materials.²⁹ Passive solar applications of concrete include a purging of heat during the night to cool a building, and a sponge-type function during the day to absorb daytime heat energy to control peak heating and cooling energy consumption. Exposed indoor concrete surfaces can be modified as a reflective surface to economically control the amount and use of light fixtures.

Emissions in the production of cement and waste can be controlled by replacement with a percentage of alternative materials, such as fly ash, mineral ultrafines, blast furnace slag, silica fume, and rice husk ash. These complementary cementing materials are industrial byproducts, which means they are already carbon-neutral and would otherwise be disposed of into a landfill. An average of 0.9 ton of carbon dioxide is emitted for every 1.0 ton of cement produced, which mainly arises from two sources: decomposition of limestone, and from the thermal energy required to produce clinker. Technology is continuing to be improved in the field of managed mineralization, where carbon dioxide gas can be captured, utilized, and permanently stored or dissolved in geological reservoirs and in concrete that is used for civil and structural construction. Additional innovations in concrete placement are making strides toward sustainability in lower carbon emissions, such as 3D printed technology (see [Fig. 9.10](#)).



Figure 9.10 A 3D concrete printed residential building in Beckum, North Rhine-Westphalia, Germany. (Image by PERI GMBH.)

Sustainability issues with masonry are similar to those associated with concrete, including the use of recycled and complementary cementing materials. The predominant types of masonry used in construction today are concrete units, clay bricks, and aerated autoclaved concrete. Depending on availability of local materials, adobe, rammed earth, straw, bamboo, stone, and others have also been used in a similar fashion to traditional masonry construction. Masonry is particularly suited for work in smaller urban areas, as operations do not require a large area for staging and installation. Brick is often reused for other construction projects, and demolished concrete masonry units can be recycled for use as aggregate for road bases, pipe bedding, or construction fill.

9.6.1.2 Timber

Wood is a natural, renewable, and sustainable material that competes well with steel and concrete in reducing the overall carbon footprint. Modern forestry standards, especially those in North America, have been created to allow for a sustainable cycle of growing, harvesting, and replanting with a strong economic incentive to continue. The Forest Stewardship Council (FSC), a nonprofit independent organization based in Bonn Germany, was created in 1992 by a group of businesses, environmentalists, and community leaders to create voluntary, market-based standards that would improve forest practices around the world.³⁰ They offer certification to identify responsibly managed forests based on a set of 10 principles³¹:

1. Forest management shall respect all laws and treaties of the hosting country.
2. Long-term tenure rights shall be clearly defined.
3. Legal and customary rights of indigenous peoples shall be respected.
4. Long-term social and economic well-being of workers and local communities shall be maintained or enhanced.
5. Encourage the efficient use of forestry products and services to ensure economic viability.
6. Conserve biological diversity, ecological functions, and integrity of the forest.
7. A written management plan shall be implemented and kept up to date.
8. Monitoring shall be conducted periodically to assess the condition, yields, custody, and social and environmental impact of the forest.

9. Special maintenance procedures shall be used to sustain *high conservation value* forests.
10. Plantations shall be appropriately planned and managed.

Timber material is optimized by recycling waste products and reusing products of demolition. For many years, larger pieces of wood have been created by a combination of smaller pieces and high-strength adhesives with new technologies to reduce the initial expense. Mass timber (see [Fig. 9.11](#)) has also been introduced in recent times as a long-term durable material that locks away the carbon dioxide absorbed during the growing process and takes advantage of larger, engineered sections to optimize material use. This innovation is not just a single product or technology, rather, it is an efficient assembly of (primarily) engineered wood products that have been extracted, produced, and transported according to principles of sustainability. Structural systems include post-and-beam arrangements and panelized construction using large wood panels for the roof, floors, and walls.



Figure 9.11 An example of mass timber construction.
(Source: U.S. Department of Agriculture.)

9.6.1.3 Steel

Perhaps one of the primary ecological benefits of steel is recyclability. In the United States, for example, steel produced and fabricated for structural systems contains an average recycled content of 93% from scrapped

automobiles, appliances, and construction waste.³² Existing steel shapes are also reclaimed from decommissioned buildings for a variety of purposes, including the creation of industrial lightweight structures, such as pipe racks, and nonbuilding applications like shoring and scaffolding. Steel is a combination of metals and nonmetals, which can be continuously recycled without damage or degradation to its physical properties, lending to the longevity of use and significant reduction of unused waste material.

Attention is also being given to the production of steel, which is known to generate about 7% of global carbon dioxide emissions. *Green steel* is made using hydrogen rather than coal or natural gas and includes sustainable technologies through different stages. For example, a portion of the carbon monoxide used to strip oxygen from iron ore in a blast furnace can be replaced with hydrogen that was produced using renewable electricity sources, which will generate water instead of carbon dioxide. Other innovations include the use of biomasses as an alternative to solid coal, but the process is currently quite expensive and requires much more research and development to be practical on a larger scale.

9.6.2 Resilient and Reliable Building and Bridge Design

Buildings serve many different needs within a community, from basic storage of goods to sheltering those who need immediate medical attention, and each one requires well-defined performance goals. At a minimum, buildings should not collapse onto occupants during and immediately following a disastrous event like an earthquake, hurricane, or a terrorist attack. Common building codes include a somewhat rudimentary way of incorporating means of attaining better structural performance from buildings that

shelter more critical occupancies through the use of risk factors, which have remained relatively consistent over many code cycles. It is a simple method of increasing forces and further restricting lateral building movement that has worked well enough for the intent and purpose of those codes. When considering the complex sustainability needs of a community, however, it becomes necessary to improve upon that simplified method by taking a more measured approach.

Commonly adopted building codes mostly include prescriptive means of attaining compliance with simple goals, based on reliability for a 50-year period of service,³³ but they also allow the use of more sophisticated tools and methods for achieving a different set of performance standards. Structural *reliability* of buildings and bridges refers to the probability that a member or system will not fail during the design service period by a specific mode, such as member buckling. For nonseismic loading (gravity, wind, snow, etc.), structural design is based on member performance criteria so that there is a low probability of failure during a design-level event. For a design-level seismic event, reliability is dictated in terms of performance of a lateral force-resisting system, where the system as a whole remains stable, though individual members may fail. Further, the structure could remain operational or may be damaged beyond repair. Performance goals are not only based on structural reliability but must also consider the social needs of a community that are represented and sustained through a building's use. Structural, social, and community *resilience* was discussed earlier in this chapter.

Many different conditions can result from a hazardous event, and the suitability of a structure to support needed community services will depend on damage levels, type of function (shelter, food distribution, health care, education), speed at which services can be restored, and availability of

resources that can be committed to restoration. Hospitals should remain operational, schools can be closed for a short period of time (repairable), and businesses should be functional as soon as practical to keep the needed economy moving (a small percentage could lose usability for an extended period of time). There are four common levels of potential performance of a structure that has experienced a hazardous event:

1. Safe and operational—minor damage, functions continue without interruption
2. Requires repair, but is safe and usable—moderate damage, safe, loss of some function
3. Safe, but not usable—meets minimum safety requirements, but otherwise not functional
4. Unsafe with partial or complete collapse—dangerous

9.6.3 Principles of Climate Change Adaptation

In October 2019, the Institution of Structural Engineers, based in the United Kingdom, created the Climate Emergency Task Group in an effort to respond proactively to environmental conditions created or exacerbated by our changing world climate. The group works through four key areas, including cross-industry collaboration, support of members and the profession at large, development of clear guidance to help engineers articulate the need for attention, and professional standard setting. Six themes are identified by the group, listed in a convenient and logical order (though any of the themes can be implemented at any time)³⁴:

1. *Get informed.* Structural engineers need to understand the science, stakeholders, political positions, professional responsibilities, and even potential liabilities (though difficult to assign in most cases) involved with climate change and increase knowledge of how decisions will have an impact.
2. *Low carbon.* Structural engineers need to know how to measure and control embodied carbon using available tools and published target goals. Emission of carbon can be controlled by management of material extraction and production and by appropriate project usage, as well as through reduction of materials themselves by recycling and reuse.
3. *Lean design.* Structural engineers should advocate for sensible design decisions that call for a minimum amount of raw material, such as by optimizing member and system spans and maximum stresses. Evaluate alternative load scenarios and take advantage of code-allowable reductions, while pursuing potential adjustment of serviceability criteria.
4. *Zero waste.* Structural engineers need to understand strategies for getting the most out of materials used in construction, including projections of useful life and maximizing the potential for future uses of those materials.
5. *Influence the brief.* Structural engineers need to be aware of the potential uses of existing structures as opposed to completely new construction. Strategies of retrofit, alteration, and upgrades for changes in occupancy can help extend the life of existing building stock and prevent future carbon emissions from unnecessary new construction. Engineers should know how to discuss issues of sustainability and persuade clients to consider designs that follow these principles.

6. *Get involved.* Structural engineers have a responsibility to be familiar with the needs of society and constructed facilities in consideration of climate change and to engage the profession and other stakeholders in meaningful dialogue.

Additional Resources

1. Dirk M. Kestner, Jennifer Groupil, Emily Lorenz, eds. *Sustainability Guidelines for the Structural Engineer* (Reston, VA: ASCE, 2010).
2. Green Building Solutions (website):
<https://www.greenbuildingsolutions.org>
3. Jamal M. Khatib, "Sustainability of Construction Materials," *Woodhead Publishing Series in Civil and Structural Engineering 70* (New York: Elsevier Ltd., 2016).
4. National Institute of Standards and Technology, *Recommended Options for Improving the Built Environment for Post-Earthquake Reoccupancy and Functional Recovery Time (FEMA P-2090 / NIST SP-1254)* (Washington, DC: FEMA/NIST, January 2021).

9.7 A Global and Cooperative Responsibility

When people work together to develop solutions for collective problems, the benefits extend far beyond local boundaries and cultures. We are connected to one another through constantly emerging technologies that improve the extent and quality of interaction, enabling us to share ideas and strategies for collective advancement and improvement. It is our responsibility to use resources wisely and to encourage professionals around the world to do the same for the benefit of humanity.

The Fu Foundation School of Engineering and Applied Science at Columbia University in the City of New York developed a campaign called Engineering for Humanity with a goal of promoting optimism in the role that engineering plays in service to society. Universities around the world have been instrumental in showing how scientific disciplines can (and should) be used to sustain and improve the existence of all humanity, and the field of ethics helps participants understand sobriety and collective responsibility to implement scientific findings. The campaign promotes five visions, namely, sustainable humanity, healthy humanity, secure humanity, connected humanity, and creative humanity.

New tools and innovations are constantly emerging to improve the sustainability of common building materials and to develop new ones, oftentimes beginning at the atomic level. Sometimes this involves starting at the end—defining the goal (material properties, performance characteristics), then working backwards to determine a suitable combination of elements. The process involves advances in physics and chemistry, as well as methods of prediction and computation performance, being integrated with materials science and the civil or structural design process. These advancements serve to enhance the *sustainability of humanity* itself through an optimized use of raw materials in such a way that enhances continued use for as many generations as can be imagined.

Buildings create closed environments for people to shelter and perform activities necessary to the sustenance of life, so a healthy environment is essential. The structure needs to be stable against environmental forces and should be robust with some capacity for remodeling and renovation as the needs of future generations fluctuate. Healthcare facilities need an added dose of protection against earthquakes and hurricanes, and construction codes need to

keep up to date with the latest innovations and research. Environmental and civil engineers also recognize their role in the *health of humanity*, being tasked with the design of clean and reliable storage and distribution systems for drinking water and the management of toxic chemicals.

Society depends on reliable sources of power, and civil engineers work closely with software engineers to develop secure networks and power grids, using data-driven mathematical algorithms and techniques to determine vulnerabilities to the security of vital infrastructure. Solutions include physical structural support as well as cyber-based protections and firewalls to create a more secure and reliable system. Humanity thrives on information collected by multiple types of sensors and tools that provide data to help leaders make decisions and assist engineers in developing real solutions. It is estimated that 70% of the world's population will live in cities by 2050, so it is vital that information be gathered that can help determine the best ways to improve air and water quality, ensure a steady supply of energy, protect the environment, and sustain inhabitants with a vigorous economy, affordable and available housing and transportation. Management of these features is important to sustain the *security of humanity*.

Engineering has always been a field of creativity and cooperation. Scientists map out the rules of physical structures and systems and engineers design creations that abide by those rules. These creations fulfill a need, most often on an individual basis—person or entity—but the concepts of that creation extend to other structures and systems that may be created by other engineers on another part of the world.

9.8 Review Questions

- 9.1.** What sources of data are available to help an engineer create code-compliant designs on a local level?
- 9.2.** What does the term *harmony* mean in the context of a community of persons?
- 9.3.** Describe the two distinct perspectives identified by Professor Angela Bielefeldt for engineering ethical frameworks with regard to the environment.
- 9.4.** What were the goals of the publishers of the IgCC?
- 9.5.** Name some of the tasks assigned to the National Oceanic and Atmospheric Administration (NOAA).
- 9.6.** While the land development case in Boca Ciega Bay, Florida was still under review, how did the Army Corps of Engineers revise their regulations on navigable waterways?
- 9.7.** Explain the *passive approach* that an engineer might take to consider sustainability in her work.
- 9.8.** How does ASCE define *sustainability* for civil engineering?
- 9.9.** What does the term *community resilience* describe and what does it involve?
- 9.10.** What are some of the basic human needs identified through the UN Sustainable Development Goals?
- 9.11.** What is one of the most influential goals to address global inequality among nations?
- 9.12.** Name the three areas representing the environment that carry sustainability goals.
- 9.13.** What are the benefits of strategic shareholder partnerships in addressing sustainability goals?

- 9.14.** What are the strategies presented for making highway construction and use more environmentally friendly?
- 9.15.** How is *green infrastructure* defined and what are the benefits?
- 9.16.** Name four benefits to using engineered crumb rubber in parking lot paving mixtures.
- 9.17.** What four important questions were presented in this chapter that should be explored when considering engineering solutions to climate change?
- 9.18.** What are some of the things that need to be reviewed in the development of long-term strategies for sustainable transportation?
- 9.19.** For the design of building systems, what are six factors that contribute to the selection of materials?
- 9.20.** What are the two main reactions that produce carbon dioxide in the manufacture of cement?
- 9.21.** How is the use of wood for making structural members optimized?
- 9.22.** How is structural reliability defined?
- 9.23.** What are the five visions promoted by the Engineering for Humanity campaign of the Fu Foundation School of Engineering and Applied Science?

9.9 Discussion Questions

- 9.1D.** What are some of the important things to consider when deciding to make changes to an existing landscape?
- 9.2D.** Explain the differences between mutualism, commensalism, and parasitism and give an example of

each that illustrates the relationships that can exist between human beings and their surroundings, using land development activity as the source of symbiosis.

9.3D. Identify at least five practical work-related characteristics of an engineer who is truly tolerant and selfless.

9.4D. Discuss the benefits of harmony among the inhabitants of a single community (such as a college campus) and explain how that harmony may affect larger, related communities (such as the parent city or county).

9.5D. Describe some of the ways a government can lead by example when it comes to environmental responsibility.

9.6D. Explain how public and private engineers can work collaboratively on a project in such a way that does not constitute a conflict of interest and can be mutually beneficial.

9.7D. Do you agree with the statement, “A voluntary, non-mandatory approach to environmental sustainability is the best hope for stewardship of our planet.”? Why or why not?

9.8D. Discuss the need for certain, well-defined ethical principles to sustain humanity.

9.9D. The basic survival of a community depends on a reliable, functioning infrastructure that includes such things as waste collection and disposal, transportation, communication, food delivery and distribution, and a basic supply of water (just to name a few). What types of things could a community do if any three of the functions stated above were to be disrupted for a week? A month?

9.10D. What is the role of social ethics in the promotion of sustainability?

9.11D. How does a change in political administration affect long-term sustainability and resilience goals for a community or country? What types of things could be considered in the development of goals that would be relatively immune to changes in the political arena?

9.12D. Possible approaches to climate change have been hotly debated for years. What are some of the ways engineers can be included in these discussions without becoming biased and unhelpful?

9.13D. Write a brief summary of two additional programs described in the Network for Engineering with Nature initiative published by the U.S. Army Corps of Engineers and the University of Georgia.

9.14D. Select two of the six themes presented by the Climate Emergency Task Group of the Institute of Structural Engineers and describe at least four steps (each) an engineer can take to promote action on the subject of each theme.

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²Engineers Australia (EA), *Code of Ethics and Guidelines on Professional Conduct* (Barton, ACT: EA, November 2019).

³World Federation of Engineering Organizations (WFEO), *WFEO Model Code of Ethics* (Paris, France: WFEO, 2017).

⁴Angela R. Bielefeldt, *Professional Social Responsibility in Engineering* (London, UK: IntechOpen Limited, 2018).

⁵International Code Council, *2018 International Green Construction Code (IgCC)* (Country Club Hills, IL: ICC and ASHRAE, September 2018).

⁶National Association of Home Builders of the United States (NAHB), *National Green Building Standard (ICC 700-2020)* (Washington, DC: NAHB, April 2020).

⁷John C. Branch et al., *Report on a Case by the Board of Ethical Review, Case No. 18-9, Public Health and Safety—Building Codes to Address Environmental Risk* (Alexandria, VA: National Society of Professional Engineers, 2019).

⁸Engineers and Geoscientists BC, *Guide to the Code of Ethics* (Burnaby, British Columbia, Canada: Engineers and Geoscientists BC, 2021).

⁹*Zabel v. Tabb*, 430 F. 2d 199 (Court of Appeals, 5th Circuit 1970).

¹⁰Stuart D. Kaplow, “2018 IgCC—A Fast Paced Dive,” November 25, 2018, <http://www.stuartkaplow.com/legal-library/environmental-law/2018-igcc-fast-paced-deep-dive/>.

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¹³Andrea Colantonio and Tim Dixon, *Measuring Socially Sustainable Urban Regeneration in Europe* (Oxford, UK: Oxford Brooks University, 2009).

¹⁴ASCE, *Policy Statement 418—The Role of the Civil Engineer in Sustainable Development* (Reston, VA: ASCE).

¹⁵Council on Environmental Quality, *Guiding Principles for Sustainable Federal Buildings* (Washington, DC: GPO, December 2020).

¹⁶“Resilience,” Psychology Today, <https://www.psychologytoday.com/us/basics/resilience>.

¹⁷Presidential Policy Directive PPD-21, “Critical Infrastructure Security and Resilience” (February 12, 2013).

¹⁸Charlie Edwards, *Resilient Nation* (London, UK: Demos, 2009), p. 9.

¹⁹See ASCE, *Code of Ethics* (2020).

²⁰Engineers Canada, *Public Guideline on the Code of Ethics* (Ottawa, Ontario, Canada: Engineers Canada, 2021).

²¹NOAA, *Ocean Facts*, National Ocean Service website, <https://www.oceanservice.noaa.gov/facts>.

²²Peta de Jager, ed. *The Sustainability Handbook, Volume 1* (Cape Town, South Africa: Alive2green, 2012).

²³See Edwards, *Resilient Nation*, pp. 80–83.

²⁴National Institute of Standards and Technology (NIST), *Community Resilience Planning Guide for Buildings and Infrastructure Systems, Volume I* (Washington, D.C.: NIST, May 2016).

²⁵Laurie A. Shuster, “ASCE Headquarters Debuts a More Sustainable Parking Lot,” *Civil Engineering Source* (Reston, VA: ASCE, January 14, 2021).

²⁶“About SMART: A Brief History,” Sustainable Mobility and Accessibility Research and Transformation, www.um-smart.org/about/, 2008.

²⁷National Research Council, *Adapting to the Impacts of Climate Change* (Washington, DC: The National Academies Press, 2010).

²⁸U.S. Army Corps of Engineers, *Engineering with Nature, An Atlas, Volume 2* (Washington DC: USACE, 2021).

²⁹John Gajda, *Energy Models—An Overview of Modeling Energy Performance in Concrete Buildings* (Skokie, IL: Portland Cement Association, 2001).

³⁰“Our History,” Forest Stewardship Council, accessed December 20, 2020, <https://us.fsc.org/en-us/who-we-are/our-history>.

³¹Forest Stewardship Council (FSC), *FSC-US Forest Management Standard (V.1.0)* (Bonn, Germany: FSC, July 8, 2010).

³²American Institute of Steel Construction (AISC), *More Than Recycled Content: The Sustainable Characteristics of Structural Steel* (Chicago, IL: AISC, May 2017).

³³NIST, *Community Resilience Planning Guide for Buildings and Infrastructure Systems, Volume II* (Washington, DC: NIST, May 2016), p. 56.

³⁴"Climate Emergency," The Institution of Structural Engineers, accessed May 15, 2021, <https://www.istructe.org/resources/climate-emergency/>.

APPENDIX A

Answers to Selected Review Problems

Chapter 1

- 1.1. Three branches of ethics are metaethics, normative ethics, and applied ethics. Metaethics covers subjects like the origin or nature of ethical concepts and terms. Normative ethics identifies criteria necessary to develop specific rules of moral conduct. Applied ethics deals with the analysis and activity of specific difficult or controversial moral issues.
- 1.4. Civility is defined by the Institute for Civility in Government as being more than just politeness, but also about disagreeing without disrespect, seeking common ground as a starting point for dialogue, listening past one's preconceptions, and teaching others to do the same.
- 1.6. The Fruits of the Spirit are love, joy, peace, patience, kindness, goodness, faithfulness, gentleness, and self-control. They matter because

most people would agree that they are good to work on expressing and living.

- 1.10. A virtue is defined as a good character trait that leads to good actions and contributes to the well-being of both the actor and those who are on the receiving end.

Chapter 2

- 2.2. An employee may be offered more responsibility with higher pay because she has demonstrated more than a basic level of competence in the tasks a job requires.
- 2.4. The Technical Academy Scotland defines a chartered engineer as one who is characterized by her ability to develop appropriate solutions to engineering problems using new or existing technologies through innovation, creativity, and change.
- 2.9. One of the most influential means of developing engineering judgment is on-the-job training.
- 2.13. The United States Congress defines humanities to include the study and interpretation of modern and classical language, linguistics, literature, history, jurisprudence, philosophy, archaeology, comparative religion, ethics, art, and other social sciences that include elements of humanistic content and employ humanistic methods.
- 2.14. Four character qualities that should motivate an engineer toward moral interaction with others are creativity, cooperation, curiosity, and confidence.
- 2.17. Competency is defined by the U.S. Department of Labor as a cluster of related knowledge, skills,

and abilities that affects a major part of one's job.

- 2.20. Key elements in the process of growth in competency of a professional engineer includes recognition of current knowledge and skills, a desire to expand and enhance current capabilities, knowing where and how to access resources, seeking advice and counsel of others, assessment of growth and achievement of learning outcomes or goals, strength and courage to stay focused and diversified in material, and enjoyment.

Chapter 3

- 3.3. Since the extent of harm that may be caused by an engineering failure can affect many people and their livelihoods, an engineer's responsibility to all of society becomes clear.
- 3.4. According to the Institution of Engineers (India), a corporate member's highest regard in his actions should be equality of opportunity, social justice, and fairness.
- 3.7. Some situations of ordinary work within an engineering office that may create a more stressful working environment than may be present in a different place of work include extensive hours worked by salaried employees, added risk inherent in the construction industry, and multiple levels of leadership and oversight.
- 3.10. The tone for creating a moral working environment within a professional business is set by the words and actions of leadership, as well as employees, including communication about the types of things that are tolerated.

- 3.11. Whistleblowing occurs when an employee, or even a former employee, conveys information about a significant moral problem committed by other persons within their organization to someone who is in a position to take action.

Chapter 4

- 4.2. The sword held by Lady Justice symbolizes authority to carry out a sentence. It is unsheathed, indicating that justice will be swift, and double-edged to indicate that it can cut at either party.
- 4.5. Under home rule, municipal bodies operate with autonomy without interference from the state according to their charter.
- 4.7. The purpose of the International Building Code is to establish the minimum requirements to provide a reasonable level of safety, public health and general welfare through structural strength, means of egress facilities, stability, sanitation, adequate light and ventilation, energy conservation, and safety to life and property from fire, explosion and other hazards, and to provide a reasonable level of safety to firefighters and emergency responders during emergency operations.
- 4.12. Society is typically willing to accept risk as long as it can be managed as carefully and responsibly as possible.
- 4.15. According to *Black + Vernooy Architects v. Smith*, in order to prove negligence of a design professional, the other party must prove that (1) a

legal duty was owed by one person to another, (2) a breach of that duty occurred, and (3) damages proximately resulted from that breach of duty.

Chapter 5

- 5.1. The four main branches of philosophy include ethics, epistemology, logic, and metaphysics.
- 5.4. Confucius explains that promises should be kept punctually, that the statement of a promise is cheaper than the execution of what is promised, those who are disloyal and untrustworthy in their speech will not hope to succeed, and a person must learn to recognize false promises and cling to honesty.
- 5.8. Aristotle teaches that a perfect expression of goodness is one that is directed to the right person, to the right extent, at the right time, with the right motive, and in the right way.
- 5.10. Miskawayh explains that justice is expressed through friendship, concord, family fellowship, recompense, fair play, honest dealing, amiability, and piety.
- 5.16. According to Kant, the three character qualities that constitute offices of charity include beneficence, gratitude, and sympathy.

Chapter 6

- 6.6. The well-being of individuals is expressed in the freedom and opportunity to participate in activities that increase happiness, to advance the potential to achieve goals, and to broaden the

range of available choices for a variety of lifestyle conditions.

- 6.7. The correspondence theory of truth states that truth corresponds with facts or reality. This is important because science has carefully laid out how facts can be discovered, and identified as such, and how facts are related to reality. Reality includes statistical variance, and although a measurement does not need to be exact (it can fall within an acceptable range), it can still be called “true.”
- 6.14. One of the causes for a rise in the establishment of engineering societies in the United Kingdom during the 1950s was specialization of engineering disciplines, such as mechanical and electrical engineering.
- 6.15. The four main ethical principles promoted by the Royal Academy of Engineering are honesty and integrity; respect for life, law, the environment, and the public good; accuracy and rigor; and leadership and communication.
- 6.19. Social infrastructure includes a range of services and facilities that meet local and strategic needs of a society and contribute toward a good quality of life for all. It includes health care, education, transportation, and recreation.

Chapter 7

- 7.2. Four elements of evaluation that are involved in making and analyzing choices include reason, proof, refutation, and correction.

- 7.4. Truth is defined as sincerity in action, character, and utterance; the state of being the case; the property of being in accord with fact or reality; and fidelity to an original or to a standard.
- 7.9. We should search for our own errors by indefatigable rational criticism and self-criticism.
- 7.13. Three ethical problems that may involve multiple solutions include conflicts of interest, making public statements, and issues of sustainability.
- 7.14. The building blocks of the McMaster Five-Point Strategy heuristic include define, generate, decide, implement, and evaluate.

Chapter 8

- 8.3. Four nontechnical conditions of humanity that can negatively affect our performance are laziness, irritability, discouragement, and argumentativeness.
- 8.8. The core drilling program in the site evaluation for the Teton Dam revealed the presence of individual cracks and joints that were randomly oriented, which could turn out to be problematic.
- 8.13. During the fitting of supports for the fascia panels at the Hartford Civic Center Stadium, the subcontractor ran into extreme difficulties due to excessive deflections, but the project manager instructed him to make it work.
- 8.15. The probable cause of collapse of the I-35 bridge in Minneapolis turned out to be a design error that created insufficient load carrying capacity in one of the steel gusset plates.

- 8.17. The pedestrian bridge at the Florida International University collapsed during the third stage of construction. For this stage, the main truss was transported and placed over the south pier and north pylon and set into a simply supported condition until the back span could be secured.

Chapter 9

- 9.1. Sources of data that are available to help an engineer create code-compliant designs on a local level include geotechnical reports, environmental impact reports, zoning regulations, existing land development patterns, and political bodies.
- 9.5. Some of the tasks assigned to the National Oceanic and Atmospheric Administration include research on climate change, general weather conditions, issues affecting oceans and coasts, and the conservation of coastal and marine ecosystems and resources.
- 9.10. Some of the basic human needs identified through the UN Sustainable Development Goals include clean water, removal of waste, safe travel between regions beyond a community, food growth and production, food distribution networks, energy production and delivery, and means of communication.
- 9.20. Two main reactions that produce carbon dioxide in the manufacture of cement are decomposition of limestone and the thermal energy required to produce clinker.
- 9.22. Structural reliability of buildings and bridges refers to the probability that a member or system

will not fail during the design service period by a specific mode, such as member buckling.

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