

Sustainable Engineering in Infrastructure Governance

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Abstract—Engineers are increasingly expected to take on leadership roles in promoting sustainable development as they address global challenges such as resource depletion, environmental pollution, rapid population growth, and ecosystem damage. Engineering advancements in the 20th century were often pursued without consideration of their effects on social, economic, and environmental systems. Given the issues facing our planet today and those anticipated in the early twenty-first century, it is essential for engineers to rethink their approach and adopt a new mission to help create a more sustainable, stable, and equitable world. Achieving this requires engineers to develop a fundamentally different perspective on natural and cultural systems, as well as reevaluate the interactions between engineering disciplines, non-technical fields, and society. As we progress into the twenty-first century, embracing a more comprehensive approach to engineering is crucial. This will necessitate a significant shift in perspective from controlling nature to engaging with it, an understanding of ecosystems, the services they provide, and the need to preserve and restore natural capital; and a mindset that supports the mutual enhancement of nature and humanity, in line with the principles of sustainable development.

Index Terms—Engineers, sustainable development, ecosystems, environmental pollution, society, economic resources, global challenges

I. INTRODUCTION

One of the first sources of confusion, especially for those who are not engineers or scientists, is the difference between science and engineering. Scientists focus on gaining knowledge and understanding of the physical universe. Science seeks knowledge in its purest form, without considering societal needs. In contrast, engineering combines both science and society. Some describe scientific research as curiosity-based, driven more by human interest than by societal values. These values do not always set the limits, direction, or scope of scientific curiosity. Engineering

serves as a bridge between pure science and society (Figure 1).

Relationship between Societal Needs, Scientific Knowledge, and Engineering

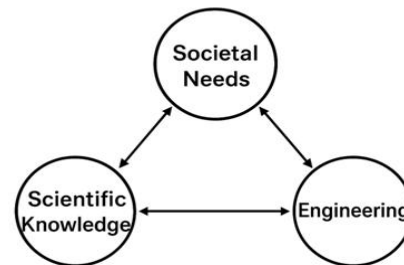


Figure 1: Relationship between societal needs, scientific knowledge and engineering.

Unlike science, engineering operates in a constantly changing environment. Engineers must be ready to handle various risks and outcomes. They play a significant role in society, but their contributions often go unnoticed. Most essential services in modern life like electricity, air travel, television, medical imaging, sewage systems, telecommunication, water supply, and railways result from engineering. Engineers design and create the physical structures that support how society lives, works, and plays.

To truly appreciate the engineer's role, we need to explore the relationship between engineers and society. With this understanding, 21st-century engineers may be able to create a sustainable world that balances with nature, helping to address some of the unavoidable global crises, if given the chance.

II. ENGINEERING ACHIEVEMENTS IN 20th CENTURY AND FUTURE CHALLENGES

For the past 150 years, engineering has focused on controlling nature rather than working with it. In this control-focused approach, humans are separate from the natural world, creating a confrontational and manipulative attitude toward nature. Although this method has its downsides, it has brought about

impressive engineering feats in the nineteenth and twentieth centuries. For example, civil and environmental engineers have significantly improved life on Earth by enhancing sanitation, developing water resources, and building transportation systems. The twentieth century saw great advancements in engineering technology across various fields, including design, information technology, construction, manufacturing, robotics, advanced materials, and management techniques for solving problems. Some new and improved technologies include:

- a) Nuclear technologies: These provide new sources of electric power and capabilities in medical research and imaging, as well as potential military uses.
- b) Lasers and fiber optics: Laser pulses are used in industrial tools, surgical devices, satellites, and more. In communications, a single fiber-optic cable can carry tens of millions of phone calls, data files, and video images.
- c) Petroleum and gas technologies: These serve as fuel for cars, homes, and industries. Petrochemicals are found in products ranging from aspirin to zippers. Engineering in oil exploration and processing significantly affects world economies, people, the environment, and politics.
- d) Health technologies: Medical professionals have access to a range of diagnostic and treatment equipment. Artificial organs, replacement joints, and biomaterials are just a few examples of engineered products that enhance the quality of life for millions.
- e) Imaging technologies have expanded the reach of our vision. Probing the human body, mapping ocean floors, and tracking weather patterns are all the result of engineering advances in imaging technologies.
- f) The development of spacecraft has broadened our knowledge and improved our capabilities. Thousands of useful products and services have come from the space program, including medical devices and wireless communications.
- g) Farm machinery like tractors, cultivators, and combines has dramatically increased farm efficiency and productivity.
- h) Electronics form the basis for countless innovations such as CD players, TVs, and

computers. From vacuum tubes to transistors to integrated circuits, engineers have made electronics smaller, more powerful, and more efficient.

- i) Modern air travel quickly transports goods and people around the globe, facilitating personal, cultural, and commercial interaction.
- j) Automobiles are the world's primary transporters of people and goods and a strong source of economic growth and stability. The automobile showcases 20th-century engineering ingenuity with innovations in design, production, and safety.
- k) Electrification has literally lit the world and impacted many areas of daily life, including food production and processing, air conditioning and heating, refrigeration, entertainment, transportation, communication, health care, and computers.

Most engineering achievements in the past were developed without considering their social, economic, and environmental effects on natural systems. There was little focus on reducing the risk and scale of unexpected or unwanted disruptions in natural systems related to engineering.

The world is becoming more crowded, more consuming, more polluting, and more interconnected. There is growing awareness that humans are changing the Earth's natural systems at all levels, from local to global, at an unprecedented rate. This raises a key issue: how to balance the needs of a rapidly growing population with the preservation of our ecosystems and both biological and cultural diversity. An important question is what actions should be taken now, and in the near future, to ensure that everyone has access to basic needs like water, sanitation, nutrition, health, safety, and meaningful work. These goals are often referred to as "Millennium Development Goals." The increasing population is creating exceptional demands for energy, food, land, water, transportation, materials, waste disposal, earth moving, health care, environmental cleanup, telecommunication, and infrastructure. Engineers will play a critical role in meeting those demands, from small remote communities to large urban areas, particularly in the developing world (Cruickshank and Fenner, 2007). If engineers are not prepared to meet these demands, who will? The growth of large urban areas is likely to

impact the future prosperity and stability of the entire world.

Given the challenges our planet faces today and those expected in the first half of the twenty-first century, the engineering profession must rethink its approach and adopt a new mission statement: to help build a more sustainable, stable, and fair world. Sustainable development will be impossible without the full involvement of the engineering profession. For this to happen, engineers must change their attitude toward natural and cultural systems and rethink the interactions between engineering and non-technical fields.

As we enter the twenty-first century, we need to start a global shift toward a more inclusive approach to engineering. This will require: (1) a significant change from controlling nature to cooperating with it; (2) an understanding of ecosystems, their services, and the preservation and restoration of natural resources; and (3) a new mindset that recognizes the mutual benefit of nature and humans while embracing the principles of sustainable development.

III. ENGINEERS AND SUSTAINABLE DEVELOPMENT

Sustainability is a quality of a process that can be maintained at a certain level indefinitely. From an environmental perspective, it refers to the lasting ability of vital support systems for human life, such as the planet's climate system, agriculture, industry, forestry, and fisheries, as well as the communities that depend on them. Sustainability is a way of making decisions that takes into account the connections and effects of economic, social, and environmental factors on the quality of life for both current and future generations. It is a changing idea that aims to be participatory, clear, fair, informed, and responsible.

Sustainable development is the process of guiding human activities toward a pattern that can be sustained over time. It addresses environmental and development issues by attempting to balance human needs with the planet's ability to handle the impacts of those activities. This concept includes three main themes: social, environmental, and economic accountability, collectively known as the Triple Bottom Line (Elkington, 1994) (Figure 2). A sustainable community is one that maintains, improves, or enhances its environmental, social,

cultural, and economic resources in a way that supports current and future members in leading healthy, productive, and happy lives.

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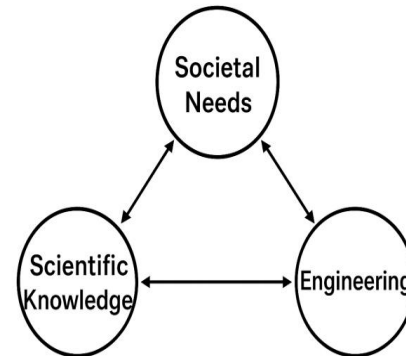


Figure 2: Triple bottom line concept of sustainable development

Professional engineers play a vital role in promoting sustainability. They focus on improving welfare, health, and safety while minimizing the use of natural resources and considering environmental impacts. Their work is shaped by the opportunities and challenges related to sustainability. Engineers provide options and solutions to maximize social value and reduce environmental harm. They face pressing challenges from issues like pollution, resource depletion, rapid population growth, and ecosystem damage. Thus, relying solely on an environmental approach is not enough. Engineers increasingly need to adopt a broader perspective that includes goals like reducing poverty, promoting social justice, and fostering local and global connections.

Globalization offers important opportunities for engineers to drive change by sharing knowledge and best practices. The leadership and influence of engineers in achieving sustainability should not be overlooked. They increasingly work as part of multidisciplinary teams that include non-engineers and cross-national borders. The main goal of sustainable development is to enable everyone worldwide to meet their basic needs and enjoy a better quality of life without compromising the quality of life for future generations. Sustainable development is based on two concepts: needs and the limits set by current technology and future demands. The following principles have been agreed upon to achieve sustainable development:

- Living within environmental goals
- Ensuring a strong, healthy, and just society
- Promoting good governance
- Achieving a sustainable economy
- Using sound science responsibly

IV. GUIDING PRINCIPLES FOR ENGINEERS TO ACHIEVE SUSTAINABILITY

Engineers should perform their roles in a global context that includes social, ethical, environmental, and economic challenges. These six principles will help engineers achieve sustainable development (Dodds and Venables, 2005). They will support engineers in meeting their responsibilities to pursue sustainability and make sure this goal is part of all their engineering work.

Contribute to building a sustainable society, present and future. Engineers have a duty to maximize the value of their work in building a sustainable world. This requires understanding what society needs and what is possible, as well as recognizing that these needs change over time. They should:

- Recognize that while their work may be local and immediate, the potential impacts can be global and long-lasting.
- Understand social and cultural structures beyond their usual community of practice.
- Grasp their key role in the sustainable development of communities.
- Acknowledge the effects of an engineering project on communities, both global and local, and incorporate the views and concerns of these communities.

Apply professional and responsible judgment and take a leadership role. Engineering is a profession with a strong ethical focus. Engineers play a crucial role in solving problems such as poverty, under-development, and environmental harm. Therefore, professional engineers should:

- Consider the big picture.
- Keep their knowledge about sustainable development current.
- Be ready to influence decision-makers for a project.
- Identify all issues and options for decision-makers to ensure sound decisions.

- Recognize options that consider economic, social, and environmental outcomes.
- Ensure that proposed solutions and options will support sustainability.
- Be mindful of the conflicting and unmeasured aspects of sustainability.

Do more than just comply with legislation and codes. In pursuing sustainable solutions, simply following current laws, codes, and environmental regulations may not be enough. Engineers should:

- Go beyond the minimum when possible, anticipating stronger future laws.
- Set an example to help others improve their performance.
- Inform authorities of any weaknesses in legislation that could threaten sustainable solutions.
- Use their technical expertise to promote new laws and codes.

Use resources efficiently and effectively. Engineers have a key role in managing planetary resources and a duty to society to create more useful products and services while minimizing the consumption of raw materials, water, and energy. This requires them to:

- Understand environmental limits and finite resources.
- Reduce demand by using less from the beginning.
- Cut waste production by being efficient with the resources they use.
- Use systems and products that lower embedded carbon, energy and water use, waste, and pollution.
- Adopt strategies for reusing, recycling, decommissioning, and disposing of components and materials.
- Minimize negative impacts on sustainability during the design phase.

Seek multiple views to solve sustainability challenges. The growing complexity of sustainability challenges means that engineers cannot tackle all the problems alone. Therefore, it is important for engineers to:

- Engage with stakeholders, listening to and valuing the perspectives of others, including non-specialists.
- Avoid working in isolation by involving other professionals at every stage of a project.

- Use knowledge from different disciplines and diverse skills.
- Promote the engineer's vital leadership role in finding solutions to sustainability challenges that benefit society.
- Strive for a balanced approach.

Manage risk to minimize negative effects on people or the environment. Engineers often plan and manage projects, where they should:

- Use their skills to reduce harm to people or the environment from engineering processes and products.
- Conduct a thorough risk assessment before starting a project.
- Ensure the risk assessment includes potential environmental, economic, and social impacts beyond the project's lifetime.
- Favor sustainability in uncertain situations, taking a precautionary approach when scientific knowledge is inconclusive.
- Set up monitoring systems to identify any environmental and social impacts of engineering projects early on.

V. CONCLUSION

The modern world has been shaped by science, engineering, and technology. The engineer's role is closely tied to society's needs. Unfortunately, engineers often struggle with public relations and don't effectively communicate their achievements. Famous scientists frequently develop medicines and are seen by society as more philanthropic. In this paper, the term engineer refers to any scientist, technologist, or engineer who uses her skills and training to create practical applications.

The 21st century will be marked by significant challenges facing humanity. These include energy and food security, competition and scarcity of natural resources, and climate change. This year's engineering graduates will encounter these issues throughout their careers. The demand for engineering skills will likely be greater than ever to create sustainable systems, develop low-carbon energy technologies, and build strong infrastructure to guard against geophysical hazards like rising sea levels and extreme weather events.