CHAPTER I

Technically Based Programs in Science, Technology, and Public Policy

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1.1 Background

In this chapter, we review and discuss academic programs in technology and public policy, focusing on those that are either located in an engineering college or have a strong engineering focus. We consider what constitutes technically focused research in programs melding engineering and policy, where and how this work is done, the focus of these programs at the undergraduate and graduate levels, and the challenges of building and sustaining such programs.

Many academic programs in the United States and elsewhere focus on the social studies aspects of science, technology, and public policy. Indeed, most programs listed in the original American Association for the Advancement of Science guide to graduate education in science, engineering, and public policy were in this category (Levey, 1995). Few programs combine deep technical education and understanding with modern social science and policy-analytical skills and knowledge.

Of course, some policy problems related to technology do not require the policy maker or analyst to get “inside the black box” (Rosenberg, 1982), meaning he or she has no need to understand the detailed workings of technology at play. Indeed, for many such problems, spending too much time considering the technical details can be a distraction or lead the analyst astray. However, a subset of policy problems can lead to poor or nonsensical results: those in which the technical details are integral to the policy issue. Table 1.1 illustrates both kinds of problems. Examples of both types of problems involve direct satellite communication in which the technical details are not critical to a solution of the policy problem and in which it is essential to “get inside the black box,” for which a reasonable technical solution requires a deep familiarity with the technical details.

*Morgan (2010, 2011) were used with permission from the publisher.
In the United States, most programs in technology and policy date to the early 1970s. One notably earlier high-visibility program was the Harvard Program on Technology and Society, created with a substantial endowment from IBM. This program started in 1964 and ran through 1972 under the direction of philosopher Emmanuel (Manny) Mesthene. The focus was not particularly on policy analysis but rather on technology impacts on society and on technology and social change. The program published a series of high-visibility annual reports but was never successfully integrated into the mainstream of academics at Harvard. Later, a portion of the endowment was used to support the professorship of Louis M. Branscomb, who ran the Science, Technology, and Public Policy Program in the Belfer Center for Science and International Affairs of the Kennedy School at Harvard. In contrast to Mesthene, Branscomb had a much stronger involvement in policy-analytic work, leading to a focus that continues at the Belfer Center today. The Harvard program predated most other programs that started to emerge in its very last years.

In the early 1970s, Arthur Singer at the Sloan Foundation made a series of grants to develop programs in science, technology, and public policy. A few years later, William Blanpied at the National Science Foundation also made a number of grants to build programs in this area. Since the late 1970s, however, no major ongoing foundation or government support has emerged in the United States to build interdisciplinary academic programs.

Table 1.1 Examples of problems

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<th>A problem related to technology</th>
<th>A problem in which technical details are centrally important</th>
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<td>Delivery of continuing adult education through direct-broadcast satellite to rural India. To adequately address this problem, the analyst does not need to know much at all about how direct-broadcast satellites work. So long as the analyst knows what the technology costs, who is needed to run it, and similar details, a nontechnical policy analyst can address this problem very well. Indeed, getting too bogged down in the technical details could easily distract the analyst from the central issues.</td>
<td>Developing India’s negotiating positions for an upcoming international conference on reallocated parking orbits for geostationary satellites. To adequately address this problem, the analyst must have a deep technical understanding of the relative advantage of gain on the ground versus gain on the spacecraft, the likely future cost and performance of microwave amplifiers, and a variety of similar issues. Without such knowledge, the resulting policy conclusions could be seriously misinformed.</td>
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in science, technology, and public policy, although foundations, such as the Exxon Education Foundation, have made occasional grants.

Despite limited support, many science and engineering educators have come to recognize the importance of preparing students with rigorous technical backgrounds who are also capable of addressing policy problems in which technical details matter. This has not always been true. In the 1950s and 1960s – and even today on some campuses – the strong postwar tradition of engineering science and education created an environment in which many faculty belittled any activity that was not laden with partial differential equations. Fortunately, recent decades have witnessed a rebalancing of engineering education. However, even today, developing and sustaining programs in technology and policy present numerous challenges:

- Processes for academic promotion and tenure apply traditional disciplinary templates in evaluating junior faculty and give no weight to cross-disciplinary accomplishments and impact in that realm, such as technical policy surrounding energy, environment, information and communications technology, and biomedical engineering issues.
- Few faculty candidates can combine deep technical knowledge and skill with solid modern social-scientific, policy-analytic, and policy-application knowledge and skills.
- Many faculty candidates educated in the more qualitative social sciences, or in social studies of technology, have limited interest in or ability to address policy problems with deep technical content.
- There is difficulty engaging the nature and interests of funding sources and the relative ease of funding.
- Stakeholders lack vision in defining interesting research questions and in being watchful for – and building on – insights that can be generalized in this field.

1.2 Building and Sustaining a Program in Technology and Policy

In a conversation I had years ago with physicist Ray Bowers (who, together with chemist Frank Long, started Cornell’s program in science, technology, and policy), Bowers spoke about why Mesthene’s Harvard Program on Technology and Society had not survived, despite a generous endowment from IBM. Bowers argued that it had not been integrated into the academic fabric at Harvard but rather had been built off to the side. Thus no one was available to defend it “among those with real power in the
Bowers and Long worked to weave science and technology policy into the academic fabric of Cornell University. The Cornell department that grew out of their early efforts, Science and Technology Studies, is now an established department in the College of Arts and Sciences. However, it no longer performs the deep, technically focused policy work that Bowers and Long pioneered.

For a number of reasons, sustaining a program in technology and policy in which technical rigor is integral to the program’s education and research involves an unstable equilibrium, illustrated in Figure 1.1. Without continuous effort to maintain the unstable balance, a program will evolve either into more conventional forms of engineering or into social studies of science and technology.

Cornell faculty and administrators applied that continuous effort. When Bowers and Long left the program, a number of excellent non-scientists took their place, including sociologist Dorothy Nelkin and linguist and lawyer Sheila Jasanoff. Walter Lynn continued to contribute a technical perspective while he was still active, but as the program grew and was merged with a program in the history of science, it evolved into a very different kind of effort. Today, the undergraduate major in science and technology studies “aims to further students’ understanding of the social and cultural meanings of science and technology” (Cornell University Department of Science and Technology Studies, 2018c,
para. 2). Using perspectives and tools “that cross the traditional boundaries of sociology, philosophy, politics, and history,” doctoral-level studies in the department treat “science and technology as historical and cultural productions” (Cornell, 2018a, para. 3). The “approach throughout is both descriptive (aimed at understanding how science and technology are accomplished) and normative (e.g., showing where actual practices and professed norms are in conflict)” (Cornell, 2018b, para. 2). Although such work is interesting and important, it is quite different in focus from the pioneering technology-assessment activities of Bowers, Long, and their colleagues on topics such as video telephony and solid-state microwave devices, where deep technical knowledge was applied to substantive policy analysis.

A second way activities that begin in technology and public policy may migrate toward the social studies side of Figure 1.1 is to shift toward conventional public policy. We make no normative argument. Important problems in public policy are either unrelated to technology or concern it but do not require a deep understanding of technical issues.

A third example of a movement away from the unstable equilibrium toward the social studies side of Figure 1.1 is the evolution of the Association of Public Policy and Management (APPAM) and its Journal of Policy Analysis and Management (JPAM). Individuals at the Sloan Foundation and academics like Charlie Wolf, Pat Crecine, Toby Davis, and Ray Vernon worked intently to include scientists and engineers in the workshops that led to APPAM’s creation. Participants made a serious effort to include technical people in the early mix of those involved in the organization. However, over time, most members of the association and most readers of JPAM had no deep interest in technical issues. As a result, the technical people shifted their efforts away from APPAM/JPAM to more technically focused societies and journals.

On the right-hand side of the unstable equilibrium in Figure 1.1 is the example of the Department of Technology and Human Affairs at the School of Engineering and Applied Sciences at Washington University. Under the leadership of chemical engineer Robert Morgan, Washington University established the Interdepartmental Program in Technology and Human Affairs in 1971; it grew into a full-fledged department in the engineering school in 1976. Its name was subsequently changed to the Department of Engineering and Policy. The department offered a full range of degrees, from BS to PhD. However, when Morgan stepped down,
the new department head and several deans became interested in issues like midcareer continuing technical education, and the department’s new leadership did not devote the necessary attention and energy to sustaining the program, which ultimately collapsed.

In addition to requiring continual balancing of energies from faculty and administrators, programs in technology and policy that have survived and grown have evolved in ways that allowed them to adapt to the strengths and limitations of their host institutions. However, all have faced some common problems, of which the greatest may be finding appropriate faculty who combine strong technical knowledge with well-honed policy analysis skills. The careers of most First-Wave faculty active in this area evolved from traditional roots. Some had already developed strong technical careers, were safely tenured, and had the luxury to move into more interdisciplinary undertakings. In other cases, young faculty took considerable career risks to pursue an intellectual venture they viewed as critically important.

In the Department of Engineering and Public Policy (EPP) at Carnegie Mellon University, where we teach, the strategy has been never to compromise on the technical credentials of new faculty. In some cases, we found faculty candidates who had already built strong backgrounds in technology and policy. A few junior hires had strong technical backgrounds and clear policy interests but little formal or practical policy background. Because Carnegie Mellon actively encourages interdisciplinary work, it has been practical to hire such individuals and develop their policy expertise over time, cultivated by those in leadership positions and by faculty who already have such expertise. Many institutions find it difficult or impossible to do this. However, the situation is changing. Although the pool remains small, in the last fifteen years, EPP has increasingly been able to recruit junior faculty who combine excellent technical skills with strong policy interests and demonstrated accomplishments.

1.3 Undergraduate Technology and Policy Programs Offered by Engineering-Based Departments

In the United States and a number of other countries, many engineering undergraduate programs flourish in areas, such as industrial engineering, environmental engineering, and systems engineering, that sometimes touch on issues of public policy. However, we are aware of only a few technically based programs that offer undergraduate degrees in science, technology, and public policy. One of the oldest is the set of double-major
programs offered with each of the five traditional engineering departments of Carnegie Mellon’s Department of Engineering and Public Policy. We describe these in detail in the section on Carnegie Mellon undergraduate programs in engineering and public policy.

The Department of Management Science and Engineering at Stanford offers a BS degree program that “trains students in the fundamentals of engineering systems analysis to prepare them to plan, design and implement complex economic and technological management systems where a scientific or engineering background is necessary or desirable” (Stanford University, 2018, para. 1). In addition to a set of standard science, mathematics, and engineering core courses, students take accounting, computer science, deterministic optimization, economics, and organizational theory and complete a capstone senior project.

The Department of Technology and Society in the College of Engineering and Applied Sciences at the State University of New York, Stony Brook, offers an undergraduate degree in technology-systems management and a minor. The department describes its program as focusing “on technological advances that shape every facet of modern life. Students develop an understanding of the characteristics, capabilities, and limitations of current and emerging technologies. Successful practices in government, industry, education, and personal life depend on such understanding” (Stony Brook University, 2018a, para. 3). Students take several courses in mathematics and natural sciences and select a cluster of “seven related courses . . . in one area of natural science, engineering, applied science or environmental studies” from a traditional department (Stony Brook University, 2018b, para. 6). The department offers a significant number of its own courses in technology-systems management, from which students are expected to select eleven. The department also offers minors in technology-systems management and nanotechnology studies.

The Engineering School at McMaster University in Ontario, Canada, offers a BS program in engineering and society that combines historic analysis, social science, and engineering to “investigate how technology affects society and how in turn society influences the development of technology” (McMaster University, 2018, para. 2).

University College London (UCL) has recently developed an undergraduate minor in engineering and public policy for students in any of the core engineering disciplines. Jason Blackstock, who has been leading efforts to establish an EPP program at UCL, told us that a recent trend in the United Kingdom incorporates policy exposure into mainstream
undergraduate engineering programs. For example, Blackstock is working with the Royal Academy of Engineering to run some Engineering a Better World programs aimed at UK undergraduate engineers. This program will expose students to sustainable-development goals and help them identify how their capabilities might contribute. Several universities have asked for support to model offerings on UCL’s curriculum. Blackstock noted, 

This is definitely not the same as training in technically rigorous engineering-policy analysis, but the trend is starting to generate considerably more interest (most importantly, a pipeline of interested engineering graduates) in graduate degrees that blend technical engineering and policy analyses.

At Delft University of Technology in The Netherlands, the faculty in Technology, Policy, and Management offers a BS program in Technische Bestuurskunde (loosely translated as “systems engineering and policy analysis”). Although the faculty’s graduate programs operate in English, the BS program operates in Dutch. In a recent self-assessment prepared for one of the national reviews that all Dutch academic programs receive, faculty at Delft explained:

The BSc programme Technische Bestuurskunde teaches students to analyze systems that are technically, socio-economically and politically complex. Examples include large-scale infrastructures for telecom, transport and energy, or medium-scale systems like business information systems or wind farms. Many disciplines are involved, and therefore the TB curriculum includes subjects ranging from calculus, computational modelling and technology to economics, law and governance.

Some universities, including Ohio State University (John Glenn College of Public Affairs, 2018) and Pennsylvania State University, offer minors in public policy or additional policy coursework for engineering students. Although more abbreviated than a major, these often involve only three to five courses. Dartmouth offers a “major modified with Public Policy” in a “program for the aspiring public servant who realizes it will be useful to understand technology – and for the engineer who realizes that public policy affects which technologies are funded and chosen for development and adoption” (Thayer School of Engineering at Dartmouth, 2018, para. 4). Programs such as the civil engineering program at the University of Michigan (Michigan Engineering, 2018) consider policy issues related to a specific discipline, such as civil or environmental engineering, but narrowly tailor these and do not provide the scope of methods or breadth of a full major.
1.4 The Undergraduate Program in Engineering and Public Policy at Carnegie Mellon

In contrast with other programs that began with a focus on graduate education, the activity that led to the Department of Engineering and Public Policy at Carnegie Mellon began with an undergraduate program designed to add additional dimensions and skills for engineering students, most of whom go on to conventional engineering careers. EPP now offers undergraduate programs designed to suit the needs of engineering and nonengineering students.

The main undergraduate degree is the EPP double-major program, which earns students a joint degree between EPP and any of the five primary engineering departments: chemical, civil, electrical and computer, mechanical, and materials science. EPP also offers double majors and minors in Science, Technology, and Public Policy for students outside the engineering college who are earning a BS, including students in the Mellon College of Science, the School of Computer Science, and in select majors in Dietrich College. Similar to the double major in engineering and public policy, this new double major is meant to broaden perspectives on a student’s primary major and provide additional career skills. Last, for Carnegie Mellon University students outside the College of Engineering, EPP administers the technology and policy minor, designed to allow students to explore the interactions of technology and policy without adding too much to the course requirements in their major curriculum.

Students earn double-major degrees by EPP taking over all the technical and nontechnical elective-course space in the single-major undergraduate curriculum to comprise the second half of the degree. In that elective-course space, all students must take introductory courses in microeconomics and engineering statistics. Then, they select one of several social-analysis electives in the area of decision science; a course in writing and communication (beyond their freshman writing course); at least three “technology-policy” electives, most of which are offered by the department; and a course entitled Applied Methods for Technology-Policy Analysis. They also complete two EPP project courses.

EPP has evolved undergraduate courses and course sequences in areas such as energy systems; air pollution; telecommunication policy; computer security and privacy; management of technical innovation; and risk perception, assessment, and analysis. These are regular technical electives in the College of Engineering (often double-listed in traditional departments as well), open to all students in the college who meet the prerequisites. It is
not unusual for a large portion of students in EPP technical elective courses in telecommunication policy to be single majors in electrical and computer engineering. Similarly, many students in EPP courses in air pollution are pursuing single majors such as civil engineering, chemical engineering, or mechanical engineering. This cross-pollination is supported across the college and is very common.

An important feature of the EPP undergraduate curriculum is project courses, run jointly by faculty in the Department of Engineering and Public Policy and the Department of Social and Decision Sciences in the College of Humanities and Social Sciences. The typical course hosts 20 to 25 students. Projects address some real-world problems in technology and public policy, typically with an outside client for whom the work is being done. (See Table 1.2 for examples of recent topics.) The Department has run project courses since 1970. Today, it runs two such projects every semester. Students start the semester with a vaguely defined problem area and various background materials, which they use to define and shape a workable problem. Then, they undertake the necessary analysis to frame and address the problem. Typically, two faculty advisors and two PhD students serve as managers. Over the first few weeks, students work to develop a thorough understanding of the subject and define the focus of the work they propose to do. Approximately halfway through the semester, they make a first formal presentation to an outside review panel who bring various types of expertise and represent differing points of view in the problem area. The review panel assists students by providing critical comments on their structuring of the problem and by suggesting various resources and information sources. At the end of the semester, the students prepare a final written project report of about 100 pages and make a final verbal presentation of their findings and conclusions to the review panel. It is impossible for 20 to 25 people to work on a single problem collaboratively, so much of the work occurs in smaller working groups of four to six students.

Project courses serve several important educational functions. First, they are the venue in which students have an opportunity to assemble various technical and social-analysis components of their education and gain practical experience applying them to a real-world problem. Second, they provide a valuable opportunity for students to develop and refine their verbal, oral, and presentation skills. In the real world of daily engineering practice, these skills are as important for success as core mathematical and quantitative analytical skills. Project courses are rigorous and complex, requiring a great deal of work. However, over the past 20 years, EPP has undertaken three surveys of all of its double-major undergraduate alumni.