



Peace, Conflict and Sustainability: Addressing Global and Ethical Issues in Engineering Education

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Engineers play central design and policy roles globally in infrastructure and construction projects -- in transportation, power generation, irrigation, mining and other sectors. Particularly in developing countries, this may thrust them into violent conflict situations arising from geopolitical disputes, rival claims over resources, unequal distribution of benefits and costs, or power struggles. Conflicts among communities, peoples, and nations can arise from many causes. Engineering programs and projects may themselves be among the problems at issue. Where efforts to bring about peaceful solutions fail, the resulting violent conflict can create the greatest possible threat to a project's sustainability, i.e. outright destruction.

These issues raise many questions addressed in a panel discussion: Is engineering education preparing students to understand and address these problems? If not, how should these perspectives be introduced into engineering curricula? Do the perspectives raised in this paper need to be more widely considered by the engineering profession, and if so, how should this be accomplished? How should engineering research be enriched to integrate these socio-political aspects with purely technical research subjects?

Engineering professionals may unavoidably be parties in conflict situations. Depending on how engineers approach the identification, design, and implementation of projects, they can aggravate underlying tensions among stakeholders, even creating new divisions between winners and losers, or they can ameliorate or even prevent conflict in the first place. Social responsibilities facing engineers has become a subject of its own, explored in books and engineering ethics journals. Apart from their role in the development and manufacture of armaments, the relationships between engineering and conflict, especially in developing countries, have been less well examined. Engineers have a responsibility to ensure that decision makers are aware of the potential effects of engineering works in situations of social and political contention, and of the need to explore alternative solutions that may ease tensions at issue.

Many engineering projects in the U.S. are sources of political conflict, e.g. disputes over the location of wind farms; the technology for, and unintended consequences of, extracting natural gas from shale formations; environmental effects of mining projects; location and risks of off-shore oil drilling; new pipeline location and environmental risks. Although such disputes can reach fever pitch, they have rarely ended in violent conflict, thanks to the country's strong traditions and institutions for legal and legislative conflict resolution. In many developing countries, by contrast, groups that viewed their vital interests at stake in engineering decisions have sometimes resorted to violence to resolve disputes not settled through negotiation or orderly political process. In some cases, engineering projects have deepened inter-group animosities that may have arisen initially for other reasons -- religious, cultural, economic or political.

There have also been positive-sum outcomes, where projects have been designed and decided through processes deliberately aimed at avoiding exacerbation of underlying animosities. Even more proactive are engineering investments designed to create common economic and/or communal interests among groups in societies marked by socio-economic fault lines.

In the most extreme cases (for example, in Iraq and Afghanistan), engineering projects have been implemented in the midst of active warfare, often designed to influence the allegiance of the expected beneficiaries. Engineering in the midst of violent conflict poses a special set of problems for, even personal dangers to, the engineers involved. The US Institute of Peace, the National Academy of Engineering, and other scholarly and professional organizations have for some time been encouraging examination of the role of engineers in conflict environments. This effort has focused on problem analysis processes, coordination among actors with different mandates and capabilities, methods for ensuring the “buying-in” of the relevant stakeholders, and the special difficulties posed by working in situations of active conflict. (The special challenges of engineering in the midst of violent hostilities are outside the scope of this paper.)

This paper and associated panel discussion draws attention to an important aspect that has not gotten sufficient examination: How the *substance* of engineering programs and projects -- location, design, and effects on potential winners and losers -- can worsen, or ameliorate, hostilities in conflicted societies. In these situations, it is important that the engineers involved have the knowledge and tools needed for developing peace-building solutions.

Global climate change is emerging rapidly as a threat to the sustainability of entire ecosystems and patterns of human settlement. Coping with climate change may pose engineering and sociopolitical challenges of historic dimensions. Engineering solutions will be central components for dealing with problems such as emissions reduction, flood control, migration and resettlement of forced migrant populations, coastal erosion, seaport viability, development of alternative energy, and resistance of structures to weather extremes. Inherent in many of these problems is a high potential for social and political, even inter-country, conflict. To help ensure that their technical contributions are appropriate and fully understood engineers will need to learn skills of multi-disciplinary analysis, and how to dialogue effectively with stakeholders and with partners from other disciplines.

The Roles of Engineers

Engineers are found at advisory, decision-making, or design levels in the processes leading up to project realization in conflict situations. Engineers also play important roles in the management and operation of projects once they come on line. While senior engineers will have greater responsibility for decisions and options chosen, professionals at all levels are in position to consider the social and conflict consequences of projects they work on, and to put their views on the table. The individual engineer may be a political office-holder, a civil servant, an executive or employee in a private (local or international) contracting firm, a private consultant, an academic on an engineering faculty, or on the staff of an international development organization. Many engineering fields may be involved in conflict-laden contexts – civil, hydraulic, electrical, transport, mining, petroleum, agricultural, etc. Those responsible for the technical core need to develop a) skills of coordination, negotiation, and communication with stakeholders, b) the ability to take account of environmental, social, and other impact studies, and c) the ability to work in multidisciplinary teams that include expertise in political and social analysis.

The scope for engineers to determine the final design and implementation of a project, therefore, will be determined by the interplay of the preferences of the various players and by where the

influence of the design team's perspectives can be applied. Engineers on the staff of the World Bank, or in an engineering firm contracted by the Bank, for example, might be well positioned to affect the outcome if the Bank's financing is crucial. On the other hand, engineers working within their own government or for a local contractor may have greater say on the domestic policy-making process. Needless to say, the engineer will have wider scope to shape a peace-enhancing outcome where the government also seeks to discourage conflict. Conversely, if a government deliberately pursues a policy that exacerbates internal hostilities, there may be few options to promote amelioration.

The World Bank's experience with hydroelectric and irrigation projects in developing countries shows how projects have had to be developed beyond their technically-defined boundaries to take account of connections with other disciplines, and of possible conflict effects. For years the Bank avoided hydroelectric projects after incurring severe criticism for ignoring bad outcomes for displaced and indigenous people. The Bank resumed hydro projects in the 1990s after adopting safeguard requirements on compensation, and attention to potential conflicts. In fact, the Bank has adopted a set of "Safeguards" in project formulation across the board, requiring project designers to take account of potentially adverse consequences. The safeguards include, for example, attention to problems of international or disputed waterways, potentially adverse social or environmental effects, impact on indigenous peoples, involuntary settlement requirements, and impact on physical cultural resources.

Examples: Exacerbation vs. Prevention

International frictions over natural resource development claims can grow into outright conflict. Examples of areas with worrisome overlapping claims include islands in the South China Sea (with oil-potential), claimed by Vietnam, the Philippines, Japan, and China; northern and southern Sudan (oil production and pipelines); division of water resources among Lebanon, Israel, and West Bank Palestine; and hydro and irrigation schemes along the Mekong affecting downstream countries. Internal conflicts in developing countries - over mineral, land, water and other development projects - have arisen in (among others) Peru, Colombia, India, Papua New Guinea, Mexico, Ecuador, Ghana, and Bangladesh.

Proper engineering solutions can help prevent violent outcomes. Soon after partition separated Pakistan from India in 1947, it became clear that failure to create a system for control and distribution of the Indus River waters acceptable to both countries could result in warfare. The World Bank took the lead in designing, negotiating, and financing a multi-dam irrigation solution. Unfortunately, although the program was adopted and implemented, resolving the Indus dispute, India and Pakistan have had other disputes that have led to recurrent armed conflict.

An unequivocally successful example is the Gal Oya irrigation project in Sri Lanka, built in 1948-1952. The upper arms of the canals watered areas occupied by ethnic Sinhalese, the country's dominant ethnicity, who drew most of the water before it could reach the lower stretches that fed minority Tamil areas. To create a win-win situation, farmer groups were set up to oversee cooperative water distribution, ensuring that the downstream Tamils received enough flow for cultivation. Despite efforts of the Tamil Tigers, the insurgent side in the Sri Lankan civil

war (1983-2009), to persuade Tamil farmers to cease cooperating with their Sinhalese neighbors, the groups held fast. Relations between the Gal Oya ethnic communities remained, and still are, peaceful and mutually beneficial.

By contrast, another Sri Lankan irrigation scheme became a major missed opportunity where engineering works exacerbated rather than ameliorating a deep socio-political conflict. The massive Mahaweli project, begun in 1970, the biggest engineering works in the island's history, was first designed with a channel that would have delivered water to the largely Tamil region of northern Sri Lanka. In 1977 the Sri Lankan authorities redesigned the project to exclude the northern channel. The decision was defended on ostensibly technical engineering grounds, but was seen by the Tamils as demonstrating Sinhalese discrimination and hegemony. The government also favored Sinhalese in the settlement plan for land that would be newly opened by the project. Retaining the original designs of this major project might have helped avert the subsequent political deterioration that spiraled into warfare.

A rural development project in Rwanda that started in 1974 is another example of a missed opportunity that turned out instead to exacerbate tensions. In this case, the benefits (including structures, roads, and land access) were largely captured by local Hutus, excluding Tutsis. The final result was judged by one Africa scholar to be “a great increase in inequality between regions, social classes, groups and individuals.”

In two examples from Thailand, irrigation projects were constructed (in the 1950s-1970s) to win population loyalty in a region that was poor and had been traditionally neglected by the central government. Some were built despite awareness that the projects' economic justifications were dubious. Others were built even though the sponsoring and designing engineering authorities knew that due to poor soil conditions the projects could not even meet minimum engineering standards. In these decisions, the expected social and political benefits were seen as justifying the sub-optimal engineering.

Projects to improve transportation can help develop poor regions. New or improved roads can lower the costs of getting agricultural produce to markets. These projects can also have downsides where they open up areas already inhabited by people previously marginal in terms of economic or political power. New low-cost access can draw developers of large-scale agriculture, cattle-ranching, or resource extraction, who may expropriate the land of the previously isolated inhabitants. This has been a significant problem in Brazil.

As these examples show, there are no cookie-cutter solutions; each project is imbedded in a different and unique socio-political context. The standard methodologies for technical and economic analysis have to be complemented with in-depth local social analysis. Technical sustainability alone will be insufficient. To accomplish this, close inter-disciplinary dialogue will usually be essential.

Examples of Questions in Project Design

To be alert to the relevance of projects to potential conflict, engineers (and others involved in planning and implementation) should take account of factors such as:

1. Is the project located near borders between rival groups?
2. Will the location and design of irrigation channels impinge on divisions between different ethnic (or religious, etc) groups?
3. In the case of international waterways, consider the World Bank's safeguard cautions.
4. The World Bank cautions should similarly be applied to projects in internationally contested areas, and in border-spanning resource development (e.g. natural gas, petroleum, water).
5. Are there external "diseconomies" (e.g. pollution causing health or economic damage) that should be taken into account in the project design?
6. Is a project affecting areas inhabited by indigenous people? How will this affect design, cost, negotiation, and implementation?
7. Will environmental degradation caused by a mining project be avoided or at least minimized?
8. Will there be fair compensation payments/projects for people negatively affected?
9. Will road location raise issues of equity and benefits between favored and bypassed communities?
10. The feasibility of projects often depends on how stakeholders view the potential consequences. Have provisions for stakeholder consultation been included in the design process?

Peace-Building and Engineering Education

Engineering education curricula should be enriched with peace education components, relevant multi-disciplinary materials, and specific engineering case studies and issues, as suggested above.

Engineering schools located at universities with faculties or institutes that offer programs, or advanced degrees, in conflict studies/management, could draw on such capabilities to develop options for introducing a conflict perspective into engineering curricula. For conflict studies programs, exposure of their students to the relevant roles and perspectives of the engineering profession would also be a curriculum enrichment. Engineering schools at universities that do not have resident conflict studies faculty could draw on outside sources such as the US Institute of Peace; Engineers Without Borders; the Engineering, Peace and Social Justice network; the ASEE Engineering Ethics Division, or other relevant organizations, like Global Peace Services USA.

Options for such curriculum enhancement might include the following:

1. A one-day or half-day module requirement: a general introduction to the field of peace studies, both academic and applied. The role of engineering projects and engineers in situations of socio-political tension and conflict. Building in sustainability against the threats posed by stakeholder divisiveness, and by climate change effects.
2. A workshop on options and responsibilities of engineers needing to work with communities, stakeholders, peace-builders, and policy makers, in conflict environments.
3. A two-day "saturation" experience expanding on the above.
4. A full credit seminar (meeting, say, once a week for a semester) during which students would research actual cases to design possible solutions, project location/design alternatives, and

methods for achieving stakeholder buy-in in the specific political and cultural environment settings.

5. Possible special perspectives:
 - a. The unique challenges posed for engineering organizations working in situations of on-going violent conflict, including working with (UN and/or NATO-backed) military forces attempting to resolve hostilities or maintain a peace agreement.
 - b. Coping with the effects of global climate change in many different geographic, climate and settlement environments will require large-scale engineering works and innovative challenges. There may be winners and losers (say, where the effects force large population movements). Different engineering solutions may produce different distributions of benefits and costs, entailing substantial potential conflicts of interest.
 - c. Finally, it is worth noting that inclusion of sustainability and global issues is a recent development in engineering education. It opens up new possibilities for internship with non-governmental organizations and for in-service learning. It also has the potential to engage students with concrete issues of professional ethics, and to provide motivation to be part of a service profession.

Panelists

Robert J. Muscat is an economist specializing in problems of conflict in developing countries and has written the bulk of this paper. He was formerly Chief Economist of the US Agency for International Development and has consulted for the World Bank and UN agencies. He has authored books and articles on Thailand, development aid and conflict, aid effectiveness, malnutrition, population, and other subjects. He received his PhD in economics from Columbia University. He is currently an independent scholar, living in Sarasota, FL. Dr. Muscat is a board member of Global Peace Services (<http://www.globalpeaceservices.org>).

Angela Bielefeldt is a civil and environmental engineering professor at the University of Colorado Boulder and has interests in sustainability, Learning Through Service (course-based service-learning and extracurricular service programs), social responsibility development in students, ethics, and global issues. Her teaching for undergraduate students has focused primarily in the first year and capstone design, with learning outcomes targeting sustainability in all of her courses. She has found that project-based learning is an effective method to achieve a diversity of inter-related, complex learning outcomes. She has also found that case studies can serve as the basis for stimulating students' considerations of complex issues such as ethics and sustainability. A case study that she has used for many years in her first year introduction to engineering course during the ethics module is the story of Fred Cuny from the National Academies Online Ethics Center for Engineering and Science. Fred Cuny used his engineering training in humanitarian work in disaster relief and war-torn areas. She has found that many engineering are attracted to scoring systems and "rules" that reduce the complex ideas of sustainability and ethics to quantification and simplification. However, engineering students must be encouraged to progress beyond their comfort zone if they are to successfully contribute to meeting global challenges for sustainable development, peace, and social justice. Alternatively, other students come to engineering with grand plans to "save the world", and end up leaving engineering as students or later in the workforce – finding that it overemphasizes only technical elements and does not appear sufficiently concerned with helping people and society.

For individuals who persist in engineering, research is finding that their value and aspirations toward social benefits from their work often decreases (Cech; Canney and Bielefeldt; Vesilind; Vesilind and Gunn). What and how we teach our students will help determine if engineers in the future place a higher value on contributing to solutions to pressing social and global sustainability issues.

Donna Riley is Professor of Engineering Education at Virginia Tech. Riley spent thirteen years as a founding faculty member of the Picker Engineering Program at Smith College, the first engineering program at a U.S. women's college, and one of very few engineering programs in a liberal arts context. Since March 2013 she has been Program Director for Engineering Education at the National Science Foundation. Riley's research interests include engineering and social justice; engineering ethics; social inequality in engineering education; the liberal education of engineers; and engineering studies. Riley is the author of two books, *Engineering and Social Justice* and *Engineering Thermodynamics and 21st Century Energy Problems*, both published by Morgan and Claypool. Riley earned a B.S.E. in chemical engineering from Princeton University and a Ph.D. from Carnegie Mellon University in Engineering and Public Policy.

The panel moderator, Rebecca Bates, is the chair of Integrated Engineering at Minnesota State University, Mankato where she directs the Iron Range and Twin Cities Engineering programs. She was a Fulbright Scholar in Brazil and is interested in expanding global experiences for engineering students. She is the current chair of the ASEE engineering ethics division.

Some Questions for Panel Discussion

1. To what extent are engineering schools' curricula addressing these issues, including preparing students for multi-disciplinary professional collaboration? Do the curricula need enrichment in these respects, and if so, how should this be done?
2. Do the perspectives raised here need to be widely understood and considered by the engineering professions, and if so, how could this be accomplished? What institutions/organizations within the engineering community are best placed for leadership roles in such an effort?
3. In the next few decades, global climate change is likely to be a major new source of conflict, and a major subject for engineering responses (and engineering employment). To what extent are engineering schools preparing the next generation of engineers for the central role they will be playing in this area? Does this preparation include appreciation of the social and political complexities involved, including the stresses and conflicts of interest that are likely to be intense?
4. How should engineering research be enriched to integrate these socio-political aspects with the purely technical engineering research subjects?

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