# DEVELOPMENT AND ENGINEERING

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**EXECUTIVE SUMMARY:**

At one extreme, development is mostly about technology: places that have technology are developed and those that do not are not. At the other extreme, development is about creating the economic and regulatory environment for innovation, with no need to explicitly worry about technology as market forces or government projects will naturally exploit technology as needed. In our three-leg view, the purpose of engineering is to create—proactively—the technologies and ecosystems needed to facilitate development. Development to date has been driven by a focus on macroeconomics and governance. Despite potentially huge impacts in clean water, energy generation, health care, education, commerce and good governance, engineering remains outside the development tent. Perhaps this stems from their differences in methodology: engineering is inherently about interventions, while much of social science tends to be purely observational. A movement away from the fundamentally top-down approach of development toward a more decentralized approach enables engineering by promoting a focus on concrete and thus solvable problems. Although engineering should not replace macroeconomics and governance as the fundamental elements, it needs to be a key, on-the-ground player in order to advance the progress of development.

"Technophile" seems to be a disparaging term in development—I have often heard it used to dismiss a viewpoint or even a whole project. As a technophile, I find this not only unfortunate, but representative of a much larger problem in development: the disconnect between development and engineering. The critics applying "technophile" are correct in that technology-led solutions often lack a realistic understanding of the social and cultural issues involved, and that the expectation that technology can magically solve problems is naïve. As we discuss, this implies we need better-educated engineers.

Conversely, the limited expertise for most technologies (and some technophobia) that is pervasive throughout development circles exacerbates mistrust of technology and hinders real development in multiple ways. First, with the exception of grass roots efforts, development has generally been very conservative technically, restricting itself to established technologies designed for different markets and different challenges. Not surprisingly, these technologies are less effective in the developing world, which reinforces a general suspicion of technology. Second, technology advice tends to come from external consultants, which leads to a strong bias toward large centralized engineering projects that, generally speaking, have been unsuccessful and have also come with significant debt.

We make two related arguments:

1. The broad argument that the bottom-up concrete approach of engineering is an essential missing element in development (along with good governance, healthcare, education, macroeconomics, etc.).

2. It is time to revisit (and update) the decentralized development approach of E. F. Schumacher as described in his classic *Small is Beautiful*, which among other advantages enables engineering to be fully engaged in development.

## THE ROLE OF ENGINEERING

At one extreme, the biased technophile's view, development is mostly about technology; places that have technology are developed and those that do not are not. This incorrectly assumes causality, but certainly the correlation is undeniable. At the other extreme, development is about creating the economic and regulatory environment for innovation, with no need to explicitly worry about technology— market forces or government projects will naturally exploit technology as needed. This incorrectly assumes the presence of appropriate technologies, and/or the appropriate ecosystem of vendors and local personnel to exploit technology. In our three-leg view, the purpose of engineering is to create (proactively) the technologies and ecosystems needed to facilitate development. For some technologies, such as agricultural hybrids, this process is already well established, but for "higher" technologies there is much to do.

Before exploring this role further, it is worth looking at the spread of technology. In *Guns, Germs and Steel*, Jared Diamond looks at the root causes of the higher rate of development in Europe and the Middle East that led to the relative strength of Western civilization. One of the proximate causes was the broad east-west trading area that was a geographic advantage of Europe and Asia (compared to other continents). The relatively even climate along the east-west axis enabled the spread of agricultural technology (e.g. better crops) and thus increased the relative rate of development, as different regions could easily assimilate the new crops or technologies. Indeed for many centuries innovations moved along this axis (e.g. the Silk Route).

Extending this observation, the spread of technology requires a certain readiness in the receiver, which includes not only the constituent technologies, but also an environment with sufficient infrastructure and sufficient human capacity and education. A core challenge for development is exactly that developing regions lack the necessary environment. As one example, consider a high-end videoconferencing system that was donated from a European company to a hospital in Africa. The lack of readiness shows up not only in the insufficient electrical infrastructure, but also in the limited local capabilities for maintenance and even transportation. By the time the unit arrived via truck over a terribly bumpy road, it no longer worked; as there was no ability to repair it, it was sent back for a new one. The new one failed to survive the trip and the project was cancelled.

Important exceptions to limited readiness include some of the highly developed urban areas of India and China, which although located in developing countries, can best be viewed as islands of readiness for new technology. In this view, the world is not "flat" at all. The technically advanced areas are arguably in one plane (the "developed plane"), and as with the original east-west axis are well suited for spreading new technologies. On the other hand, the rest of the planet, typically rural, is not in this plane, is not able to exploit new technologies, and is on a path to fall further behind.

In *The Economy of Cities*, Jane Jacobs argues that rural development stems from the movement of technology outward from local cities. It is important to realize that the movement of urban centers into the developed plane breaks this age-old mechanism; such cities become well prepared to develop quickly at the expense of disconnection from their surrounding rural areas. Modern development thus becomes about the worldwide urban-rural divide and about managing the challenges of urbanization, which are likely to become worse over time due to differential development rates.

The role of engineering in development is to bridge this gap proactively with solutions designed with the receivers' readiness in mind. Engineers can solve some of these problems, yet they have never been asked to do so. Although there have always been generic calls for help for developing regions, there have been almost no requests for engineering help.[1] One reason for this is the implicit assumption that market forces will steer engineers to work on the right topics; however, almost by definition the engineers are in the developed plane (even when indigenous!) and their industrialized-nation oriented solutions rarely apply. On the university front, which should be asking these questions, engineering students largely do not realize that the problems of developing regions are within their purview or that problems exist that could benefit even from undergraduate engineering skills.

Ironically, even engineering students in India and China rarely work on development issues. One explanation for this is simply that these students and their faculty measure themselves against the US and Europe: "good" problems are those that are valued by the prestigious conferences, which places the emphasis on the hot topics of industrialized nations. A second factor is that most of the students in these universities have limited

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[1] In fact, some of my engineering friends and students that volunteered after the Indian Ocean tsunami ended up contributing only manual labor, as there was no organized way to make use of engineering talent even though it would have been useful. The same was true to a lesser extent even for visiting doctors.

experience themselves with rural problems; they mostly grew up in the developed plane and aspire to it. We are in the process of evangelizing technology for development as a legitimate research topic within engineering, with the hope that respect for this topic at top conferences will enable such research worldwide.

Fortunately, there are important exceptions to this that provide some guidance. Professor Jhunjhunwala at IIT Madras has led a successful technology for development effort for many years, including work in health care, kiosks, and rural banking. Students at the Dhirubhai Ambani Institute of Information and Communication Technology (DAIICT) in Bangalore spend a semester working in rural areas, which connects them to the real issues, and also makes them excellent partners for our own work in India. These efforts are successful essentially because they connect students not only to the (noble) values of development but also to specific concrete problems.

This "concreteness" is really the core of the disconnect. Quoting Jane Jacobs from *The Economy of Cities* (p. 210):

> "…people who run government activities, the world over, tend to seek sweeping answers to problems; that is, answers capable of being applied wholesale the instant they are adopted. [They] do not seem to bring their minds to bear on a particular and often seemingly small problem in one particular place. And yet that is how innovations of any sort are apt to begin…"

Development to date has been a very top-down discipline, driven by a focus on macroeconomics and governance. There are some strong benefits to this approach, but it also induces some problems. As it is a fundamentally abstract approach, it tends to homogenize vastly different regions, tends to look only at solutions that apply very broadly (the so-called "best practice"), and tends to depend on a third party to deal with "the details". However, the key point here is that the top-down framing generally leaves no room for engineering, or to a lesser extent other relevant concrete disciplines such as medicine or environmental science. These fields are part of the details and only rarely affect the perceived options or the approaches taken, and even more rarely create *new* options.

It is unrealistic to have a single development conversation that is both broad (as it is now) and deep (as implied by the participation of concrete disciplines), although some movement in this direction would be good. More realistic is to promote an environment with many smaller conversations that share values and ideas. In fact, it can be argued that much of development is already happening through small conversations – the local (focused) NGOs, the student projects, and the diaspora-led projects that make progress on many fronts every day. In these conversations, engineering and medicine can and do play a role, and thus we believe these conversations are the path forward.

This framing issue can be seen in *The Fortune at the Bottom of the Pyramid* by C. K. Prahalad, despite its generally positive view of the role of engineering in development. First, the basic view is that there is a large homogeneous group, the "bottom", that forms an untapped market for multinationals. The path to include engineering is to define development problems as market problems so that market forces will cause the right engineering to occur. This can be a great approach and certainly should be tried often.

However, market forces are already pretty good at finding new markets and in fact have spread new technology well in urban areas (in turn increasing homogeneity). In rural areas, however, the "bottom" is actually a hugely fragmented population with different languages and values, which limits the approach and implies the need for small conversations.

Our own work with the Aravind Eye Hospital, one of Prahalad's case studies, worked exactly this way: a small conversation on their specific challenges followed by the development and deployment of a technically novel solution—a "new option". In fact, we had many conversations with them, but we had limited traction until we found the right one (telemedicine). Furthermore, it took many refinements on many fronts to find a sustainable solution that took into account issues with power, capacity building, spare parts, user interface, remote management, etc. To really bring engineering to bear on development challenges, we need this fundamentally bottom-up approach—engineers are best at solving specific, well-defined problems. Aravind also developed much of the technology itself, including the optics to convert a digital camera into something suitable for retina imaging. Both the conversation and Aravind's own work highlight the importance of indigenous engineering capacity, which forms an important part of the long-term role of engineering in development.

## SMALL IS MORE BEAUTIFUL THAN EVER

In his classic book *Small is Beautiful,* E. F. Schumacher promoted a different kind of development that was fundamentally distributed and decentralized. His arguments included localized needs, the dignity of independence and good work, and a belief that local stewards using local resources would be better for the environment. He argued strongly against powerful centralized industries that tend toward dehumanizing work and unsustainable use of natural resources. His approach included both smaller administrative domains, as a way to maintain some friction against ever-larger efforts, and limited "appropriate" technology for local jobs rather than highly efficient centralized technology that would lead to unemployment.

In the past, the appropriate technology movement evolved to be somewhat anti-establishment and at odds with mainstream development groups. However, there is no fundamental conflict between the bottom-up localized view promoted here and large development players such as the World Bank or USAID. For example, we have current project with USAID in Guinea-Bissau that uses novel technology to connect community radio stations, which in turn promotes transparency and supports the local language. The solutions were derived locally and bottom-up, with the engineering led by African engineering students, assisted by Berkeley students.

The technophile view of technology differs some from Schumacher even if we accept the goal of limited efficiency to promote employment. Although this goal is against classic economics, it certainly fits well with the views of many in developing regions. We have had many interactions with people worried about labor-saving practices (technology induced or not), including both the financial and the dignity aspects of working. In one project in Cambodia that was slowly losing funding, we saw the staff at a rural kiosk repeatedly choose to keep everyone working part time until the whole staff was working only a few hours a week each, and in sum, well less than one whole job. Similarly, students new to development regularly (and sincerely) suggest labor-saving ideas; after one such suggestion, the response from a rural Indian woman was "What will those people do?"

Thus although the "appropriate technology" movement, inspired by Schumacher's work, is associated with relatively simple technology, Schumacher's argument was actually against large-scale technology for efficient production and not against advanced technology per se. Furthermore, the use of technology in developing regions has become more complicated since 1973, including the broadly successful use of very advanced technology in the form of cellular phones. Cellphones actually promote the kind of local development Schumacher sought— they make local workers more efficient, and seem to increase dignity as well.

Another example is Kenya's burgeoning home solar market. These solutions are "appropriate" along many dimensions: they are not too complicated to use or maintain, they enable local, green power generation, and they have created rural jobs. However, solar cells are clearly high technology and a hot topic of research and development in industrialized nations. The key point is that appropriateness has more to do with the complexity of usage than the complexity of creation. And technology that is inherently more complex can be easier to use in practice, such as an oven with a thermostat rather than a wood stove.

*We argue that the time has come for a return to decentralized development, but one that exploits advanced technology, rather than shuns it.*

The decentralized approach has several other advantages besides enabling engineering: solutions are inherently localized, tend to have community "buy in" and thus permanence, and can create the local capacity to manage a new solution as needed. The rise of the Internet and cellular service has simplified finding and supporting local groups, simplified the distribution of information and training, and has enabled the diaspora to contribute despite their separation. Also important is the rise of microfinance, which can be viewed as decentralized financial services that provide local capital in a scalable way.

In addition to cellular phones, it is clear that decentralized information and communications technology (ICT) will continue to have a huge impact on development. Wireless connectivity (in many forms) is arguably the first affordable rural infrastructure since dirt roads. Rural areas normally do not have the population density necessary to make infrastructure economically viable, including both electricity and water distribution. But wireless costs are low and falling – connectivity is already viable for some rural areas and will spread naturally over time as the costs drop. We have hypothesized that the spread of connectivity infrastructure may lead to enough economic development (through jobs, remittances, etc.) to lead to other forms of infrastructure. In addition, thanks to the ongoing progress of Moore's Law, we can expect that the computing power of a cellular phone will become an essentially free local resource.[2]

[2] Moore's Law, attributed to Intel Co-founder Gordon E. Moore, is based on an empirical observation he made in 1965 and states that the number of transistors in an integrated circuit doubles every 18 months, implying a doubling in capabilities at roughly the same rate.

Beyond ICT, many other engineering and scientific fields can contribute to decentralized development. Mechanical engineering has been a primary focus of appropriate technology (and Schumacher's related term "Intermediate Technology") since the beginning. Typical projects include pedal-powered pumps, small hydroelectric turbines, and simple mills. Taking our technophile view, there are potentially huge gains to be had via both modern mechanical engineering and related newer fields such as materials science and nanotechnology. We are looking at Sterling engines to create energy from heat (including solar), and many remarkable nanotechnology projects, including energy generation directly from heat via molecular conversion, and advanced but very easy to use antibacterial water filters.

Clean water and sanitation are broadly in need of advanced technology, especially for decentralized "point of use" water treatment solutions. These solutions avoid the issues of water distribution and leverage local water supplies for clean water. Kara Nelson at UC Berkeley has developed a variety of mechanical and biological approaches to point-of-use clean water, and there appears to be many relatively unexplored high-tech approaches to sanitation, including even local energy generation.

Despite potentially huge impacts in clean water, energy generation, health care, education, commerce and good governance, engineering remains outside the development tent. A movement toward a more decentralized approach *enables* engineering by promoting a focus on concrete and thus solvable problems. The top-down views of governance and macroeconomics are still critical (and probably more important overall), but they must be complemented with a bottom-up, solution-oriented approach that is inherently tied to the real problems on the ground.

## Some Recommendations

We conclude with some recommendations for both development groups and universities (in no particular order).

- NGOs and development agencies need to increase their understanding of technology (broadly construed). Although there are some exceptions, very few development groups understand technology or its potential impact on development. It is not sufficient to leave technology to the implementation contractors or to outside consultants.

- Funding agencies need to promote technology creation and specialization that specifically targets development (particularly rural development). Funding needs to occur exactly where (industrialized nation) market forces are not leading to appropriate solutions, including ICT, clean water and sanitation, energy generation and storage, rural healthcare, and educational technology.

- We need a broad call to young engineers that their services are relevant and needed. At Berkeley, we refer to this idea as the "Technology Peace Corps," with the idea that young technically savvy people would help with technology projects and training throughout the developing world. Such a mechanism addresses not only decentralized development, but also inspires engineering students to consider development-oriented careers in other ways as well.

- Universities need to connect the engineering problems of developing regions to the modern curriculum. Unlike the key problems of industrialized nations, these problems are approachable easily at the undergraduate level; obvious fields including mechanical engineering, civil and environmental engineering, and electrical engineering and computer science.

- The challenges of developing regions are inherently multidisciplinary, and the integration of engineering into development has to start with this kind of cooperation. Although easy in theory, this is quite challenging in practice for several reasons and thus will take a concerted effort. First, engineering is inherently about interventions, while much of social science tends to be purely observational. Second, thanks to increasingly early specialization, there is limited overlap of common ideas and vocabulary between engineers and social scientists—it is literally hard for the two groups to communicate well. Universities should take the lead here as well, aiming for a new generation of "development oriented" engineers.

- Engineers can only solve problems that they understand. It will likely take a whole generation to produce engineers that really understand the issues of development, including how to account for social and cultural aspects, and how to create authentic participation, capacity building, and sustainable ecosystems around new technologies. For the immediate future, we need a humble iterative approach to problem solving: instead of designing a solution and deploying it (the current model), we must steer to the right solution through a series of small steps. With each step we incorporate more local feedback and refine not only the solution but more importantly the definition of the problem.

Finally, I close by admitting that making the connection between engineering and development is not easy. There is much to learn for engineers, myself included. I have tried to avoid the most egregious misunderstandings of development and social science, but to the extent I have failed please forgive me and view it as evidence of the need for a stronger connection.