# Chapter 4
# Engineering Brazil: National Engineering Capability at Stake

**Édison Renato Silva, Roberto Bartholo, and Domício Proença Jr**

**Abstract** This presentation of Brazilian engineering sketches its trajectory in the nineteenth, twentieth and twenty-first centuries. Well into the nineteenth century, engineering was unwelcome in Brazil: its agricultural slaver society had little use for it. Although the oldest engineering school in the Americas was founded in Rio de Janeiro in 1792, Brazilian engineering was an unwanted novelty. It took Vargas' 1930 dictatorship to bring about Brazilian engineering. Engineering in the Brazilian context became more than buildings and machines. It emerged as the core of institutional innovations, as a tool of a national development project. It bloomed in the late 1950s, leading to almost half a century of accelerated industrialization. A peculiarity of this contextualized process was the leading role of graduate studies over undergraduate education, and its emphasis on intervention in Brazilian reality in engineering education. Since the beginning of the twenty-first century, however, a new political coalition seeks to redesign the institutionality of federal universities in Brazil, jeopardizing the future of Brazilian engineering and putting national engineering capability at stake.

**Keywords** Brazil • History of engineering • Engineering education • National development • National engineering capability • Engineering policy

## Introduction

This chapter sketches the changing contexts of engineering activities in Brazil in the nineteenth, twentieth, and twenty-first centuries. It divides this history into three periods according to the role and place of engineering in Brazilian society.

É.R. Silva (✉)
Industrial Engineering Department, Escola Politécnica/UFRJ,
PO Box 68507, Rio de Janeiro, RJ 21941-972, Brazil
e-mail: edison@ufrj.br

R. Bartholo • D. Proença Jr
Production Engineering Program, COPPE/UFRJ,
PO Box 68507, Rio de Janeiro, RJ 21941-972, Brazil
e-mail: bartholo.roberto@gmail.com; domicio@centroin.com.br

© Springer International Publishing Switzerland 2015

S.H. Christensen et al. (eds.), *International Perspectives on Engineering Education*,
Philosophy of Engineering and Technology 20, DOI 10.1007/978-3-319-16169-3_4

The presentation follows four interpretative keys that illuminate different facets of engineering: practice, education, development, and national engineering capability.

In 1500, Portugal colonized Brazil, beginning "economic cycles" of exploitation: Brazil-wood from trade with natives, sugar, then gold, and then coffee with African slaves. On the wake of the exile of the Portuguese Imperial court to Rio de Janeiro from 1808 to 1821, Brazil became independent under the heir to the throne of Portugal, Peter I, Emperor of Brazil, in 1822.

Engineering *practice* explains the distinction between Engineering *in Brazil* and *Brazilian* Engineering. Engineering in Brazil describes works that serve exploitation, with no concern for local prosperity or national development. Brazilian Engineering describes the pursuit of national interests, directed, and often carried out by Brazilian engineers. These might be engineering, without qualifiers, in developed countries; but the distinction is opportune for developing ones.

Engineering *education* followed practice. All engineering education took place abroad, with occasional local training of auxiliaries, until it became expedient to facilitate replacements locally. This was the rationale, and illuminates the restrictions, of the first engineering school in the Americas, established in 1792 in Rio de Janeiro. The Army School of Artillery, Fortification, and Drawing trained military officers for State-mandated civil engineering works. Private works relied on self-styled "practical engineers".

Brazilian *development* became a burning issue by the late eighteenth century. Colonial exploitation in "cycles" lacked any concern for enduring prosperity. Foreign trade, ironworks, industry, the press, and universities were forbidden. The logic of empire was monopolistical exploitation until riches gave out, leaving regions destitute in its wake. However, Brazil had an inland economy largely insensible to imperial priorities. The combination of successive "cycles" with an independent economy made development a longstanding concern. It offered a bright line for appreciating the economic and political significance of engineering.

Hence, the presentation offers a synthetic characterization of the role of engineering and engineers in Brazilian society, appreciating practice, education, development, and national engineering capability. It addresses three periods: the first, in which Brazilian Engineering can be described as an unwanted novelty; the second, in which federal universities made it a tool of State-led national development; the third, in which a new political coalition seeks to redesign the institutionality of federal universities in Brazil.

## Engineering: The Unwanted Novelty

The nineteenth century Brazilian repugnance to manual labor accorded with that of most slaver societies, holding it as the mark of the slave, favoring idleness and the alleged elevation of the law as fitting activities of gentlemen. The abundance of cheap slaves and the continuity of centuries-old solutions made engineering improvements seem superfluous. From the 1820s, the "cycle" of coffee moved slaves and prosperity from sugar to coffee producing regions. Rail allowed coffee

farms to spread away from the coast. There was no gradual passage to modern transportation. Rail arrived suddenly, bringing as if by magic the full panoply of industrial production, of communications, of travel. It imposed trade, goods, news, books, free laborers, technicians, and engineers on slave plantation communities. Gilberto Freyre, one of Brazil's most insightful authors, remarked in his Preface to the Catalogue of the Center for Preservation of Railroad History "to talk of rail … is to talk of a whole socio-cultural complex. Not just material engineering, but engineering that unfolds into human and social engineering" (Freyre 1982, *apud* Telles 1993, p. 119). Rail also contributed to questioning long-standing social power relations in terms of race. Telles (2009, p. 86) points out to how scandalous it was, in the construction of Paranaguá-Curitiba Railway, that the chief engineer was a dark-skinned half-breed, Antonio Rebouças, leading German engineers such as Peter Scherer, Mauricio Schwartz and Julio Kallman.

Rail changed the *practice* of engineering and the place of engineers in society, making them necessary and, like military engineers, tolerated, even commemorated. But this did not make engineering a gentleman's profession. Enrollment in Law remained five times that of Engineering through the late nineteenth century. Engineers had to know their place. Just because they were there, this did not mean they would change things just because they could. Engineers faced hindrance and death threats when they tried. In that very substantive sense, rail, employing 75 % of all engineers in 1880, remained a case of Engineering in Brazil: a tool for exploitation of riches.

There was a single Army school for engineers, which split in 1874 into schools for military and civilians – the *Academia Militar* (Military Academy) and the *Escola Central* (Central School) respectively, both offering free-ride courses through competitive examination. Engineering *education* stood aloof from engineering practice. Contents were very narrow, for the most a single curricular track that preserved an eighteenth century logic of "mathematics, physics, and natural science": rote learning with bouts of "practice", full courses as small as 2 years' duration. Bibliography was dated and predominantly French. The very structure of engineering education was inspired by the French model. That the civilian school was to be an *Ecole Centrale* intimated a subordination, presumably to the military one. But soon the civilian school gained ascendancy, and like the capstone of the French system, became a *Polytechnique* – the *Escola Politécnica*. But the French emphasis on a measure of mathematics side by side with a measure of broad, general understanding remained. Railroad engineering specifics and mechanics seem to have been left up for on-the-job training – engineering education was behind the times. One should be cautious, however, in seeing more than inspiration in this: French influence was pervasive, but diffuse, its interpretation open to local adaptation rather than following formal precepts or implementing models (Bethell 1986).

Rail offered boundless prospects. It promised *development*: an end to exploitation. For Brazilians, development meant *industrialization*. Brazilians dreaded the fate of selling fashionable commodities, hostage to the whims of importers, exhausting successive riches with little left afterwards. But there were problems, the most important of which proved to be neither financial nor technical, but institutional. Painfully, slowly, Brazilians came to realize that no amount of Engineering in Brazil,

importing engineers or turnkey factories, could hope to achieve their goal (see Freyre 1988). With development at stake, they realized the need for Brazilian Engineering, capable of more than replication. They had to pursue not one, but two goals: industrialization, yes, but through *national engineering capability*.

Brazilians had to go beyond the illuminist motto of "thinking with our own heads" to add "… and doing with our own hands". This meant deliberate, conscious social engineering, abolishing slavery and changing the laws to introduce the dignity of labor, free enterprise, and industry to a slave-holding, agricultural, oligarchical society. The Republic came about in 1889 in a military coup, and the military shared the same vision. The Army began sending a few engineers a year abroad, to learn about something which would not become a reality for half a century, despite many failed attempts: how to make steel.

## Engineering: Nation-Building

The Republic led to a brief war between Army and Navy, after which the "Old Republic" emerged to try to restore oligarchical power. But something had began which could no longer be prevented, only delayed. In 1930, Getúlio Vargas seized power as dictator until 1945, returned elected president in 1951, committing suicide mid-mandate to prevent a coup in 1954. Vargas capitalized on decades of institutional innovation efforts and ideas to implement an ambitious national development project to industrialize Brazil. The coup came in 1964, inaugurating a quarter century of military rule, which kept largely true to Vargas' ambitions.

In 1930 Brazil, the beginning of the Vargas Era, engineering was an activity open to all comers, just as it had been during the Empire. Experienced foremen, "practical engineers", and charlatans were as entitled to *practice* engineering as diploma engineers. Specialized tasks might require formal qualifications, but they were few. However, electricity and ferroconcrete led to a radical change in the context of practice. Both required calculations, which foremen and practical engineers could not handle, and which scared charlatans. Federal Decree 23569 of December the 11th, 1933 made a diploma from acknowledged national universities (with provision for the validation of foreign diplomas by those universities) compulsory for the legal exercise for the practice of any engineering. This institutional framework heralded the maturity of Brazilian Engineering – engineering was a profession organized, supported and accountable to the State.

Engineering *education* took a peculiar turn: schools and colleges were formed into universities under federal administration ("public universities") with tenured faculties and substantial budgets, offering free-ride education through national competitive examinations. Universities began to participate, to anticipate, to shape. Under Vargas, all Brazilian engineering schools were called upon to prepare and undertake major projects. The Empire had but two: the civilian *Escola Central*, later the *Politécnica*, and the *Academia Militar*. The *Escola de Minas de Ouro Preto* (School of Mines of Ouro Preto) would become an engineering school in the

twentieth century, but under the Empire it was a research institution, specialized on Brazilian geology. On the decades following the Republic, many others were created. By Vargas' time, there were 14 engineering schools in operation. They began to work with State and private firms. Policy decisions relied upon public engineering schools to assess which opportunities could lead to development – and to provide personnel and knowledge to pursue them. Brazil was awarded its first steel complex for joining the Allies in 1943, and there were qualified Brazilian engineers for all aspects of its operation and expansion. This was the outcome of 50 years of anticipation by the Army and the ready support of public engineering schools. Conversely, Brazil's 1950s "Fifty Years in Five" program, despite the multiplication of universities and engineering schools, revealed that engineering research capability was lacking. "Fifty Years in Five" was an overambitious modernization based on a radical import-substitution model. Being merely up to date with the present proved insufficient when possible futures were at stake – capability had to be prepared ahead of needs.

In the 1960s, Coppe, part of the Federal University of Rio de Janeiro, started graduate programs tailored to specific policy priorities and in anticipation of engineering needs. It developed frameworks to manage the finance and execution of projects. Petrobras' need for underwater robots exemplifies such a collaboration. Brazil alone had to deal with deep water off shore oil exploration. There were no solutions abroad, nor interest in developing such solutions. Brazilian Engineering alone could dare to provide it. It took many years – many projects, thesis and dissertations – to formulate, engineer, and then implement a solution. Much of this work could not be made public until there was a solution, for industrial and national security issues.

From the early 1970s, graduate engineering departments took the lead in engineering education, practice, and research, defining new undergraduate specialties, forecasting and providing for possible Brazilian Engineering needs through foundations, expedient parallel structures for managing funds that did not derive from the federal budget. From 1964 to 1988, the Military Regime pursued initiatives to bring Brazil to the same level as the developed countries. Some would blossom, such as Brazil's quest for oil autonomy, began by Vargas in the 1950s; others flounder, such as Brazil's hope of domestic autarchy in computing in the mid 1980s.

Vargas' national development project relied on State-led initiatives. He reorganized undergraduate education on federal universities as part of free-ride education in all levels; modernized labor, professional, union, and public service legislation and standards; streamlined and formalized Brazil's national policies and foreign relations; established national monopolies in steel and oil; tried the same in electricity, navigation, and railroads. But Vargas' most telling institutional innovation was the National Development Bank (BNDES), to provide capital for investment in national priorities. The same intent supported Finance for Study and Projects (FINEP), the primary source of funding for engineering projects in Brazil.

Engineering capability in the narrow sense was necessary, but insufficient: development required engineers capable of pioneering, groundbreaking projects. Most engineering research takes place in federal public universities, particularly in

graduate departments, which rely on foundations to propose, contract, organize, regulate, and manage projects. Brazilian development was a century-long struggle against traditional privileges. It bred the informal motto "there is everything left to be done".

## Engineering: Institutional Redesign

The Military Regime ended in 1988. A neoliberal agenda became predominant in the 1990s. National plans and policies became less directive, with expectations that the market would find the best path to prosperity. Privatization dismantled whatever coherence or rationale might have existed among the large state-owned firms inherited from Vargas and expanded through the Military Regime. This has led to substantial change in Brazil's engineering context.

Today's panorama of engineering *practice* offers contrasting realities. There are sectors in which Brazilian Engineering predominates, making opportunistic and more or less integrated use of Engineering in Brazil, such as oil & gas or agribusiness (including biofuels), and, to a lesser extent, construction, mining, and aeronautics. There are sectors in which Engineering in Brazil predominates without prospect of ever leading to Brazilian Engineering, such as capital goods, automobiles, electro-electronics. As nineteenth century Brazilians were wont to acknowledge, there is more to engineering than operation and maintenance – there is design, there is ambition. Car manufacturing has been one of the largest economic and exporting sectors in Brazil for 50 years. However, it is not, and there is no real prospect that it will ever become, more than "made in Brazil" – the specter of *maquiladoras* – assembly plants in which cheap local labor work to assemble imported components into products. Further, the example of South Korea, which leveraged its Engineering to world-class standards over the last decade after building cheaper, low-cost cars to finance its development, raises many galling issues about Brazil's current choices.

Brazilian *education* policy has changed over the last 15 years. This is an ongoing process that continued even after the assumption of power by a new political coalition. It expresses a varied set of agendas, in part justified by misinformed scientometrics, in part conditioned by political goals of social inclusion, in part obedient to privatization interests, in part expressing ideologically motivated interventions on federal institutions. They come together through three main vectors:

1. CAPES, an agency of the Ministry of Education, grades graduate activities every 3 years, assessing faculty and student performance. It adopted unified criteria for all disciplinary areas in 1998, which have made publication in indexed (ISI-JCR) journals the paramount measure of performance. CAPES grades have become the overriding input to the creation, certification, and funding of graduate activities, and for qualification in federal initiatives.
2. Starting 2003, education policy for federal undergraduate education has changed from providing cadres for development to the universalization of access to

university courses, taking increased student population as proxy for social inclusion. Increased enrollment has complete priority over educational quality, as expressed by the multiplication of courses in, and "advanced *campii*" by, existing universities, the creation of new federal universities, and the use of federal funds to support enrollment in private universities, far outstripping that in public universities. Federal public universities' courses are being biased toward supposed operational employability: training, rather than education.

3. Starting 2008, federal comptrollers, who hold powers of autonomous inquiry, have repeatedly denounced federal public university freedom of project and enterprise as improper, choosing to hold individuals responsible for allegedly illegitimate or illegal institutional decisions. This ongoing political controversy clashes with Constitutional university autonomy, enshrined in Article 207. Animated by non-academic politico-ideological convictions of their own about what the role of university *should be*, comptrollers continue to question contract, funding, fund-raising or financial management by university foundations.

To assess engineering graduate activities primarily by publication misunderstands the nature of engineering. Engineering does involve the production of knowledge, but in the final analysis it is change in reality that matters. Engineering cannot be reduced to knowledge production. Engineering knowledge, in turn, cannot be reduced to scientific knowledge. Hence, the performance of graduate engineering departments cannot be assessed by the number and trend of publication in indexed scientific journals every 3 years.

To choose quantity over quality, mass over cadres, training over education is a valid policy decision. However, such an expansion of student population in federal universities and the dilution of federal education resources makes it difficult to keep pace with the cutting edge and to provide for, or anticipate, future needs – imperiling Brazil's future engineers' project capability.

Comptrollers' conception of federal universities devoid of supporting foundations leads to isolation from economy and society through the strangulation of engineering projects as part of academic activities. Considering the last century of engineering experience in Brazil, this would entail material, human and social impoverishment.

CAPES' standards are valid to all universities in Brazil – a broad spectrum that comprises privately-owned universities, ran as businesses; "communitarian" universities, associated with a given creed or faith, ran as businesses; and public universities, which offer free-ride courses: these can be owned either by the individual federal entities within the Union (state universities or municipal universities) or by the Federal government (federal universities). However, the drive to enrollment expansion and comptrollers' charges against autonomous financial management by university foundations applies *only* to federal universities. In all states but one, federal institutions are the core of university education and research. It is only in the State of São Paulo that state universities rank with federal ones. As a result, it is impossible to avoid discussing federative implications, particularly for engineering.

Top-ten engineering departments in Brazil belong to public universities: eight are federal, two are state universities in the State of São Paulo. The combined effect of the above three restrictions discriminates strongly against federal universities. Should they persist, they would endow the State universities of São Paulo with *de facto*, even conceivably *de jure* exclusivity on the freedom to pursue quality education and manage its relations with Brazilian economy and society. This outlines a major shift in the Brazilian Engineering context. It seems impossible to avoid the conclusion that it would substantially diminish Brazil's national engineering capability, with the future of Brazilian Engineering at stake.

## Conclusions

It took one and a half centuries of struggle to bring about Brazilian Engineering, a century for engineering education to catch up with engineering practice, half a century more for it to become capable of meeting policy priorities, shaping and anticipating engineering needs, and yet it may take less than a decade to cripple it. This presentation of engineering in the evolving, willful Brazilian context amounts to a story of "engineering Brazil", touching practice, education, development and national capability over two centuries. What would be the moral of this story? The past exemplifies a moderately successful tale of a peripheral country's break with its colonial legacy, seeking national development on a long term basis, highlighting the value of staying the course. The present gives evidence of how easy it is to imperil dynamics that sustained over half a century of burgeoning development. Ultimately, the future might turn out to be a terrible cautionary tale on the prerequisites, demands, potential, achievements, and frailty of a national engineering policy.

## References[1]

Alder, K. (2010). *Engineering the revolution arms and enlightenment in France, 1763–1815*. Chicago: University of Chicago Press.

Bethell, L. (Ed.). (1986). *The Cambridge history of Latin America, Volume 5: c. 1870–1930*. Cambridge: Cambridge University Press.

[1] A note appears the best way to annotate the synthesis presented above. The reconstruction of Brazil's history is grounded on Gilberto Freyre (1933/2005, 1959, 1987), Celso Furtado (1959/2009) and Sergio Buarque de Hollanda (1936), with François Chevalier (1977) and Leslie Bethell (1987, 1989, 1995, 2008). The history of Brazilian engineering is far more fragmentary, with pride of place for the ongoing efforts by Pedro Carlos da Silva Telles (1993, 1994, 2009, 2010), to which Paulo Pardal (1984, 1986) adds detail, and which benefits of Schultz (2001) and Alder (2010) for the role of French inspiration. The issue of steel benefits from memories of the free-docent thesis of Maria Luiza de Carvalho Proença, Domício's mother, towards full professorship, no copy of which survives. Silva & Proença Jr. (2013) offers a more extensive and annotated presentation on CAPES and Engineering with both documentary and critical references.

Bethell, L. (Ed.). (1987). *Colonial Brazil*. Cambridge : Cambridge University Press.
Bethell, L. (Ed.). (1989). *Brazil: empire and republic, 1822–1930*. Cambridge: Cambridge University Press.
Bethell, L. (Ed.). (1995). *The Cambridge history of Latin America, Volume 6, Part 1: Latin America since 1930: Economy and society*. Cambridge: Cambridge University Press.
Bethell, L. (Ed.). (2008). *The Cambridge history of Latin America, Volume 9: Brazil since 1930*. Cambridge: Cambridge University Press.
Chevalier, F. (1977). *L'Amerique Latine de l'independance a nos jours*. Paris: Presses Universitaires De France.
Freyre, G. (1933/2005). *Casa-Grande e Senzala* (47th ed.). São Paulo: Global.
Freyre, G. (1959). *Ordem e Progresso,* two volumes. Rio de Janeiro: José Olympio Editora.
Freyre, G. (1987). *Homens, engenharias e rumos sociais*. Rio de Janeiro: Editora Record.
Freyre, G. (1988). *Ferro e civilização no Brasil*. Rio de Janeiro: Record Editora.
Furtado, C. (1959/2009). *Formação Econômica do Brasil*. São Paulo: Companhia das Letras.
Hollanda, S. B. D. (1936). *Raízes do Brasil*. Rio de Janeiro: Olympio.
Pardal, P. (1984). *Memórias da Escola Politécnica*. Rio de Janeiro: Escola Politécnica da UFRJ.
Pardal, P. (1986). *140 anos de doutorado e 75 de livre docência no Ensino de Engenharia no Brasil*. Rio de Janeiro: Escola Politécnica da UFRJ.
Schultz, K. (2001). *Tropical Versailles: empire, monarchy, and the Portuguese royal court in Rio de Janeiro, 1808–1821*. New York: Routledge.
Silva, É. R. P. D., & Proença Júnior, D. (2013). *Os indicadores CAPES na Engenharia arriscam a perda da capacidade de projeto do Brasil*. Rio de Janeiro: Édison Renato Pereira da Silva.
Telles, P. C. D. S. (1993). *História da Engenharia no Brasil, v. 2, Século XX* (2a ed.). Rio de Janeiro: Clavero.
Telles, P. C. D. S. (1994). *História da Engenharia no Brasil, v. 1, Séculos XVI a XIX* (2a ed.). Rio de Janeiro: Clavero.
Telles, P. C. D. S. (2009). *História da Engenharia Ferroviária no Brasil*. Rio de Janeiro: Notícia & Cia.
Telles, P. C. D. S. (2010). *Escola Politécnica da UFRJ, a mais antiga das Américas, 1792*. Rio de Janeiro: Synergia.

**Édison Renato Silva** M.Sc. and D.Sc. in Production Engineering, Coppe, Universidade Federal do Rio de Janeiro, The University of Brazil, Rio de Janeiro. Adjunct Professor, Industrial Engineering Department, Escola Politécnica, Universidade Federal do Rio de Janeiro. He was nominated 2014–2015 International Scholar of the Society for the History of Technology. His main research interests include the history and epistemology of engineering, design research and methods for systematic literature review.

**Roberto Bartholo** M.Sc. in Production Engineering, Coppe, *Universidade Federal do Rio de Janeiro*, The University of Brazil, Rio de Janeiro, and Dr. in Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany. Professor, Production Engineering Program, Coppe, Chairman, The Laboratory for Technology and Social Development (a multi-institutional national research group), *Universidade Federal do Rio de Janeiro*, The University of Brazil, Rio de Janeiro. Senior Visiting Researcher and Chairman, Production Engineering and Local Development Network, *Universidade do Estado do Amazonas* (Amazonas State University). Coordinates the *Network Africa-Brazil Dialogues on Social Innovation,* with fellow researchers in the Cape Peninsula University of Technology, South Africa, University of Botswana, Makerere University, Uganda, University of Nairobi, Kenia and Université Mohammed V, Maroc. Coordinates the Brazilian research group in the Choices Project: *Leveraging Buying Power for Development – Ethical Consumption and Sustainable Procurement in Chile and Brazil.*

**Domício Proença Jr** M.Sc. in Science and Technology Policy and Politics and DSc in Strategic Studies in Production Engineering, Coppe, *Universidade Federal do Rio de Janeiro*, The University of Brazil (Rio de Janeiro). Awarded the Brazilian Order of Merit (for National Defense). Professor, Production Engineering Program, Coppe and Public Policies, Strategies and Development Program, Institute for Economics; Chairman, The Group for Strategic Studies (a multi-institution national research group), *Universidade Federal do Rio de Janeiro*, The University of Brazil (Rio de Janeiro). He has the first Brazilian Ph.D. in Strategic Studies, and has worked for 25 years in research, education, policy advice, private consulting and the media in subjects related to international security, national defense and public security; he has published on war, technology, arms industry, strategy, peace missions, drug trafficking, police organization and policy, guerilla and terrorism.