Technology Assessment in Developing Countries: The Case of India—Examples of Governmental and Informal TA

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1 Introduction

Technology assessment (TA) has a rich history of more than fifty years. Especially, in many developed countries, TA is part of the institutional framework surrounding science, technology, and innovation (STI), or part of the policy advice system that enables parliaments to understand, debate, and decide on STI issues. TA is a generic term and there is a broad variety of different types and practices of TA (cf. van Est & Brom, 2012). TA can be considered as a stand-alone exercise or policy tool, or may be used with other policy tools, including analysis of ethical, legal, and social issues (regularly abbreviated as ELSI). According to Grunwald, TA should "enrich technology governance by integrating any available knowledge on possible side effects at the early stage of decision-making processes, by supporting the evaluation of technologies against a broad set of societal values and ethical principles, by elaborating strategies to deal with the inevitable uncertainties, and by contributing to the constructive handling of societal conflicts" (Grunwald, 2019, 702). He also suggests anticipation, inclusion, and complexity as three conceptual dimensions of TA (Grunwald, 2019, 704).

In most developing countries, TA is weakly institutionalized, or not at all. This has little to do with the fact that TA is not relevant for developing countries. For example, in the context of the UN Millennium Development Goals (MDG), Ely et al. (2011) underscored the need for TA for developing countries. Moreover, UNCTAD,

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which is the part of the United Nations Secretariat dealing with trade, investment, and development issues, currently sees a growing interest in TA and points out its relevance for sustainable development. In 2021, UNCTAD (2021, 82) launched the project, "Technology assessment in the energy and agricultural sectors in Africa to accelerate progress on Science, Technology and Innovation," which aims to build capacity in three African countries to carry out technology assessments in the energy and agricultural sectors, and to utilize technologies as catalysts for sustainable development. If TA is to contribute to sustainable development, particularly in meeting the UN Sustainable Development Goals (SDGs), what needs to be done? If we see TA as an important practice for developing countries, then how can that practice be institutionalized? And if developing countries do not have robust STI policies, and have weak institutions for doing TA, will the typical TA approach work, or is a modified form of TA needed?

This chapter examines TA in India, as an example of a developing country, and describes various types of TA being undertaken by different actors. It is argued that in developing countries like India, where the state plays a major role in stimulating and regulating STI, civil society may provide an important alternative perspective on STI, which may lead to STI becoming a contested terrain. Societal engagement may also support alternative forms of innovation that are not initially recognized by the formal innovation system. In this way, civil society may pave the way for more participation in STI and/or may lead to a further institutionalization of TA practices—similarly to what happened historically in European countries such as Denmark and the Netherlands.

As Rip (1986) and Cambrosio and Limoges (1991) have argued, both societal deliberations on and controversies surrounding STI can be considered as informal processes of TA. Such informal TA activities may open up spaces for citizens and societal stakeholders to intervene in the development and decision-making processes around STI. Moreover, formal TA can be considered either as a social process working largely in a space created by societal controversies, or as the wish to prevent such controversies. The role of public controversies around STI is relevant in each country, but likely even more so in developing countries, where formal TA is weakly institutionalized. We will argue, therefore, that both formal and informal TA are needed and can complement each other. So any study on TA in developing countries should go beyond the traditional view of TA. This is exactly what we want to do in this chapter.

For this, we can use the institutional perspective provided by Ganzevles et al. (2014) on the TA landscape. These authors model TA as an activity at the interplay between four spheres: parliament, government, science and technology, and society. TA can act as a mediator of knowledge and actors between these spheres. In the literature, there is relatively more attention for TA directed towards members of parliament, known as Parliamentary TA (PTA), that is: "technology assessment specially aimed at informing and contributing to opinion formation of the members of parliament as main clients of the TA activity" (Enzing et al., 2011, i) But actors from the three other spheres can also act as clients of TA. In cases, where scientists and engineers are the main addressees, TA can be used as a means to guide research and technology development from a societal perspective. The term constructive technology assessment is regularly used to pinpoint TA that is aimed at influencing technological choice and design processes (Schot & Rip, 1997). Policy-makers are also potential clients of TA. The task of TA is then to inform them about the societal aspects of science and technology. TA activities can also be aimed at the general public in order to stimulate the public debate on science and technology in society.

India has no parliamentary TA organization. Most TA-like activities and practices are organized by and for governmental agencies. Such policy advising TA has been somewhat en vogue, although the term TA is not usually explicitly mentioned. Section 3 describes three examples of governmental TA in India. First, the central role played by the Technology Information, Forecasting and Assessment Council (TIFAC) under the Department of Science & Technology (DST) (Ministry of Science & Technology) is described. In addition, the role of health technology assessment and TA for pollution control and prevention is described. Section 4 provides an example of constructive TA, whereby TA plays a role in the social shaping of technology. This type of TA has been used to evaluate and adopt crop varieties. Section 5 provides various examples of formal and informal TA activities that are directed towards the public domain. In Sect. 6, we draw some conclusions. But first, we reflect on the role and relevance of TA for developing countries in general.

2 Some Reflections on TA for Developing Countries

Over the past two centuries, economies and societies have been reshaped by successive waves of technological change. Global technological change clearly has two faces, in particular for developing countries. On the one hand, STI is seen as a driver of economic and social inequalities between and within countries. On the other hand, STI has helped to reduce poverty in low-income countries, like China and India, but also including countries in Africa, as shown for example by the impact of smartphones. Regardless of whether more attention is paid to the opportunities or risks of STI, it is widely acknowledged that STI has key roles to play in achieving the MDGs and thus are of great importance for developing countries. It is, therefore, crucial that developing countries have the capacities to avoid or mitigate the risks of STI and to seize its opportunities, especially from the perspective of the many challenges that exist in the field of poverty reduction, the need for sufficient healthy food, social justice, and sustainability (cf. Pansera et al., 2020). According to UNCTAD (2021, 102), foresight and TA initiatives may help "to better understand the socio-economic and environmental implications of new and innovative technologies," and "to identify the risks and benefits of technologies and the policy options for steering innovation so as to leave no one behind."

2.1 Technology Transfer and Needs Assessment

Since there remains a large technological gap between developed and developing countries, one important way to interpret the importance of TA for developing countries is to place it in the context of technology transfer. Kebede and Mulder (2008, 91) state that "The dominant mode of thinking in most developing nations is that one should try to obtain the sophisticated technologies from industrialized countries, with very often a lack of understanding for the preconditions for these technologies to be successfully applied." The authors state that needs assessment and TA could greatly increase the chances of success of technology transfer. However according to Kebede and Mulder (2008, 91) "… both formal and informal TA are almost absent in most developing nations. … So in general, not even an informal TA takes place." Given this current situation, they have developed an accessible TA framework for developing countries in order to link technology transfer with TA and needs assessment (Table 1). This framework identifies four types of relevant factors—technical, economic, institutional, and ecological—that should be addressed before a specific technology is transferred to the respective country and social practices.

A major advantage of this framework is its simplicity and the identification of practical aspects that are important for a TA in the context of technology transfer. As many developing countries are also major importers of technology, this framework can be used to perform TA in a rudimentary manner. The framework, however, pays little attention to legal issues (except for patents and licences), and basically ignores ethical issues, and issues related to access, equity and inclusion, which are crucial for developing countries.

Table 1 Technology assessment factors (*source* Kebede & Mulder, 2008)

Technical factors	• Physical facilities (infrastructures and support technologies) • Services and systems (operation and maintenance)
Economic factors	• Human resources (both technical and non-technical expertise) • Capital, land, and raw materials • Macro-economic conditions • Market and property right (patents and licenses)
Institutional factors	• Organizational factors (structure, flexibility for change, and decision-making) • Social factors (religion, taboos, language, concepts of time and honour, respect, and work ethics) • Cultural factors (taste and habit) • Political factors (political instability and corruption)
Environmental factors	• Geographical and climatic conditions • Ecological systems imbalance, and human health effects • Effects of pollution • Resource depletion and environmental destruction

2.2 TA for Access, Equity, and Inclusion

Recently Cozzens (2021) cautioned that STI policies tend to enhance inequality, unless they are particularly designed to be otherwise, and this should be analysed by practitioners of STI policy. She has pointed out that alternative designs are possible to address this. Seen in this light there can be a role for TA in assessing whether innovation can be designed to be inclusive or reduce inequality caused by STI policies. TA combined with what is known as equity assessment may offer a solution here. For example, in the field of health TA (HTA), Benkhalti et al. (2021) developed a check list for equity considerations. Moreover, we may be inspired by forms of inclusive innovation (UNESCAP, 2021), grassroots innovation (Smith et al., 2016), and frugal innovation (Hindocha et al., 2021) that are specifically aimed at promoting equity and broad access to the benefits of technology, an objective often not met by the traditional forms of innovation.

Finally, we want to draw attention to the access, equity, and inclusion (AEI) framework, which is under development at the Research and Information System for developing countries (RIS) in India (Chaturvedi et al., 2015). The basic idea is that the assessment of the societal benefits of STI needs to be based on a set of broadly accepted public values and norms. Since from a societal perspective, access, equality and inclusion are particularly relevant for developing countries, the framework uses AEI indicators to assess the impact of STI in these areas. This is under development and more work is required, particularly regarding indicators. Linking this with STI policy has been proposed, and some of the suggestions have been identified as useful for developing further (Srinivas, 2020). This framework can contribute to the existing theorization and literature on equity, inequality, and inclusion in STI, and design of policies that antidote trends that result in inequitable distribution of outcomes and benefits (c.f. Cozzens, 2021; Mirza et al., 2019; Bozeman et al., 2011).

2.3 Participatory TA

Ely et al., (2011, 7) hold that conventional TA studies are often not sufficient, since "They provide inadequate accounts of the social, technical, and ecological complexities and uncertainties at stake, and pay insufficient attention to the power relations that often drive directions of technological change." They claim that more participatory models of technology assessment that combine citizen and decision-maker participation with technical expertise are required, which "position technologies within dynamic pathways of change at the system level, recognize alternative understandings of these systems by different groups within society and attempt to build resilience in the face of pervasive uncertainty" (ibid.). As such, these participatory TA activities "can contribute to more democratic governance—not only of science, technology, and innovation, but also more widely." (Ely et al., 2011, 10).

We are sympathetic to this appeal for the use of participatory methods of TA in developing countries. However, it is important to ask, in which political and institutional situations will and can such methods actually be used? A first crucial issue is whether there is a political will to engage with participatory TA. In cases, where a technocratic model of development is dominant there may be no support for public and multi-stakeholder engagement. Besides the will to use participatory TA, such methods also presuppose the organizational TA capacity and, maybe more importantly, the presence of organizations that can represent various stakeholders. So the use of participative TA methods is particularly desirable in socially controversial technology. But if that option is not politically feasible or practically impossible to realize, due to a lack of organizational TA capacity or the lack of organizations that can bring relevant societal perspectives, then conventional TA may be a feasible fall-back option. Analysing TA in theory and practice in India can give some ideas and insights into the adoption and adaptation of TA in developing countries.

3 Governmental TA in India: For S&T, Health, and Pollution Policy

In India, the state is the dominant player in STI, playing multiple roles including regulator, policymaker, promotor, and agenda-setter. The same counts for TA, a field where private organizations are absent. Thus, given its prominent role, describing governmental TA is essential for understanding the state of TA in India and exploring potential future pathways. This section provides three examples of governmental TA. We will first describe the S&T policy advice role played by the Technology Information, Forecasting and Assessment Council (TIFAC), which is the primary agency for TA in India. Secondly, the emerging role of health technology assessment, which is strongly promoted by the government, is described. Finally, we will cover the application of TA for pollution control and prevention.

3.1 The S&T Policy Advice Role of TIFAC

S&T ecosystem and policy

For a long time in India, the private sector invested little in S&T, which made the state the prime mover, in terms of funding S&T development. The state has funded both basic and applied research through different ministries and research councils (see Box 1). In 1991, India embarked upon a series of reforms that reduced governmental control over technology imports and opened up the economy for greater investment and capital flows from abroad. Technology liberalization, removal of restrictions on royalty payments, reduction in tariffs of capital goods imports coupled with the implementation of WTO Agreements, gave much scope for the private sector in technology acquisition and transfer. Since then, the S&T ecosystem in India has grown and diversified. And the focus of S&T policy has shifted to incentivizing innovation in both public and private sectors, and leveraging start-ups and venture capital as new sources for innovation. Over recent years the share of the private sector is steadily increasing. India has emerged as a major destination for R&D centres set up by multi-national companies (MNCs). Bi-lateral and multi-lateral co-operation in S&T has been expanding and is also diversifying. India is also a member of, or associated with, various mega-science-projects, such as CERN, the European Organization for Nuclear Research in Geneva.

Box 1. Key Departments/Agencies Dealing with STI (Source: Srinivas et al., 2018)

- Council of Scientific and Industrial Research (CSIR) under the Ministry of S&T
- Department of Science & Technology (DST) under the Ministry of S&T
- Defense Research and Development Organization (DRDO) under the Ministry of Defense
- Department of Atomic Energy (DAE) under the Prime Minister
- Department of Space (DoS) under the Prime Minister
- Department of Biotechnology (DBT) under the Ministry of S&T
- Indian Council of Agricultural Research (ICAR) under Department of Agricultural Research
- Indian Council of Medical Research (ICMR) under the Department of Health Research.

S&T policy in India is strongly guided by the techno-positivist idea that S&T is a non-controversial tool for modernizing and developing the country. India is quite committed to centralize planning in S&T and uses five year plans for targeted development in different sectors. So-called "Missions" are presented in specific medium- to long-term programmes to build capacity, develop self-reliance in specific sectors, and harness technologies to meet national objectives. There have been many missions, ranging from the peaceful use of atomic energy, to exploring Mars. Since 1988, the activities of the Technology Information, Forecasting and Assessment Council (TIFAC), under the Department of S&T, have played a central role in developing these plans.

S&T policy advice: TIFAC

The Advisory Committee for Coordination of Scientific Research (ACCSR) was active from 1948 to 1955. Since its establishment, there have been many committees and institutional mechanisms to provide S&T policy advice. Until 2014, the Planning Commission which prepared the five year plans and evaluated their performance had a division on S&T. Its successor, NITI Aayong, also has a division on S&T, while in 2018, the Office of the Principal Scientific Advisor was created.

There are internal ministerial mechanisms in place to evaluate and assess various S&T programmes, study the impacts and examine the outcomes vis-a-vis the costs and estimated benefits. External evaluations by agencies like the Comptroller and Auditor General of India is limited to the functioning of regulatory frameworks and administrative activities (e.g. CAG, 2016).

The Technology Policy Statement of 1983 signalled a need to undertake systematic technology forecasting and assessment on a continuous basis and make it compulsory for ministries and departments involved in large investments or large volumes of production. Three years later, the Cabinet approved the formation of the Technology Information, Forecasting and Assessment Council (TIFAC) under the Department of S&T. And in 1988, TIFAC was set up as an autonomous organization. Its broad mandate emphasizes conducting studies and giving policy advice.[1] TIFAC was to work with stakeholders including industry, and conduct studies in forecasting and assessment. It has undertaken technology missions besides conducting feasibility studies. As an autonomous organization its mandate and operational freedom are broad, and there is no other institution in India that plays a role similar to TIFAC.

The then Secretary of the Department of S&T (DST), Vasant Gowariker, hoped that with the creation of TIFAC and the TIFA network "… the national capabilities in the area of technological planning and assessment will be strengthened. This will contribute to the much needed inputs and advice for improved socio-economic and industrial planning" (Gowariker, 1988). At the time, it was envisaged that there would be TIFAC Groups at various ministries and industry levels.

TIFAC's approach

The founding of TIFAC was based on a strong belief in technology and centralized, top-down expert-driven policy advice, planning, and implementation in the field of S&T. As a result, TIFAC's approach is expert-driven and technology-oriented. At the same time, TIFAC's approach has been holistic, covering the entire innovation chain, including commercialization and upgrading, economic benefits, and meeting societal needs. A five step process is employed: (1) brainstorming, (2) defining the scope of assessment, (3) defining the time horizon to be covered, (4) assessing the effects of technology, and (5) analysing policy options. Given its broad mandate, TIFAC uses forecasting and integrated that with TA. This integration was done "with practical goals in mind, namely to create alternative technology trajectories for various important sectors with broad acceptance from stakeholders, ranging from scientists to industrial and technical personnel, to business leaders and government" (Bhatnagar & Jancy, 2003, 24). As such, TIFAC needed to look at available technologies, and alternatives, and situate TA in the larger context of using S&T for national development.

According to Bhatnagar and Jancy (2003), TIFAC focussed on capacity-building and global competitiveness, evaluated emerging technologies, and assessed technologies for promoting sustainable development. TIFAC worked across sectors and managed technology missions concerning the utilization of bamboo, fly ash,

[1] See: https://www.tifac.org.in/index.php/about-us/mandate.

construction waste, and nicotine waste, and the commercial extraction of potash from sea water. TIFAC has been doing TA with the motto of "make technologies work for people" in different sectors of the economy. For this, the council assessed technology readiness levels, societal needs, and the socio-economic and technology import or development needed to provide for those needs. Given the importance of developing alternative technologies and substituting imported technologies with indigenous ones, TIFAC played a key role in technology assessment and absorption. In 2012, TIFAC claimed that it had completed more than 500 technology assessment, demonstration and development projects, involving more than 1500 experts. Although TIFAC's TA is done to assess utility and relevance for the users, it seems to be driven more by the institution than by users or society. There is hardly any reference to participatory TA or constructive TA in its work.

Although TA was one of the key initial mandates of TIFAC, TIFAC is now more focussed on technology forecasting exercises. TIFAC developed a Technology Vision 2035 and follow-ups to that and is involved in scaling up of technologies. However, its work on emerging technologies does not seem to have a TA dimension. With focus on forecasting and foresight studies, and on ideation and scaling up, TIFAC is active on many fronts. According to Goswami and Selvan of TIFAC, TIFAC has employed TA in a particular mode.[2] In the Technology Vision 2035 program, technologies were assessed based on their technology readiness levels and to what extent they were able to address the needs of citizens of India.[3] Similarly, for preparing their Technology roadmaps, TIFAC has identified many technologies after carrying out TA-like processes. Recently, TIFAC did a comprehensive TA exercise and identified technologies in 10 key sectors for the governmental climate change mitigation and adaptation agenda. Currently, TIFAC prepares a database of Global Technologies and assesses India's needs by means of a quantitative multi-criteria decision analysis (MCDA). Moreover, an assessment of technologies developed in Indian R&D institutions is underway, which analyses the scale of their adoption, economic feasibility, and commercial potential.

3.2 Health Technology Assessment

The government supports health technology assessment (HTA) in India, which is emerging as an important component in decision-making on medical technologies and treatments. In 2017, the Government of India proposed setting up a Medical Technology Assessment Board (MTAB).[4] But later this idea was replaced with the health technology assessment in India network (HTAIn).[5] HTAIn comprises of three

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[2] Based on e-mail communication with Janice Selvan and Gautam Goswami, 13 December 2021.

[3] See: https://www.tifac.org.in/index.php/programmes/activities/technology-vision-2035.

[4] See: https://nhm.gov.in/New_Updates_2018/Innovation_summit/6th/Health_Technology_Assessment_in_India_Deptt_of_Health_Research.pptx.

[5] See: https://pib.nic.in/newsite/mbErel.aspx?relid=157976.

organizations, including HTAIn Secretariat, HTAIn Technical Appraisal Committee (TAC), and HTAIn Board. The HTAIn Secretariat collaborates with identified technical partners (TPs) and regional resource hubs (RRHs). Requests to conduct a HTA study can emanate from health departments in central and state governments. The HTA study goes far beyond cost–benefit analysis and has to be rather comprehensive; it should also include systematic literature reviews, economic evaluations, measuring and valuing the health outcomes, and analyses on equity and access issues. An HTA also has provisions for stakeholder consultations. For example, the "HTA of intraocular lenses for treatment of age-related cataracts in India" published in 2018 addresses equity issues through literature survey, compares different technological options and makes recommendations.[6] Finally, the HTA report, together with a policy brief, is sent to the department that requested it (Jain et al., 2018).

3.3 *Governmental TA for Prevention, Control, and Abatement of Pollution*

In the National Clean Air Program (NCAP 2019), the Ministry of Environment, Forest and Climate Change (MoEFCC) announced that a Technology Assessment Cell will be established. According to NCAP (2019, 60f.) the Technology Assessment Cell is envisaged to:

- evaluate significant technologies with reference to prevention, control, and abatement of pollution;
- to focus on both indigenous and international monitoring and abatement technologies, ranging from engineering and chemical to biological technologies, including extensive development of plantations
- contribute towards evaluating the technology and devising the mechanism of technology transfer under various bilateral and multi-lateral agreements.

This is a welcome development given the need to curb pollution and address issues related to climate change. The Technology Assessment Cell will use the existing mechanisms and programmes of the Department of Science & Technology and the India Innovation Hub (NCAP 2019, 61). Moreover, it will involve the Indian Institutes of Technology (IITs), Indian Institutes of Management (IIMs), major universities and industries. However, the involvement of other stakeholders is not mentioned, nor does a consultative mechanism seem to be envisaged. Thus, it seems that a technocratic exercise is envisioned, involving experts, academic institutions, and industry.

From the above, it is clear that TA is growing in India, in terms of themes and as a relevant input for policymaking, particularly in the field of health. Some of the activities on TA are linked with other objectives such as transfer of technology (ToT) and diffusion of technology.

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[6] See: https://dhr.gov.in/sites/default/files/htaincataract_0.pdf.

4 Constructive TA: Evaluating and Adopting Technologies in Agriculture—ICAR

4.1 Extension and Technology Assessment and Refinement

In India, there are many agricultural research organizations and activities, such as agricultural universities, private sector entities, farmers doing research, and civil society-supported initiatives. The Indian Council of Agricultural Research (ICAR) is the premier research agency in agriculture in India. ICAR engages in technology development and assessment through research laboratories and extension centres. Extension is a service or system which assists farm people, through educational procedures, in improving farming methods and techniques, increasing production efficiency and income, bettering their standard of living and lifting social and educational standards. The agricultural extension system was developed in the 1960s and was expanded on account of the Green Revolution. At that time, the focus was on adopting technology, and not on TA.

In 1995, ICAR institutionalized technology assessment and refinement (TAR) as part of the extension services, through the Institute Village Linkage Programme (IVLP), in 42 centres linking with 42,000 families (ICAR 1995, 6). TAR is meant to assess technologies at the field level and refine them in such a way that they will fit the ecological, social, and technological context of farmers. Important questions within the TAR, therefore, are (ICAR 1995, 10): What are the constraints in the farming system? Which indicators do farmers use to assess the various technologies for their worth, or relevance, and could there be rationality in adopting, rejecting, or modifying a technology? Are there differences among the indicators chosen for technology assessment by big, small, and marginal farmers? (ibid). The objective of the TAR is thus to produce and transfer technologies that are suitable, based on the needs and aspirations of the farmers.

4.2 Krishi Vigyan Kendras (KVKs) as Extension Centres

The Krishi Vigyan Kendras (KVKs) act as extension centres and disseminate technologies. As part of their work, they do technology assessment, technology evaluation, and refinement. KVKs are the key component of TA in agriculture in India although their work goes beyond TA. For ICAR, TA is part of its mandate to help farmers and society through the development, dissemination, and adoption of technologies. As a public sector research institution, ICAR is funded mostly by the Government of India and also collaborates with stakeholders, in particular farmers, in TA-related activities.

Spread across different states and climatic zones of India, there are 722 KVKs that play a part in the testing of crop varieties and other technologies in farmers' fields (ICAR, 2020). In 2019–2020, more than five thousand technologies were assessed in some thirteen thousand locations through more than twenty-five thousand trials. For different assessments, different criteria, like drudgery reduction, and purposes, like resource conservation, value addition and production of planting materials, are included. Regarding livestock, 1034 "technological interventions" were made in 3338 locations, with 5156 trials related to different themes, such as disease management, breed evaluation and production management. KVKs are involved in demonstrating the potential of new plant varieties and technologies developed by ICAR (ICAR, 2020, 143). Besides analysing samples for farmers, KVKs produce seeds and planting materials. Thus, in ICAR, TA is integrated in many developing technological activities. This type of TA is known as constructive TA, which implies that ICAR is both the developer and assessor of technology. Similarly, both assessment and adaptation are done by ICAR, or under its aegis through the KVKs.

ICAR also does participatory technology assessment (pTA) in a limited way. But the issue is complicated by the fact that TA activities are linked with adaptation, since "Technology assessment is one of the main activities of KVKs to identify the location specificity of agricultural technologies developed by the National Agricultural Research System (NARS) under various farming systems." (ICAR, 2020, 6). Refinement, therefore, is linked with TA, and TA results in refinement. For example, according to ICAR, demonstration in a participatory mode resulted in adoption of pineapple as an intercrop as it scored 86.6 in the Sustainable Livelihood Index (ibid., 138). However, it is not clear how this Index was developed or whether the same index is used for different agro-climatic zones with the same methodology and data set. Other projects have made use of the Sustainable Livelihood Security Index, developed by the Department of International Development (DFID) for different agro-climatic zones, to assess the livelihood of cassava and rice paddy-growing farmers in Tamil Nadu, and used this assessment to suggest which crops and farming methods are preferable.

4.3 Gender Assessment of Technologies

ICAR's Central Institute for Women in Agriculture is the leading institute in gender assessment of technologies. ICAR links TA with gender empowerment by assessing how technologies could help women to reduce their drudgery and enhance livelihoods. According to the Annual Report "Farm women related 280 technologies were assessed through 2,797 trials at 699 locations. Major themes under this category were drudgery reduction (technologies 92, trials 880, locations 126), and health and nutrition (technologies 59, trials 492, locations 74)." (ICAR, 2020, 153). In this, ICAR evaluates the available technologies, "Drudgery experienced by women was assessed on a 5 point scale, with the highest score given to drudgery experience during marketing of fish (28.01). Two model prototypes of disc ridger—a primary soil tillage machine—were tested and developed based on the anthropometry and strength of farm women. As a part of livelihood improvement of tribal farm women through secondary agriculture, technological interventions in the processing of ragi, mango, tomato, and cashew nut were given to tribal women of Ganjam district and a schematic model for establishing small scale enterprise was developed.” How exactly the notion of gender is integrated in TA is not clearly known. Moreover, there has not yet been an external or independent evaluation of ICAR’s role, and that of the KVKs, in TA and how successful its TA activities have been.

In summary, ICAR has institutionalized TA in agriculture and has been sensitive to women’s issues and concerns. This shows that formal systems for TA are widely used in India. The TA methodology is oriented towards adapting a technology which is developed elsewhere, to suit local conditions. Such a locally constructive TA approach is valuable, but not sufficient for controversial technologies, such as GM crops, which need a more comprehensive socio-economic impact analysis, which include the perceptions of all relevant stakeholders. A locally constructive TA should be able to weigh technological options and alternatives. ICAR’s TA is oriented towards adapting the technology in question. For controversial technologies, a different type of constructive TA is needed that pays attention to the usefulness and necessity discussion surrounding such technologies.

In such cases, firstly, there is a more generic usefulness and necessity discussion needed, in which conflicting visions can play a role, and secondly, there are various social issues that go far beyond the local application level, such as dependence on large biotech companies, and the future role of organic farming in India.

5 Formal and Informal Participatory TA in the Public Domain

India has a rich history of civil society engagement with S&T. In this section, we discuss the case study of Bt brinjal in which the government experimented with participatory TA. Next, we describe some examples of the engagement of civil society with STI. These examples could be described as informal participatory TA-like activities (cf. Rip, 1986). In order to contextualize these examples, it is important to first outline three relevant Indian political-cultural visions of the social role of science and technology.

5.1 Three Political-Cultural Visions on the Relationship Between S&T and Society

Prior to 1947, civil society initiatives were focussed on science education, communication, and popularization. Post-1947, such engagements include people’s science movements (PSM), movements against specific policies, projects, and institutions, as well as initiatives for promoting the development of alternative technologies. At the risk of simplification, the responses to S&T in India can be organized into three categories: Nehruvian, Gandhian, and the leftist vision of the PSM.

The Nehruvian approach represents the dominant understanding and thinking based on state-led S&T, and faith in its power and potential for socio-economic development. S&T is also regarded as an alternative mode of thinking and practice, and the Nehruvian scientific temper is part of this. This understanding had an almost unquestionable faith in S&T, and saw only the positive aspects of S&T, ignoring the negative ones as exceptions, or failures of individuals and organizations, rather than as a quality inherent in S&T. Hence, it supported large dams, nuclear power, green revolution, and other technology missions.

The Gandhian thinking inspired institutions and individuals who accepted the view that science without morals is a form of sin, and that S&T should be used for people, and decentralized production and consumption. Its rejection of the idea of endless growth is in a sense a harbinger of the current notion of de-growth. This response to S&T is concerned with an uncontrolled expansion of S&T that results in a concentration of wealth, growing inequities, and centralization of power and control. As a result, its supporters sought human-centred alternatives that focussed on community concerns and technology in the hands of communities. There are many institutions that are inspired by Gandhi and his ideas on S&T. Some of them are supported by the state—in particular, the Science for Equity Empowerment and Development (SEED) Division of DST—while others are based in institutions of higher learning and research. While these institutions are more focussed on developing alternatives and getting adopted, the people's science movement has provided both a critique and suggestions for alternatives.

The leftist PSM in India is critical of S&T policies. It favoured linking science with social revolution and alternative approaches to S&T. It took positions that were critical without romanticizing village life or questioning technology solely on the basis of size and impact. Inspired by the USSR and China in the initial years, the PSM later built an indigenous discourse on S&T that accepted people's knowledge without romanticizing it.

While the Nehruvian approach and the leftist PSM give importance to the modernizing potential of S&T and its use for societal transformation, the Gandhian approach emphasizes rural industrialization that meets people's basic needs of through decentralized production and consumption, and the use of small and intermediate technologies. These approaches have had their share of influence in S&T policy. In terms of TA, Nehruvian and leftist PSM consider formal TA as important. Moreover, the PSM sees public engagement and assessment as important. In the Gandhian approach, TA will be based on ethics, values, and the realization of societal goals, and how technology enables democratic sovereignty of the people, in particular the poor and vulnerable.

5.2 Governmental Participatory TA: The Case of Bt brinjal

A major exercise in TA involving the public at large was undertaken in the case of Bt brinjal. This genetically modified brinjal (also known as eggplant or aubergine) was created by inserting a crystal protein gene (Cry1Ac) from the soil bacterium Bacillus thuringiensis (Bt) into the genome of various brinjal cultivars. For example, the University of Agricultural Sciences in Dharwad, in the Indian state of Karnataka, chose six varieties (malapur local, majari gota, udupi gulla, rabkavi local, kudchi local, and GO-112) for Bt transgenic conversion (Krishnaraj et al., 2009). The initial work was started in 2000 and it took about nine years for trials to be completed and evaluated. After multi-state, multi-trials, and assessments of performance of the outcomes, Bt brinjal was recommended for commercial cultivation in 2009 by the Genetic Engineering Advisory Committee (GEAC).[7]

But this development was contested by many civil society organizations. The extensive debate on Bt brinjal brought into sharp focus the divide on the use of GMOs in agriculture, as well as questions on the regulation of agricultural biotechnology. Then, the Minister for Environment and Forest, Jairam Ramesh, called for a public consultation and sought comments and inputs from the wider public. The consultations were held in 2010, from January 13 to February 5. And on 9 February 2010 the Government of India declared a moratorium on the release of Bt brinjal for commercial use and cultivation, which is still in force. The government cited lack of evidence of safety as the reason.[8]

Another reason might have been that states like Karnataka, Uttarakhand, and Himachal Pradesh, had already decided to not allow cultivation of Bt brinjal, to avoid a confrontation in the absence of a consensus. Commenting on this controversy, Shah (2011, 37) pointed out that "The social and scientific appraisal of Bt brinjal, thus needs to be based on a methodology that can combine … scientific expertise with democratic participation, and such an appraisal also needs to include the issues of injustice in the assessment of insecurity."

This broad public consultation could be considered as a pTA, as it opened up for the first time a broader process of public engagement with technology, instead of narrowing it to issues of safety as decided by scientists and expert views. But this TA conducted by the government was the first and last one on agricultural technology, or for that matter on any technological intervention. Interestingly, while opening up the consultation to the public, the government did not indicate any preference, neither in support of nor opposition to Bt brinjal. So this exercise in TA, if we can call it so, reinforced the view that such forms of pTA are feasible in developing countries.

Despite the moratorium, the research on genetic engineering applications in agriculture has not stopped, and the divide in opinions continues. Although there have been no further approvals for the commercial use or cultivation of GM, India has not yet taken a clear stand on not using GM technology. Moreover, there is no official policy on adoption of gene-edited crops in agriculture. Thus, while this exercise in

[7] See: https://www.isaaa.org/resources/publications/pocketk/35/default.asp.

[8] See: https://prsindia.org/theprsblog/to-eat-or-not-to-eat-bt-brinjal.

TA resulted in a decision, it neither opened up opportunities for such exercises in the future, nor brought clarity in policy.

5.3 Civil Society Engagement with S&T—Informal TA

There have been many examples of technology development and evaluation centred on the needs of the poor, with the objective of developing and adopting pro-poor innovations. Abrol (2014, 373–374), however, holds that "pro-poor innovation generation and diffusion in India have not been successful, because … Technology platforms, ecologies, and pro-poor innovation systems were not constructed with the pragmatic aim of achieving ecological and social justice and economic empowerment of the poor—but as a residual socio-technical system without ensuring any systemic competitiveness."

But we can look at controversies as types of informal TA, using examples like the Silent Valley controversy. The Silent Valley Movement started in 1973 to save the Silent Valley Reserve Forest from being flooded by a hydroelectric project. As a result, the government abandoned the power project on account of assessments by civil society group KSSP, whose concerns were shared by others. In terms of technology development and adoption, a first example is the system of rice intensification (SRI), which is a farming methodology aimed at increasing the yield of rice. It is a low-water, labour-intensive method that uses younger seedlings singly spaced and typically hand-weeded with special tools. Although at first the S&T establishment ignored it, SRI later became widely accepted as a workable model. A second example is the promotion and adoption of community seed banks as an alternative approach to institutionalized S&T seed banking. Community seed banks were promoted by Deccan Development Society (DDS) as part of its response to technological changes in agriculture induced by the Green Revolution and the introduction of GMOs in agriculture, particularly Bt cotton. DDS works with women's groups in about seventy-five villages in Telangana State. DDS promotes natural farming and organic agriculture as an alternative to GMOs. The 5,000 women members of DDS have developed community-based food sovereignty systems based on local knowledge, including grain, and seed banks.

In all these instances, there were no formal TA activities. Instead, technologies ignored by the formal innovation system were adopted and popularized. Although not all such initiatives were successful, it is not unknown for attempts by civil society actors result in a certain reorientation in thinking. Thus despite the lack of state support, various informal TA-like activities have resulted in the development and adoption of technological and/or organizational alternatives through demonstrating their viability and feasibility.

6 Conclusion

This chapter has provided an overview of the TA landscape in India, as an example of TA in a developing country. The example of India shows that despite the lack of a specialized TA organization or institution, TA activities are included in a broad spectrum of governmental STI initiatives and agencies, as well as in STI-focussed activities of civil society. We described five formally institutionalized governmental TA-like activities (Table 2) and three informal TA-like grassroots activities (Table 3).

6.1 Governmental TA Activities

Since the end of the 1980s, India has set up governmental TA-like capabilities for technological foresight in general (via TIFAC), and for agricultural, medical and pollution abatement technologies in particular (Table 2). Such activities are mainly performed by experts and aim to strengthen India's technological capacities in the above-named fields. While there is still some focus on the utilization phase of technology, in particular technology transfer, India nowadays is involved with the entire innovation chain; from research, development and demonstration towards market introduction and upscaling. Because of its tradition in the field of technology transfer, India has gained a lot of experience regarding the fact that technology is only useful if it matches the needs and the technological, economic, environmental, and social context of the user. In particular, TA in the field of agriculture (TAR) and medical technology (HTA) has given serious attention to issues of access, equity and inclusion.

The various governmental TA activities show a mix of top-down expert- and technology-driven studies on the one hand, with attention to the needs of users and the social context on the other. This seems to reflect a mixture of the Nehruvian and Gandhian views on the relationships between science, technology, and society. Finally, the government only once employed participatory TA, as a response to the public controversy around the introduction of a genetically modified eggplant (Bt brinjal). This is despite the fact that the S&T and Innovation Policy of 2013 mentions public engagement, and the Economic Survey of 2018 has highlighted the need for public engagement in science and by scientists (DoEA 2018, 129).

The governmental TA-like activities take into account technical, economic, institutional, and environmental factors, but none of them assess or take into account all four. For example, in the case of GMOs, it was questioned to what extent all relevant scientific factors were considered (Aga, 2022, 170–172). The TA cell and HTAIn are new TA-like initiatives. It would be valuable and timely to assess to what extent these TA-like activities meet the needs of society and to what extent the methods employed are adequate for assessing emerging technologies.

Table 2 Overview of characteristics of five governmental TA-like activities in India

Characteristics	TIFAC (1988)	TAR (1995)	Bt brinjal (2010)	HTAIn (2017)	TA cell (2019)
Performance by	Technology Information, Forecasting and Assessment Council (TIFAC)	Indian Council of Agricultural Research (ICAR); KVKs; Central Institute for women in agriculture	Ministry for Environment and Forest	Health Technology Assessment in India network (HTAIn)	Technology Assessment Cell as part of the Ministry of Environment, Forest and Climate Change (MoEFCC)
Directed at	Government departments dealing with STI (see Box 1)	Farmer community	Genetic Engineering Advisory Committee (GEAC)	Health departments in central and state governments	Department of Science & Technology and India Innovation Hub
Type of technology	All kinds	Agricultural technology	GMO in agriculture	Medical technology	Pollution abatement technology
Stage of technology	Entire innovation chain	Entire innovation chain, in particular technology transfer	Market approval	Utilization phase	Utilization phase (e.g. technology transfer)
Institutional goal	Strengthen national capabilities in technological planning and assessment for improved socio-economic and industrial planning	Strengthening capacity to assess agricultural technology	Dealing with societal protest	Strengthen institutional capacity in the field of health TA (HTA)	Strengthen technological capacity to prevent, control, and abate pollution
Policy goal	Global competitiveness, sustainable development	Produce and transfer technologies that are suitable, based on the needs and aspirations of (female) farmers	Clarifying regulation of GMO in agriculture	Public health	Prevention, control, and abatement of pollution

(continued)

Table 2 (continued)

Characteristics	TIFAC (1988)	TAR (1995)	Bt brinjal (2010)	HTAIn (2017)	TA cell (2019)
TA-like activity	Technology forecasting and needs assessment	Technology Assessment and Refinement (TAR)	Public consultation	Health technology assessment (HTA)	Evaluating technological potential
Engagement	Experts	Experts, (female) farmers	Experts, stakeholders (incl. civil society organizations), citizens	Experts	Experts
Factors addressed	Technological, economic, societal needs	Technological, economic, ecological, gender, livelihood	Safety, social	Technological, economic, health gain, access and equity	Technological, economic

Table 3 Overview of characteristics of three informal TA-like grassroots activities in India

Characteristics of TA-like activity	Silent valley movement	System of rice intensification (SRI)	Community seed banks
Performed by	Civil society organization KSSP	Farmer organizations	Deccan Development Society (DDS)
Directed at	State	Farmers	Female farmers
Type of technology	Hydroelectric project	Agricultural technology	Agricultural technology
Stage of technology	Implementation	Development and implementation	Development and implementation
Goal	Save the Silent Valley forest	Increasing the yield of poor farmers with poor soil	Promoting community-based food sovereignty systems
Policy goal	State stops hydroelectric project	Strengthening livelihood of poor farmers	Natural farming and organic agriculture
TA-like activity	Societal movement and controversy as informal TA	Informal constructive TA: Grassroots development of technology suitable to the needs of poor farmers	Informal constructive TA: grassroots development of technology suitable for female farmers
Engagement	Silent Valley Movement	Poor farmers	Female farmers
Factors addressed	Technological, ecological, social	Technological, economic, ecological, social	Technological, economic, ecological, social

6.2 Informal Societal TA Activities

Besides governmental TA-like activities, we described three informal TA-like grassroots activities in India (Table 3). These activities are driven by civil society organizations, which often choose one or more of the following three strategies (cf. Cramer, 1990, 145):

(1) educating or mobilizing the public and stimulating the public debate on STI,
(2) putting an emphasis on influencing governmental STI policy or trying to stop governmental projects (as in the case of the Silent Valley movement), or
(3) developing exemplary alternative technologies and organizations (as in the cases of the system of rice intensification, and the community seed banks).

As noted above, Rip (1986) denotes public controversies, which are related to the first two strategies, as informal technology assessment. In line with that argument, the third strategy could be described as informal constructive TA.

The informal TA-like grassroots activities provide a contrast to the governmental TA-like activities. While informality is one aspect, these grassroots activities often represent and give voice to marginalized stakeholders, and in some cases provide an alternative option in terms of technology and organization. The system of rice intensification (SRI) is now recognized by the formal agricultural research and extension system of the state. The Silent Valley Movement questioned the logic of generating electricity at any cost. Community seed banks are part of informal seed and germplasm conservation and various development initiatives. But there are not many such informal TA-like initiatives in India. Moreover, there is often a weak linkage between informal TA-like activities and the formal innovation ecosystems of universities or institutions of higher learning.

6.3 Lessons from India for Developing Countries

So India does have both formal and informal TA, which according to Kebede and Mulder (2008) are almost absent in most developing nations. In terms of TA, therefore, India cannot be seen as a typical developing country. We should note, however, that Kebebe and Mulder made their observation in 2008 and a lot may have changed since then. This certainly applies for India, which has expanded its TA capacity, especially in the field of HTA and pollution TA. Moreover, the Indian government organized a participatory TA event on the introduction of Bt brinjal in 2010.

In Sect. 2, we identified three important TA topics for developing countries: technology transfer and needs assessment, TA for access, equity and inclusion, and participatory TA, including the role civil society or informal TA can play. The developments in the field of TA in India indeed show the importance of these three TA topics. Below, we briefly review these three topics and identify a set of parameters that are important for the deployment of TA in developing countries.

Historically, TA was first given a place at the end of the 1980s in the field of technology transfer, and in particular in determining which technical areas India needed, related to societal needs and challenges (see Sect. 3.1 on TIFAC). It is interesting to note that this desire to put state-led innovation policy more at the service of societal challenges is a relatively modern turn of events in the European Union (cf. Mazzucato, 2015, 2018). It also shows that for such state-led socio-technical mission oriented innovation, TA is a natural partner. The following parameters, therefore, play a crucial role in determining the desired role of TA for developing countries:

(1) government-driven or market-driven innovation;
(2) phase of the innovation chain: beginning, middle or end;
(3) type of grand societal challenges; and
(4) institutional capacity in STI, including TA.

Access, equity and inclusion are important social issues within TA that are especially relevant for developing countries. In India, within governmental TA activities, we see attention to these issues, in particular in the fields of agricultural TA and HTA. Of course, the three described informal TA-like grassroots activities are strongly driven by the above three public values.

Finally, governmental TA in India is characterized in particular as expert-driven and technocratic, and by a lack of approaches that seek the participation of societal interest groups or citizens. This is despite the fact that the following aspects form a good breeding ground for organizing participatory TA activities:

(1) the existing attention within government institutions in the field of STI towards societal needs and issues such as access, equity, and inclusion are in principle a good breeding ground for participatory TA;
(2) the identified need for public engagement in science in various policy documents;
(3) the critical self-reflective Indian political culture with regard to the relationship between STI and society—especially the Gandhian and the leftist vision of the PSM; and
(4) the presence of an active public debate on the societal role of STI, as evidenced by the three described controversies surrounding technology and related informal grassroots TA activities.

Finally, institutional capacity in the field of participatory TA is an important precondition for the implementation of participatory TA. It could have significant impact on STI if India, and other developing countries, would choose and be able to develop such a capacity in the coming years.

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