Special Issue: Inquiring into Technoscience in India

The Socio-technical challenge between the two modes: how to engage Science and Technology Studies in a coherent Engineering practice?

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Abstract. The change in Indian political and economic conditions has brought about a change in the outlooks of academic producers and consumers alike. There has been an increasing demand for transparency and equity in government-supported modes of activity, as well as, an increase in engineering and technological activity. Demand has grown in the sectors of engineering and design. The government has concomitantly set up manpower production avenues in the form of engineering institutes and the creation of a design spine in the current engineering curriculum. While this dominant wave has continued, there is a counter growth from other academic sectors, such as Science and Technology Studies (STS), that emphasizes that the crux of technoscientific activities need to be comprehended to make their end results just and equitable to society. Most notable in this line of research is the study of large-scale technical systems, *qua* socio-technical systems, by both historians and sociologists. While both the engineering and STS academic literature have continued to grow steadily in these large technological systems, there is still a need for integrating the insights of STS into core engineering practices for systems design in Indian technological development trajectories. This chapter aims to highlight that the dichotomy of the two modes of knowledge production, in terms of state-led top-down and actor-led bottom-up, does not fare well for socio-technical systems. Thus, there is a need for tighter integration between the existing modes of engineering activity with the new alternatives, such as STS, with the long-term view of comprehending the two waves, Post–Nehruvian *vs.* new technoscientific consensus, together rather than seeing them as alternatives.

Keywords. Socio-technical system; Social science; STS; technoscience

1 Introduction

One major challenge that India, as well as the world, is facing is the recognition of newer forms of systems called socio-technical systems. Socio-technical systems are constructs that involve a significant role of people to ensure their functioning. Examples include air-traffic control, sanitation systems, homeland security, computerization for civic engagements as well as more broadly, other mission-critical and safety-critical systems. Some of these sectors are highly technically oriented, such as the nuclear sector; whereas, others are more socially oriented, such as the sanitation sector. Socio-technical systems involve a number of disciplines from social sciences as well as from engineering. As a result, these systems require a conjoined understanding of both engineering and social science-oriented educational disciplines. In other words, we have to understand the working of these systems from the viewpoint of the people involved as well as the system from a holistic construct comprising of both people and technologies.

In broader social sciences and science and technology studies (STS) literature, two modes of knowledge production have been highlighted broadly in the following ways. First, in the top-down approach, the state has been the primary producer of technoscientific knowledge. Examples of this mode of knowledge involve large projects and reliance on state-based institutions that create the knowledge and products related to this approach. However, the new mode of knowledge production has been rapidly shifting away from the expert-technical mode, with citizen-actors who are rapidly being recognized as legitimate creators of knowledge. In this second bottom-up approach, the public and activists are involved in producing knowledge that is vital to the understanding of novel technoscience. The disjunct between these two modes of knowledge production is rapidly emerging as prominent with the public focus moving towards issues related to citizen science, activism, and technoscientific interventions.

The new knowledge-based understanding that arises from the bottom-up (technology enthusiasts, communities and also citizen-led schemes) involves a mode of understanding that is participative in nature and thus is markedly human-centred. In contrast, the state-oriented technoscience approaches provide us with an understanding from the top-down which oftentimes may miss out on the social fabric of everyday technologies as lived experience. In the new citizen-led initiatives such as local cleaning of community spaces, energy sheds for local solar energy harvesting, cams for studying plant phenology, urban farming, among many other innovations (see Thackara 2017 for a list of projects). While these ideas are slowly developing from the ground up, the top-down approach of the state-devised technoscience is also important for the long-term understanding of the operation and maintenance of these systems. Therefore, the challenge for socio-technical systems, both from the bottom-up and the top-down influences mutually constrain each other and result in long-term systemic growth.

While the two modes of knowledge have been pitted against each other, we highlight one dimension of the debate as it reflects in the design, operation and development of socio-technical systems. We emphasize that both these modes of production of knowledge have to be taken together for understanding socio-technical systems. Thus, this chapter aims to highlight the specific case of socio-technical systems design and to show how the meta-theoretical assumptions behind the construal of the concept of socio-technical and what it means for India. Research in socio-technical systems is found in both systems engineering as well as in Science and Technology Studies (STS, including the history and philosophy of technology). However, their scope, conceptualization and treatment are varied in nature. As a result, these two approaches have a different disciplinary viewpoint on the constitution, architecture and management of socio-technical systems. Thus, this article reviews the basic premise of the two modes of knowledge concerning socio-technical systems and ponders upon ways in which synthesis can be reached where insights from both approaches can be reached for a stable, just and people-centric socio-technical system.

Towards this end, the current chapter is divided into five main sections. Section 2 introduces the meaning of the basic premise of the two modes of knowledge production in the light of socio-technical systems. Section 3 resists the dichotomy of the two modes of knowledge production in light of the basic challenges of socio-technical systems. In the next section 4, we demonstrate the need for such a synthesis through a brief examination of the Bhopal Gas tragedy. Finally, the chapter concludes with a brief discussion about the need for successfully integrating ideas from STS in engineering for socio-technical design, operations and management.

2 What does the basic premise mean for socio-technical systems?

The main idea expressed in this article is that top-down (state-led knowledge production) and bottom-up (community-oriented) knowledge production as antagonistic notions do not fit in well with the concept of socio-technical systems. Therefore, for architecting socio-technical systems, there is a need for both these modes of knowledge production. Socio-technical systems involve people and technology that interact with each other in non-trivial ways. Common examples of socio-technical systems are air-traffic control systems, transportation systems, among others. These projects have commonly been developed by the government and in many cases are state-run enterprises.

In order to understand how the state-based knowledge organization has been possible, we have to consider the initial development goals of India as a nation in its infancy. The Nehruvian consensus on science, technology, industrialization and supporting planning policies (such as the Bombay Plan, First Five year plan, as well as subsequent plans), was aimed towards a great economic leap forward in the initial years (Chibber 2003; Majumdar 2012; Mukherjee 1978). It brought about new mindsets, values and viewpoints in the rapidly changing India of the early decades of post-independence. Given this mindset, state-led institutions were streamlined to provide strategic growth to the nation. While this model seemed to provide the initial impetus, there was also a backlash after the initial decade. The initial protective cover of 'state paternalism' and monopolistic privileges of the public sector industries in the heavy engineering sectors as well as infrastructure was vigorously questioned in the 1980s and later abandoned (e.g. Bhagwati 1993).

While the backlash may have been due to a variety of reasons and motives, one claim was that the earlier premise of state-owned institutions had not fared well (e.g. Bhagwati 1993). While this reason may be highly contested and other reasons may be sought, the key idea is that the state-owned technological approaches were questioned. As a result, these institutions were lampooned as serving as a drain on the other sectors such as education, healthcare, and infrastructure (Bhagwati 1993; Chibber 2003; Majumdar 2012). The liberal reforms of the early 1990s brought about a change in not only the economy but also had an impact on a variety of sectors. This economic change brought about a revision in the mindsets and viewpoints of the new India. One major change brought about by the shift from a socialist-style policy to a market-based policy of the early 1990s was the shift in knowledge production. This impact is becoming more pronounced in recent years through alternatives to state-based narratives (Subramanian 2010). In the present times, the erstwhile state-based reliance is supplanted by more user-based alternatives such as citizen science, innovation studies and STS. The primary emphasis of these has been to question, and at times supplant the traditional state-based knowledge production mechanisms. While this disjunction can serve as an alternative model of knowledge, in the case of socio-technical systems these two categories are not necessary. In the case of socio-technical systems, we require both of these viewpoints on knowledge production to be taken together. This is due to the nature, constitution and requirement of socio-technical systems.

Socio-technical systems involve people and technologies (Vermaas 2011). This class of systems often appear as large infrastructures. These may include air-traffic systems, road transportation systems, healthcare systems, power systems, among many other large-scale infrastructural systems that involve a multitude of people and technologies interacting in complex ways. In all these systems, state-based initiatives are necessary due to security, policies and long-term regulations. The state becomes an important construct in the governance of the systems. Therefore, state-based knowledge production is not only necessary but also important for characterizing these systems. In addition, these systems involve a number of operations and activities that involve knowledge production from the bottom-up. Consider the example of insights from operators experience that engineers take into account while designing interfaces or even the case of sanitation systems where users are involved in practices to make their own neighborhood clean at the level of communities. In both these examples, considerable insights are formulated that fall squarely in the realm of new knowledge production of STS. Therefore, both the knowledge approaches have to be taken together.

Socio-technical systems are unlike different technologies, products and systems (Vermaas 2011). Firstly, they comprise of both people and technologies. The nature of interaction circumvents any straightforward division between its constituents of people and technologies. As a result, these socio-technical systems are hybrids; people and technologies have to be taken together under a common metric. These systems are social in nature as these contain people in individual roles as designers, operators, maintainers, as well as supra-individual constructs such as teams, organizations, regulatory agencies, among others (see Fig 1). It consists of engineered entities that are designed to function correctly. In turn, they also malfunction, resulting in accidents, disasters and catastrophes. These socio-technical systems are hybrids; which means that the people and technologies have to be taken together as a conjoined unit. For example, consider the control room of a nuclear power plant. From an engineering point of view, the focus will be on the electronic displays and the underlying control entities. However, from a psychological and social viewpoint, the focus will be on the operators themselves and the team in which they are functioning. In contrast to the above two from a socio-technical viewpoint, the emphasis is taking the social and the engineered dimensions together. The operator is a system's component and the technological aspect of the system is the operator's environment. These aspects make a socio-technical system hybrid in nature not completely handled by the viewpoints of either the social or the individual.

Socio-technical systems evolve over time, due to many internal and external changes, at multiple spatio-temporal scales; examples of such systems have been extensively highlighted by historians of technology. A prominent study by the historian Thomas Hughes (Hughes 1988; also Hughes 1998 for other systems development projects) shows how large electricity systems developed on both sides of the Atlantic and were shaped by a number of vested interests of stakeholders ranging from individuals as well as governments. Typically, in socio-technical systems, over a while, the multiple user groups, such as governments and regulators, among others, act downwards on the lower levels constraining their operations; whereas, the lower levels of operations have a reciprocal effect on the higher levels. In addition, changes from outside the system also have an effect on the systems' functioning. For example, changes at the ground level of environmental activism may lead to changes in organizational actions as well as legislation. Oftentimes, the growth and development of large socio-technical systems involve prolonged negotiations and deliberations involving many stakeholders of local communities that are affected (e.g. Navi Mumbai airport and the wetlands). Many examples of environmental activism exist in India as well as around the world in relation to the setup, operation and sustenance of large technological systems in relation to the environment. While several examples exist, the key idea is to note that voices, actions and operations from the bottom-up have to be taken together with the ones from the top-down for a unified understanding. Given this enigmatic basis of systems, engineers, designers, planners, managers and lawmakers require a different set of tools and methodologies used to design, operate, manage and govern these systems.

As such, the traditional divide between the two modes of knowledge production in terms of the top-down and bottom-up initiatives does not fit in well with the needs for comprehending socio-technical systems. Further, in socio-technical systems analysis, design, operation and maintenance require both these approaches for knowledge production and use. In India, socio-technical systems thinking will need the breakdown of the dichotomy of the top-down and bottom-up production viewpoints as both of these are necessary for socio-technical systems. The need for socio-technical thinking in addressing systems in India is of vital importance because of the varieties of state-based infrastructure and programs that involve a concomitant reliance on technology and people functioning together. Issues ranging from health management in remote parts of India to the functioning of the railways, all of these fall under the broad umbrella of socio-technical systems. The change in the public mode of engagement is from acceptance of ‘handed-out service from the state to that of the demand for better, faster and reliable service which is an ‘entitlement’ of the individual.

In addition to this large-scale generalized challenge, several small challenges serve as impediments for the transfer of its insights into engineering. These challenges show that there is not one focussed approach that can be readily accepted for engaging STS insights into engineering for addressing socio-technical systems. However, to bring about safe, sustainable and just socio-technical systems of the future, engineers have to systematically engage STS in their practice. Once STS is more coherently engaged, there will be mechanisms to break away from the dichotomy of the state-centred and the user-centred forms of knowledge creation towards a more unified approach to knowledge that takes both of these perspectives into account. In large socio-technical systems, this is not only desired but also required. Therefore, comprehending these local challenges is important for providing pathways for integration of its principles with STS.

3 Challenges towards attaining a mutual understanding for addressing socio-technical systems

Both STS, as well as systems engineering, are disciplinary frames that have approached the understanding of socio-technical systems. As a result, there is no one set of ideas, insights and a common basis towards which both these disciplines converge. These ideas are also important and need to be explored because along with bridging the dichotomy of state-led and citizen-led knowledge production, these internal challenges have to be addressed to coherently link STS and engineering. This section lists out a few such challenges.

3.1 *Challenge 1: Human Factors (from engineering background) and STS as disciplinary frames*

Socio-technical systems have been addressed in the engineering sector by Human Factors Engineers, who design human-centric systems such as healthcare, process-control systems among many others, which require humans as a part of the functioning loop. The label of 'socio-technical' began in the 1950s at the Tavistock Institute with studies conducted on coal mining (Trist 1981; Trist et al. 1993). Based on these studies, the emphasis on the broader social constructs of activity, beyond its physical and physiological dimensions, was highlighted.

The emphasis on the socio-technical has become quite commonplace in the current parlance of Human Factors research, where the emphasis is on recognizing complex technological systems as socio-technical systems and devising appropriate tools, methods and measure for the same. In contrast to Human Factors engineering, socio-technical systems are also addressed by STS. Both historians and sociologists have highlighted the growth, constitution, and functioning of socio-technical systems in a variety of sectors. The primary emphasis of these studies has been to address the breadth and scope of socio-technical systems in their entirety. Prominent examples include electrical, computers, defence systems, among many others. The key aspect of STS based studies is the emphasis on the multitude of actors and processes at multiple levels of abstractions at multiple temporal and spatial scales acting in ways that provide a basis and identity to the functioning of the whole system. In this endeavour, STS is supported by the power of hindsight. The concepts and methodological approaches available to STS scholars enable them to gather a holistic understanding of the functioning of the system as well as its spread. In contrast, the scope of the system is often limited for engineers based on challenges related to their foresight. At many times, the scope of the problems that may arise in the subsequent scenarios is not clear. At other times, the problems that arise may fall beyond the purview of what the system was initially designed to accomplish. Therefore, this aspect of foresight in systems changes the kind of concepts required by engineers in comparison to the ones employed by STS scholars to address the same kinds of systems.

In addition to the above challenge, STS and engineering address socio-technical systems at different temporal and spatial scales. Engineers often focus on the near future time scales in which these systems can be designed and controlled; whereas, STS scholars focus on the long term emergent time scales. Further, for STS scholars, engineers are often one set of actors among the many other actors such as economists, managers and politicians who are involved in the socio-technical system. Therefore, the nature of concepts employed by engineers and STS scholars are comparatively different; as a result, there may not be a straightforward application of the concepts from one disciplinary group to another. Notwithstanding this fact, the first challenge is to recognize the disciplinary agenda and scope of STS and engineering;

also, note that the concepts used by them for comprehending socio-technical systems are not interchangeable.

A related issue in India is that there is a lack of human factors and systems engineering based human resources in the education sector. Currently, human factors and safety are limited to engineering departments and design schools. Thus, its knowledge and availability to the public are extremely limited in scope. Human factors and their instantiation as ergonomics in India, do not have specialized undergraduate programs (for a brief history of ergonomics in India, see (ISE. n.d. 2020). It is integrated into the existing design, engineering and health sciences curriculum in a limited manner. Similarly, STS programs in India are limited but rapidly developing. Educational programs in socio-technical systems or even complex systems engineering is currently non-existent in India, despite most of the problems in the industrial and civil sector in our times are complex in nature. They transcend individual disciplines and involve a multi-disciplinary approach. However, due to an educational system focussing on excellence in individual disciplines a multi-disciplinary approach that is needed for socio-technical systems engineering becomes extremely challenging institutionally.[1] Given the multi-disciplinary nature, a major challenge is to find a common language between disciplines and use it for developing and understanding socio-technical systems and associated methods.

[1] While the emphasis on educational programs worldwide have been disciplinary in nature, this aspect has changed rapidly in the past decade, where various educational institutions in a number of developed countries are moving towards a recognition of complex systems. A variety of educational programs are being developed to cater to education in complex systems engineering.

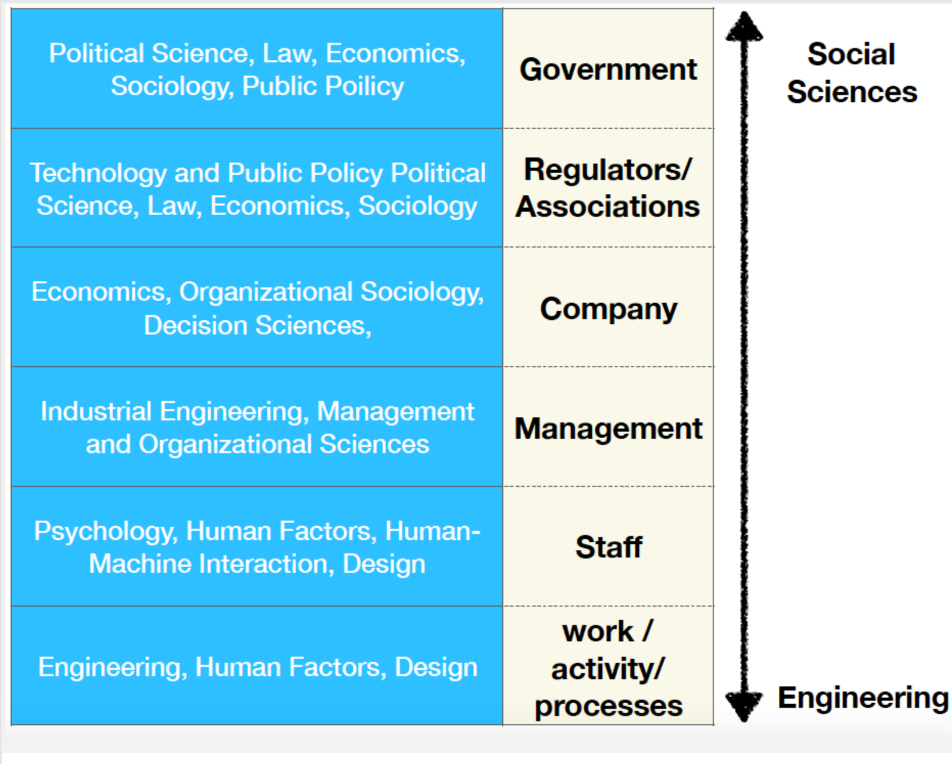

Fig 1 Multitudes of disciplines involved in socio-technical systems, ranging from social sciences to engineering, adapted from Rasmussen 1997.

3.2 *Challenge 2: STS enquiries in Engineering*

STS recognizes engineers and a number of ethnographic and historical studies have been done on engineers. A major theme in these studies has been to understand engineering knowledge and engineering practice. For example, Buciarelli (Bucciarelli 1988; Bucciarelli 2002a; Bucciarelli 2002b) addresses engineering practice where engineers are involved in the design of products. He introduces the term “object worlds” to emphasize that multiple meanings exist. While designing objects. These multiple meanings often revolve around the central idea that enables the engineering team to converge towards the final designed object in relation to the existing multiple constraints. Similarly, other ethnographic studies of engineering and engineering design exist and are known to STS scholars, which shows how engineering practice differs from scientific practice in terms of its epistemology (Henderson 1999; for e.g. Vinck 2003).

However, even though engineers have entered the discussions of STS, they have remained as one entity in the large umbrella of technology as addressed by STS. In other words, the focus of STS has been on the broader focus of technology rather than the engineer per se. As result, Downey has emphasized the ‘invisibility’ of the engineer (Downey et al. 1989). According to Downey, the engineers have remained ‘invisible’ in the disciplinary discourses of STS (Downey and Zhang 2015); the key idea of 'invisibility' was that engineering practice and engineering knowledge are not addressed in detail in the existing STS literature, which focuses on 'technology'. This focus of the STS literature has been to emphasize the construct of "technology" which is a larger construct than engineering (see Bensaude-Vincent et al. 2011; Nordmann et al. 2011 on varied meanings of technology, technoscience and engineering; also see Kant and Kerr 2019 on engineering knowledge). For example, STS scholars may address Magnetic Resonance Imaging (MRI) as a technology; however, this technology involves a number of actors, out of which engineers are one social group (Prasad 2014).

While this is not the shortcoming of STS as a field, the engineer becomes 'invisible' due to the scope and focus of the activity of STS as a disciplinary enterprise. As a result, scholars with a focus on engineering formed a network to enable discussion on engineers and their related aspects (International Network of Engineering Studies; www.ines.org). Therefore, a greater challenge is that because the emphasis on engineering knowledge is not widespread in STS as a discipline, the means to integrate the actual practice of engineering with constructs from STS becomes limited due to incommensurable ways of thinking, knowing and acting. In summary, in order to coherently engage engineering practice with that of STS constructs, there is a need for connecting both in ways that are meaningful to engineers in their practice without losing the insights provided by STS as a discipline.

3.3 *Challenge 3: 'Social' and 'technology' in socio-technical systems*

A third challenge associated with socio-technical systems is that the terms 'social' and 'technology' are keywords. They have multiple meanings that are often used in a variety of senses and meanings. As a result, the very idea of socio-technical as abstract hybrids of people and technologies often gets diluted to weak and disparate meanings. The term 'social' incidentally has two meanings that are used differently in two different disciplines (e.g. Greenwood 2003). For example, one of the meanings is prominent in American psychology, while the other in American sociology. The meaning of 'social' in American psychology denotes the presence and absence of other individuals. Therefore, the unit of understanding is the individual while the presence of another person makes the situation social; this is an 'interpersonal' view of the concept of 'social'. In contrast, in sociology, the person is understood in terms of evolving and being shaped by a larger group process. Therefore, the construal of the person is social regardless of whether other people are co-present with them or not. Therefore, in contrast to the 'interpersonal' view of psychology, the concept of 'social' is broader and recognizes that regardless of the immediate presence of others, the individual is a 'social' entity. This enables a more detailed understanding of the concept of the 'social' for socio-technical systems. This broader concept of 'social'. This broader concept of 'social' is helpful in socio-technical systems as it allows for the development of tools and frameworks that will help engineers to develop technologies that are more egalitarian in nature. By adopting the broader understanding of the concept of 'social', we expect changes in the requirements analysis phase of socio-technical systems design. As a result, a more detailed understanding of people in socio-technical systems is limited by the adopted conceptual viewpoint.

A similar situation occurs in the case of the term 'technology.' In early parts of the 1900s, this term was used as an umbrella term to denote a variety of tools, mechanisms, processes and systems (Marx 2010). In the past two decades, historians of technology have systematically shown that technological entities arise and are influenced by their milieus in which they are conceived (Bijker et al. 2012). This viewpoint has been recognized as the social constructionist view of technology. While the social constructionist view takes an agent view on technology, engineers who are not aware of these positions from a social science viewpoint, regularly ascribe to the technological viewpoint, as being guided by scientific-rational ideas.

Therefore, the important aspect to recognize in both these cases is that the social and technical aspects of socio-technical systems cannot be reduced to the category of the presence or absence of people as being involved with technology. As a result, if a broader conception of the notions of 'social' and technological are adopted, it will lead us to the design of socio-technical systems that cater to both the top-down and bottom-up conceptions of socio-technical systems design. Thus, the internal challenge for socio-technical systems is the construal of labels and the need for categories and concepts that link the disparate meanings from top-down and bottom-up into a common understanding.

3.4 *Challenge 4: Socio-technical systems and the fragmented nature of disciplines*

Another challenge that plagues the design and analysis of socio-technical systems is that they involve concepts, insights and methodologies from disciplines that are much beyond that of engineering or STS. These include political science, economics, organizational behavior and management, as well as many other disciplines that are involved in the design, operations and management of large-scale socio-technical systems. STS and engineering are often found at different time scales. Engineering and design often focus on operations and maintenance, while STS may focus on developing vignettes from these as well as higher levels of policies and strategies. The existing literature on large technical systems from the historical standpoint, in STS, emphasizes the various dimensions of STS which may range from design policies to economics of systems management. However, while historical studies consider a retrospective viewpoint, the various disciplines of political science, economics, management, among others, are employed prospectively in socio-technical systems. As a result, both engineering and STS fall short in completely characterizing the challenges of the design and evaluation of these systems.

Apart from the breadth of disciplines required for socio-technical systems, the nature of education in engineering and social sciences is highly fragmented in India. Engineering in

India has dominantly developed in a number of engineering institutes and colleges affiliated to universities. In the past three decades, the state-led examinations have resulted in creating an engineering workforce for the nation with a heavy reliance on technical-rational emphasis. While this engineering workforce relies on social sciences and management as prescribed by governing bodies (such as AICTE; www.aicte-india.org) there is no fixed method by which a common language is created in between social sciences and engineering. In turn, while a number of sociological and economic studies continue to be conducted on various aspects of technology in India, there is a lack of common language by which social scientists approach and understand engineering and its various subdivisions of mechanical, electrical, chemical and industrial, among its variety of instantiations. Thus, the challenge of finding pathways between engineering and social sciences still remain. The division of labor can be partly due to the institutional structures and practices that have a convoluted historical growth stemming from the initial visions of the Indian nation.

4 Why is there a need for mutual understanding? Knowledge production and the Bhopal disaster

While the two broad categories of state-based and citizen-based knowledge production may serve as a new understanding in the case of socio-technical systems, both these viewpoints are needed together. This aspect can be considered by examining the case of a disaster that started as a technical scenario but was later morphed into a socio-technical one. The case-in-point is the Bhopal gas tragedy of December 1984. While this industrial disaster has been examined from a multitude of viewpoints, in this chapter the emphasis will be to revisit the disaster from the viewpoint as depicted by the STS scholar Kim Fortun in her book *Advocacy after Bhopal* (Fortun 2009). The selection of the book is intentional as it supports the main point highlighted in this chapter; i.e., the disjunction between the two phases of knowledge production is not required when we are dealing with socio-technical systems. To understand this case study and Fortun’s ideas, we should first recognize that the disaster has been addressed from the viewpoint of human factors and industrial safety. However, Fortun’s analysis, set in the early 1990s, few years after the tragedy, shows that even a number of years later the repercussions of the tragedy was unabated. In counter-insurgent attempts, several local resistances and subsequent knowledge processes arose from the bottom-up in trying to come to grips with the aftermath of the tragedy. Prominent among these were women movements, environmental movements and a rethinking of technical and social problems. A prominent aspect of most of these movements were that they sprang ‘bottom-up’ to make sense, resist and bring about equity and justice. Bhopal gas tragedy had created a unique set of circumstances that required mobilization of resources and creation of local knowledge to fight back against injustice and the aftermath of the disaster.

Fortun also highlights the shifts in world orders and the perception of the global understanding of risk. The book is replete with a social construal of risk, vulnerability and disasters. However, while risk analysis as a discipline, in general, is becoming more sensitive to the social underpinnings of everyday lived experience, the requisite change in the academic engineering construal of risk as a social construct is still not present in Indian engineering in a widespread manner. As a result, the dichotomy between top-down and bottom-up knowledge production exists. Socio-technical systems and construal of risks show that this dichotomy is not necessary for socio-technical systems. Second, technical analysis should be inclusive of the social dimension of technical systems. The state-led knowledge production, which are top-down require a steady input in terms of bottom-up approaches that are citizen-focussed. This can be achieved by adopting participative approaches to design, operation and education. Participatory approaches that derive from social sciences take into account the subtleties of human experience and broader concerns of society. As result, engineering approaches that take into account citizen participation from the inception at various stages of design, planning and decision-making will support an egalitarian view of the acceptability of technology.

Even years after the Bhopal gas tragedy, the institutional structure of Indian academia has not opened up significantly to address systems as a social construct. This could be a result of two different aspects. First, socio-technical systems which has been a part of Human Factors as a discipline has not been sufficiently addressed by their Indian counterpart of the discipline of Ergonomics, in India. Traditionally, ergonomics in India has its roots in physiology, strongly rooted in the corporeal body. As result, the focus on knowledge production in large-scale systems, involving multiple stakeholder engagements, has not sufficiently recognized the social dimension of technical systems.

Second, due to the fragmentation of disciplines and institutional structures, the proper institutional setup in India is not present for addressing technical systems as social constructs. In addition, lack of disciplines such as history and sociology of technology, as well as, the polarization and exclusion of disciplines of science/technology at one end and those of social sciences at the other bring about a very interesting set of circumstances. These academic tensions in light of changing political circumstances have led to a unique scenario in India where knowledge production is being seen to shift from the mode of the state to the citizen. Subsequently, there is also a current lack of cohesiveness in large-scale technological projects run by the state-led institutions, academic or otherwise (top-down), and the local resistance from the bottom-up. Along with this aspect, there is a general lack of human-centeredness in the design of large-scale systems. This dichotomy will not go away on its own and requires careful consideration of knowledge production processes both in academia and beyond. One explicit challenge for STS and engineering in India is to work closely with engineering to bring about a unified understanding of socio-technical systems in India. Such an understanding requires going beyond technology and society based courses taught to 'sensitize' engineers. Rather the engagement demands a joint engagement between sociologists and engineers in terms of bringing the two modes of knowledge production state-led and citizen-led, to be merged coherently.

5 Conclusion: revisiting the basic premise

The basic premise that has been put forward is that in the Indian context, there has been a shift in the mode of knowledge production. The previous mode was based on the traditional reliance of top-down approaches while the new mode has renewed emphasis on bottom-up modes of production. The aim of this chapter was that in the case of socio-technical systems this dichotomy of modes of knowledge breaks down as both these modes are equally important.

In the Indian context, the growth of the existing systems such as healthcare, transportation, and sanitation, among others, requires a joint commitment from the state and its citizens. The traditional approach has been that the state acts as the producer and the citizens as the consumers; whereas, the new mode of knowledge generation has the roles reversed. In contrast, the emphasis of this chapter has been to break away from the producer-consumer model towards presenting a conjoined view that is the basis of the socio-technical systems approach. This conjoined view is manifested at various levels of design, operation and maintenance of socio-technical systems. At the design level, there is a need for conceptual analytical structures and design processes that are inclusive in nature; i.e. it takes the end-users, citizens, and other stakeholders into account right from the beginning. Therefore, the design is a human-centred design rather than a technically oriented design. At the level of operation and maintenance, citizen-led initiatives generate a wealth of knowledge at the community level; these should be factored in by state-led initiatives while making decisions about optimized operations, maintenance and repair.

A final point that needs to be highlighted is that there is a need for pathways that support innovations at the levels of operations at the ground, as well as take these innovations to improve the overall system. This can be obtained through participative planning and action-oriented research and practice. In turn, the top-down influences should be such that they enable a framework that allows for innovation and growth while ensuring that the overall functioning of the system is not affected. Further, due to the large-scale systemic nature of these socio-technical systems, distributed modes and models of functioning will have to be devised. These above-mentioned issues are a few initial steps and have to be taken together with the four challenges raised before. The epistemic challenges highlight that dealing with the socio-technical is not simply a straightforward task for systems engineering but is deeply rooted in the context in which the system develops. In our case of Indian socio-technical systems, there is a need for engaging citizens, users and other stakeholders alike in participative modes of functioning while maintaining the integrity of the technical dimension of the system.

The four challenges that were introduced earlier highlight that currently the STS-based thinking has not permeated engineering in India. The notion of socio-technical has remained fragmented and the disjunction between social sciences and engineering exists at an institutional level. All these challenges of socio-technical systems and its manifestations make its instantiation in the Indian context rather convoluted. Therefore, to ascertain proper design, maintenance and operations of systems, we need an understanding of both modes of knowledge production — top-down and bottom-up. The merging of these two modes of knowledge is important because both the bottom-up and top-down processes are to be taken together in socio-technical systems, making the technical social and supporting the social by technical.

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