Special Issue: Inquiring into Technoscience in India

Building a BUS: Technoscience and the emerging mode of organising interventions in Indian Cities

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Abstract. Despite the growing economic footprint of cities, surprisingly little attention has been devoted to understanding the relation between technoscience and cities. The field of urban technoscience seeks to develop a body of knowledge to plan and design vital urban metabolic flows including water, waste, sanitation, movement, and energy. Underlying this field is the urgency to intervene in cities to solve urban problems in a scientific fashion through the development of infrastructure plans and designs. As vital sites for India's current political economy, cities are now witness to systematic attempts to alter the technoscientific base of cities in the country. How is this shift happening in India? Drawing upon research in Science and Technology Studies (STS), history of urban planning, and allied social science fields, this paper characterizes the shift as BUS – Big Urban Science and Engineering. The paper provides an analysis of BUS and concludes with some implications of BUS for urban change in India.

Keywords. Cities; India; Big Science; Urban Science

Introduction

Cities are fascinatingly complex and polyvalent entities that, in our rapidly urbanising world, now host a large and growing fraction of the global human population. Attendant with the growing footprint of cities has been a growing scholarly scrutiny on a diverse array of cities by several fields of humanities and social sciences including history, geography, urban planning, anthropology and sociology but also the interdisciplinary field of urban studies. Despite this surfeit of scholarly focus on cities, surprisingly little attention has been devoted to understanding the relation between technoscience and cities. For reasons that we will examine a bit more closely later in the paper, studies of technoscience have largely ignored the urban in their scholarly analysis. Farias and Blok 2017 observe that "bringing [the study of science and technology] into the city remains urgent, we contend, considering how even in the last decades new technologies have been praised and introduced as a powerful force reshaping urban settings worldwide" (p.555). This paper answers this urgency by focusing on the recent interest in the field of urban science and engineering. The field of urban science and engineering seeks to develop a body of knowledge (based on gathering data and development of physical models) to plan and design vital urban metabolic flows including but not limited to water, waste, sanitation, and movement. Underlying this field is the urgency to intervene in cities to solve urban problems in a structured and deliberate fashion through the development of infrastructure plans and designs.[1] This is by no means a new pursuit but what is novel is the positioning of urgency in the field.[2]

I would propose that the recent urgency to know and intervene is a product of an urban cynosure whereby cities are located on a frontier inextricably linked with advancing the contemporary globalising political economy. This attention hinges on a discourse that emphasises the role that cities play in moving the economy forward. One metaphor that encapsulates the increased importance that cities have acquired is cities as engines of economic growth.[3] With this increased attention, cities have emerged as objects of sustained projects to streamline their constitution so that, in keeping with the mechanics of the metaphor, they perform optimally to stimulate economic growth thereby raising their host country towards progress (Kumar et al. 2020).

Cities are becoming increasingly important constituents and vital sites of India's current political economy; with a result that Indian cities are now witness to numerous attempts to intervene and transform them. While it is not simple to characterise these multiple

[1] Despite the existence of overlaps and connections, it is important to distinguish between domains of urban science and engineering and urban planning. The distinction is important because it has a bearing upon the objective of this paper, which seeks to focus primarily on urban science and engineering and not on urban planning. Urban science and engineering, as we shall clarify later in this paper, is predominantly conceived as an instrumental technological enterprise that seeks to develop the technoscientific products, processes and systems that together constitute the "connective tissues and circulatory systems of [urban] modernity" (Edwards 2003:185). In this we are led by historians Hård and Misa 2008) who referring to the European experience speak of the urban machineries of modernity – technologies that constitute the inside of urban modernity. On the other hand, underlying urban planning are particular encompassing visions of a desirable urban life and their translations into a planned sociospatial order (Hall 2014). This distinction is particularly visible now in contemporary India where a discursive shift in public planning has seen the profession shift away from the classic visionary comprehensive master planning towards project-driven plans in infrastructure development associated with more instrumental urban science and engineering (See Kumar et al. 2020).

[2] Indeed, the reliance on science and engineering in knowing and intervening in urban processes can be traced back to the bacteriological city, which Gandy 2006 characterizes as an urban epoch originating in mid-nineteenth century Western Europe marked by scientifically testable disease epidemiology, technical innovations in channeling urban metabolic flows, and technical expertise. But this overwhelming reliance on science and engineering in the modern Western industrial city of the late nineteenth and early twentieth century have marked the city in a paleotechnic age with a mechanized order marked by modernist urban planning norms (Mumford 1961).

[3] The India Infrastructure Report produced by the Expert Group on the Commercialisation of Infrastructure in 1996 for the Government of India recommended the government transform its role from being a provider of infrastructure to being a facilitator and regulator of private players providing these services (Ghosh et al. 1997). This shift has been achieved by incorporating logics of financial reform, privatization and commercialization in infrastructure development in India (Kundu 2001; Mahadevia 2003).

interventions, these efforts seek to intervene and govern the technoscientific base of cities in the country. By technoscientific base, we refer to the underlying municipal infrastructure that draws upon a range of societal knowledge on organising technology and science to allow cities to offer a range of services that modern humans expect to find in cities. This service base includes a vast range of domains including water and sewerage wastes, transport and mobility, solid waste. As Kumar et al. 2020 note a key contextual dimension associated with these interventions has been the diminishing legitimacy of master planning and shift in the public sector planning away from comprehensive planning towards project-oriented plans in infrastructure and real estate development. The reasoning behind this shift is that by enhancing the nature of infrastructure services and their technoscientific base it is possible to transform cities, thereby enabling their role as engines of economic growth in the country.

How can we characterise this shift in India's urban technoscientific infrastructure base in the context of the wider transformation of technoscience in India? This paper characterises this shift as installing a mode of technoscientific development that we refer to as Big Urban Science and Engineering (BUS) in India.[4] BUS, as the name suggests, prioritises the big in intervening in the urban fabric. This thrust towards bigness recalls the long history of choosing gigantism in organising science during the Cold War era. Although the term originates in the USA from a particular historical context in the middle of the twentieth century, Big Science could be understood as a transnational mode of organising technoscience that came to be marked by three aspects big machines, big organisations, and big politics. Big Science was particularly notable for its preference to create large industrial-scale experimental set-ups where huge and enormously complex instruments were deployed while hundreds of scientists and engineers worked together to address fundamental questions of science, all within the benevolent management of national political organisations. In the shift away from comprehensive master planning towards project-driven infrastructure plans, Big Science offers a means of framing this emerging mode of organising interventions in the urban technoscientific base.

We begin the paper by briefly reviewing, in the following section, the emerging field of urban science and engineering and its positioning within the contemporary interest in cities as frontiers driving the global political economy forward. Focusing on the history of interventions to re-shape Indian cities, this paper relies on the parallels with Big Science to frame the operationalisation of a Big Urban Science and Engineering (BUS) in India as a mode of organising urban technoscientific intervention and experimentation into big machines, big organisations, and big politics. In order to do so, in the next section, we delineate the history and politics of Big Science with an aim to discerning some salient features that have come to define its organisational and technological footprint. In the following section, we then turn

[4] A note about the acronym BUS or Big Urban Science and Engineering is in order. The acronym BUS appears to disregard to the term engineering, which we acknowledge is heart and centre of the emerging mode of urban interventions. This is unintentional for two reasons. First, it makes a more appropriate acronym by dropping the E for engineering from the acronym because JNNURM (the large project-driven intervention to reshape Indian cities) was exemplified by urban buses that continue to circulate in cities across the country. Second, we see technoscientific knowledge underlying the project-driven interventions that characterize contemporary efforts to transform Indian cities. We, thus, see science and engineering as inseparable outcomes of a particular rationality.

towards our case by describing the changing role that cities have acquired in India's contemporary political economy and how this has become the motivation behind a deliberate thrust for technoscientific interventions into the urban landscape. The following section will employ the Big Science framework to examine the constitution of Big Urban Science and Engineering (or BUS) in India. This section forms the core empirical material in the paper. It relies on extended fieldwork and research conducted between 2013-2015 especially on the recent experience of urban renewal exercises in Indian cities to substantiate the constitution of BUS. The paper concludes by offering implications for science and engineering in an increasingly urbanising Indian context.

(Urban) Science (and Engineering): An Endless Frontier or a Contested Legacy?

In July 1945 in the *Science An Endless Frontier*, Vannevar Bush made a strident call that science offers a ceaselessly expanding frontier for the United States of America whereby it can continually rejuvenate its pioneering spirit. The country would do well to heed this call because explorations on the science frontier would offer the nation benefits in safeguarding its security, in advancing health, and in promoting economic prosperity. The report proposed that to maintain this pipeline of progress, the nation need only support scientific research and the returns would follow in due course. This arrangement of states supporting scientific research to extract societal benefit (first definitively outlined in the *Science An Endless Frontier)* became the basis for post-war research funding in the USA and has since expanded beyond to become the model for national science policies around the world in the second half of the twentieth century.

The wide prevalence of a globally interconnected political economy since the late twentieth century has unravelled, to an extent, the nation-centred model of support for scientific research articulated in the *Science An Endless Frontier*. In its stead, alternate models of scientific production such as Mode 2, Triple Helix, or post-normal science have made their appearance in the policy discourse. These newer models emphasise a paradigm shift in the social contract of science (Elzinga 2004). Associated with this new contract is the shift in the locus of scientific production away from nation-centred to post-national arrangements involving a range of actors and sites. Cities are one location of technoscientific production that has attracted considerable recent attention. The attention focused on producing scientific urban knowledge is not unintended. Cities are intensely entangled within the constitution of the current economic regime. Cities and their infrastructures are key spatial fixes (Harvey 2001) that ground and enable the current round of capitalist production. Under these circumstances, cities as nodes of innovation and growth are preferred locations for the roll-out of projects of neoliberal restructuring associated with enhanced transnational linkages of capital, ideas, and information (Peck et al. 2009). Re-forming urban areas, according to this reasoning, is a particularly productive enterprise that offers increasing returns for the growth of the national political economy. In this sense, cities are characterised as potent engines that drive national economic engines. Indeed, the metaphor of cities as engines of economic growth is widely prevalent in the popular and policy discourse.[5]

As urban studies scholars have noted, the attention to a city-centred discourse of economic advance has translated into particular modes of intervention and re-fashioning to set the city 'right' and to imagine a 'world-class' city that is more hospitable place for economic advance. One pathway forward has been to utilise a host of urban interventional strategies including policies, best practices, and benchmarking techniques as instruments of power for articulating a new city-centric agenda for change. The recent literature on policy mobilities has demonstrated how urban policies are employed to reinforce the power of trans-local and mobile policy 'expertise' embodied within urban consultants to pick up and touch down best practices and techniques (Ward and McCann 2011). Yet another mode has been to inter-reference and compare cities to imagine a preferred direction of change. A range of inter-referential practices such as preferred models (Percival and Waley 2012; Zhang 2012) or mobile exemplars (Yap 2012) have been particularly prevalent in fashioning imagery of how a city can aspire to be world-class - what Roy and Ong 2011 posit as 'worlding'.[6]

Experimentation, it needs to be pointed out, has been key to the realisation of the current discourse of urban change. Experimentation in and around cities has a long history from the beginning of the twentieth century at least when cities emerged as important sites for gathering knowledge about how cities function but more importantly also sites from where knowledge gathered could then be fed back to inform policy interventions.[7] Experimentation was prevalent in the Indian colonial context with regards to how urban areas should be ordered and became the basis for advances in fields of urban planning, urban development not only in India but also in the metropolitan European context.[8] The motivation for technoscientific experimentation in cities is rooted in the twin legacies of British colonists who saw India as a laboratory for planning and other practices of statecraft and in the aspirations for planned urban modernity amongst elites in the post-independence period. In the early eighteenth century, experiments in shaping urban space were restricted to designing cantonments and civil lines to house the colonial military and administrative elites or in exerting an imperial presence (King 1990). By the late nineteenth century, British colonial spatial interventions were largely restricted to their commercial or residential zones while a laissez-faire logic prevailed in the predominantly native regions. Growing out of a desire to control disease burdens in these neighbourhoods and learning from technoscientific interventions to the crisis of health and hygiene in the European industrialising city in the mid-nineteenth century, became the basis for the field of urban science and engineering that arose in response. At its heart was the 'sanitary idea' of harnessing the power of scientific technology to engender public health reform in the nineteenth-century city (Melosi 2000).[9] However, Melosi 1990 argues that the implementation of urban infrastructure technologies was

[6] Despite the largely atemporal focus of the contemporary literature on global circulation of urban policy and planning knowledges, Harris and Moore 2013) remind us of the powerful continuities and disjunctures with planning histories from colonial and early postcolonial periods. Indeed, they point to various instances of exporting and circulation of planning techniques, norms, and systems in the colonial and postcolonial setting (King 1977; Banerjee and Chakravorty 1994; Banerjee-Guha 2009; Vidyarthi 2010).

not automatic or unintentional but outcomes of deliberate actions on the part of decision-makers to confront the numerous environmental challenges that the industrial city in the West spawned. This restricted and largely instrumental spatial intervention was dramatically altered with several instances of epidemics raging through major Indian cities culminating in the plague epidemic at the start of the twentieth century (Spodek 2013).

One response was the forging of more systematic and bureaucratic interventions starting first with City Improvement Trusts and then after 1915, continuing the trend in Britain, of adopting town planning legislation.[10] The widespread urban decay and squalor that architects, social reformers, and sanitary engineers saw in the European industrialising city, became the motivation for a comprehensive, rationalistic, and technoscientific approach to urban form. This intention to reform the physical well-being of cities congealed into the field of comprehensive physical planning to imagine new and desirable physical arrangements for the city as evident in the Parks, Garden City, and City Beautiful movements in the West.[11] Building upon these intellectual shifts, the key to town planning legislation in late colonial India of the early to mid-twentieth century was the reliance on zoning (rooted in norms of the desirable physical urban form) and associated with strategies of land acquisition and eminent domain. These, in practice, paved the way for widespread clearing of congested areas, slum tenements and older buildings to design straight wide thoroughfares and well-spaced and zoned settlement patterns (Spodek 2013).[12]

While the origin of town planning in the colonial period left many important legacies, it was in the immediate post-independence period that comprehensive city planning became a vehicle for fulfilling the aspirations of national elites to fashion modern cities. Modernisation, as embodied in architecture and systems of city planning, offered the promise of a deliberate and rational process of transformation not just of urban place but also by extension of its inhabitants and society at large (Kalia 2006). As a key component within the Nehruvian project of national planning, reshaping urban space possessed two facets. First, as in other elements of national planning, experiments in the modernisation of spatial planning were rooted in the

[7] The Chicago School in USA as the name implies was an early example of experiments that were launched in Chicago with the intention of studying and intervening in urban society. These studies then became the basis for entire fields of study such as sociology and urban studies but also interventional fields such as planning (Gieryn 2006).

[8] King 1980; King 1989 notes that colonial cities became sites for experiments in urban planning not otherwise possible in metropolitan European contexts.

[9] But, as Gandy 2006 has argued, technoscientific innovations and interventions (such as scientifically testable disease epidemiology and water and sewerage works) in cities were accompanied by a raft of innovations in municipal administration, new policy instruments, and models of municipal financing that together gave rise to an urban epoch in the mid-nineteenth century Europe that he refers to as the bacteriological city.

[10] Indeed, recognizing the long historical connection that existed between urban planning and the public health agenda, Jason Corburn (Corburn 2012) calls for a re-connection between the two fields in the face of new and emerging urban health burdens. However, he suggests that the connection should be founded on a new social contract that articulates anew the relations between science and society, expertise and participation.

[11] Recognizing the central importance that technology and engineering play in planning (especially physical planning and urban planning) and city development, planners have for a while called for a re-engagement between infrastructure, technology and planning (Pivo et al. 1990). More recently, Neuman and Smith 2010 have reiterated the need for strategic engagement between cities, planning and urban infrastructure.

[12] One notable objector to the predominant orientation in physical planning towards zoning and bulldozing of existing settlements was interdisciplinary planner and sociologist Patrick Geddes (Munshi 2000). Arising out of a perspective of seeing cities as evolutionary organisms, Geddes proposed rupturing the fossil fuel-driven paleotechnic order of cities through grounded and ameliorative interventions of diagnostic survey and conservative surgery that recognized community not zoning as the focus of planning (Spodek 2013; Srinivas 2016; Rao-Cavale 2017).

agency of modern technoscientific development (Arnold 2013; See also Raina 1997). Second, city planning was conceived as a state-driven project conceived and implemented by bureaucratic and technocratic elites in a hierarchical, top-down fashion (Vidyarthi et al. 2013). Given these attributes, the technical expert became a vital actor in animating and executing the modernisation of Indian cities (Vidyarthi et al. 2013). Initial experiments, such as the development of the Delhi Master Plan and the conception of Chandigarh as a new, planned town, were organised along these lines and supplemented with the infusion of technical assistance from abroad (Banerjee 2009). These experiments possessed enormous pedagogical value to the modernist, national enterprise and since the mid-1960s were largely institutionalised throughout the country within a town planning apparatus composed of city planning legislation and dedicated departments staffed by technical experts to conduct periodic and comprehensive master planning processes.

By the late twentieth century, the Nehruvian consensus on technoscience (and on national planning) had all but frayed and from its ashes was emerging a new consensus (Raina 2014). Within the domains of spatial and urban planning, this new consensus is reflected in the emergence of two facets. First, spatial planning has emerged as a key instrument to "coordinate and advance growth-oriented economic activity in the country" (Vidyarthi et al. 2017: xiii). One way this has manifested is through the decentering of the prominence and attention that centralised state-sponsored master planning had enjoyed in the first years after independence. Second, is the entry of a variety of new actors in the plan-making process. While, during the previous Nehruvian period, spatial planning was the exclusive domain of credentialed technical planners who designed plans for cities arising out of technocratic zoning criteria, in the current period, several new actors such as entrepreneurs, real estate developers, employees in technology services have entered the plan-making process (Vidyarthi 2010). This shift needs to be seen as an effort to instil reforms while also expanding plan-making to meet the needs of an emerging and increasingly vocal new middle-class. As a result, Vidyarthi (Vidyarthi 2018) argues that plan-making and planning itself have shifted, becoming a dynamic arena with a range of imbricated plans operating simultaneously, at different levels, and sponsored by different entities . The combination of these two facets is visible in a shift away from comprehensive master planning towards dedicated project-driven planning experiments focused on particular domains such as infrastructure, housing, etc. (Kumar et al. 2020).

This shift towards project-driven planning in India coincides with a wider trend in the germination of micro-scale urban experiments around the world but especially in the West that attempt to address intractable problems that humans face such as climate change, sustainable energy, or service provision (Evans et al. 2016; Karvonen and Heur 2014). These micro-scale experiments and plans have now emerged in the context of a renewed engagement of academic research with the technoscience of cities motivated by the coming together of several disparate strands. Advances in modelling how the city functions riding upon the rise in complexity theory (Batty 2013), the development of a wide array of technological micro-sensors that allow data to be gathered and relayed continuously and in real-time, growing computational capacity to process and analyse massive streams of data, combined with technological infrastructures that are responsive in real-time to dynamic computational analysis of urban flows have forged a new 'smart' technoscientific engagement with the city (Kitchin 2016; Kitchin 2017).[13] One now sees the re-efflorescence in the field of urban science and engineering around the world. Urban Science and engineering is a field that seeks to understand, predict, and intervene in how cities grow and change intending to make better, sustainable, and manageable cities.[14] There are several recent examples from around the world of new research and academic units that seek to understand cities and their functioning in order to be able to model, predict, and solve problems in the urban context. MIT offers an urban science major that combines urban planning and computer science. Similarly, IIT Bombay houses a Centre for Urban Science and Engineering (C-USE) that seeks to improve the quality of urban life through products and solutions to housing, transport, water management, health, governance and urban poverty amongst other things (C-USE 2020).

Against this milieu of project-driven planning orientation and micro experimentation, organising urban interventions in India have acquired a markedly distinct trajectory. Urban experimentation in India since the early 2000s has been proposed, orchestrated, monitored, and funded at the national level. As a result, urban experimental efforts have acquired enormous size and scope. Starting with the Jawaharlal Nehru National Urban Renewal Mission (JNNURM), and then followed by the Smart City Mission, and the Atal Mission for Rejuvenating Urban Transformation (AMRUT), since 2005 there has been a succession of large-scale experimental efforts to alter the technoscientific base of Indian cities and the *science of service delivery*.[15] The scale and scope of urban experimentation are evident in the magnitude of the funding associated with each of these programmes. The JNNURM, Smart City Mission, and AMRUT, together received more than 50,000 crore rupees from the national government. It is worth noting that the syntactical differences are simply on account of their attribution to different political parties in power.[16] All three programmes take a similar centre-led, consultant-driven approach focusing on improving service delivery in cities (Smith and Pathak 2018). Mahadevia 2011 argues that JNNURM was a mixed bag, achieving precious little in improving urban service delivery in the 64 cities it benefited. Given the near-absence of basic services in other Indian cities, even a marginal improvement is valorised as 'smart' (Smith et al. 2019). This 'smart' card is only meant to attract global capital to real estate and infrastructure in Indian cities (Burte 2014). But the Smart City Mission has also kicked off a command-and-control model of governance in cities, exemplified by the smartphone-enabled information technology projects that several cities have proposed as part of the programme. Overall, it can be argued that these interventions form part of the larger agenda of territorialising and state-led urban restructuring of Indian cities (Williams et al. 2021). They create a practice of urban experimentation that we refer to as Big Urban Science and Engineering or BUS. Given that there is limited precedence for the scale of this form of urban practice in India, it is important to understand some key dimensions of how BUS is being rolled out in the country. Before we investigate this phenomenon, we conduct a brief exegesis into Big Science.

Big Science

Big Science is a particularly influential term in the social and historical study of science and technology. Originating fittingly in the USA in the 1960s, the term has achieved a surprising degree of traction in several social science fields. As we shall examine in this section, the juxtaposition of the descriptive adjective Big with the word Science has granted the term enormous polemical, and to an extent, conceptual vigour. Its conceptual utility can be assessed against two registers. First, Big Science indicates a particular institutional connotation of science. Second, is the inseparable meshing with national and therefore big and weighty priorities beyond those articulated by an unadorned science. We shall describe each of these below.

Weinberg 1968 assessed Big Science as a troubling development that threatened to rock the integrity of the scientific mission, potentially destroying it. He diagnoses the troubles with this approach at multiple levels. At one level, there is the reliance on large-scale instruments for the conduct of scientific experiments. Managing and maintaining these large apparatuses necessitates an organisational approach beyond what could be managed by an individual researcher. The resulting growth in the organisation of science has meant that scientists are no longer just working amongst themselves but within an organisational structure composed not just of scientists but also technicians, and administrators. The presence of these multiple actors with their diverse motivations leads to the dilution of the scientific objectives that should, otherwise, have driven the endeavour. In addition, sustaining the presence of this infrastructure and organisation of science becomes the motivation behind an insatiable desire for large fund infusions. This increasingly divorces the objectives of science from that of the associated enterprise, with the latter often assuming predominance. Weinberg was, thus, of the opinion that Big Science was an unhealthy condition – a pathology even (Capshew and Rader 1992: 5).

By the 1960s the term Big Science was widely being used in both popular and scholarly literature to not only describe but also critique the current condition of technoscientific research in the USA. The shift from an unadorned but familiar science of the early twentieth century to the ambivalent Big Science of the 1960s was underwritten by particular technoscientific endeavours such as the Manhattan Project and the reliance on atomic energy to develop nuclear weapons for World War II and later the Cold War. But Big Science did not only connote militaristic instrumentality writ large, but it also indicated a particular paradigm of institutional development in science that engaged with the national interest. Thus, the military-industrial complexes of the superpowers that fuelled the arms race, the space exploration race, and other competitions for technoscientific superiority are equally embroiled in the articulation of Big Science. The intimate embroiling of science in these, often unsavoury, geopolitical contests has brought about a shift in the motivations of Big Science. Big Science has come to be closely associated with the achievement of national priorities for growth, aggrandisement, and status. One way this has happened is by aligning Big Science with contemporary regimes of science and technology policy. Elzinga, Mirowski and other astute observers of science policy-making suggest that paying attention to these regimes it is possible to track the periodical shifts in the organisation, funding, and even the content of science (Elzinga 2012; Mirowski and Sent 2008). Thus, Big Science in the immediate post World War II regime of elite governance was characterised as driving national priorities. As countries compete with each other, more so now in the time of frenetic global interconnectedness, Big Science is a means to maintain newness and distinctiveness. As Hallonsten 2016 points out in his recent work on a Transformed Big Science, the new Big Science of the twenty-first century is now embedded in the current policy regime of technoscientific innovation systems. But this shift towards distinctiveness was achieved through a clearer shift towards commercialisation, managerialism and auditable accountability to meet societal needs (See also Mirowski 2011 and; Mirowski and Sent 2008 for a characterisation of the current globalized, privatized science policy regime).

The combination of the concept's problematic geopolitical roots in military expansionism, its alignment with national policy-making regimes, and with the thoroughgoing enmeshing of scientific practice within the matrix of administrative and bureaucratic structures have inserted a particular dynamic into the enacting of Big Science. Hallonsten 2016: 7 offers a framework to define the enactment of the bigness of science in terms of three dimensions: big organisations, big machines, and big politics. Big organisational footprints of Big Science refer to the involvement of large groups of functionally differentiated participants who working in conjunction to make possible the assembly of Big Science. The presence of large functionally differentiated tasks performed by different groups introduces enormous complexity in the management of these organisations, especially since these organisations have to continuously reconcile between often diverging organisational priorities. Thus, their administrative bureaucratic structures are, more often than not, oriented in a different direction from the key tasks of maintaining scientific autonomy and validity in practice. Assuring that these distinct priorities are resolved requires additional administrative overlays which leads to inflating the already big organisational footprints. In addition, the dense interconnections that pervade different scales lead to organisational innovations that further compounds the bigness of the organisation. Such organisations often have to devise strategies and techniques to link together groups of individuals at multiple scales to ensure that skills are leveraged, expertise is incorporated, and performance is accomplished.

Another key feature of Big Science, according to Hallonsten's framing, is big machines. According to Hallonsten 2016, big machines refers to machineries and instrumentation assemblies that possess enormous technical complexity and are concentrated in particular locations. This understanding is broadly congruent with historical definitions of Big Science as constituted with monumental technologies such as accelerators, nuclear reactors, and space vehicles (See Weinberg 1963). Such technologies are the main engines that drive the scientific work encapsulated by Big Science. Capshew and Rader 1992 at the same time stress that machines at the heart of Big Science also embeds a mindset marked by instrumentality in achieving particular social ends. Thus, energy production through nuclear means is driven by large and complex nuclear generators because of their ability to supply enormous quantities of energy that society can then absorb. A final dimension of Big Science is big politics. It is this third dimension that is particularly impactful in the constitution of Big Science as a defining force for change in recent scientific endeavours. The political impact of Big Science can be characterised into the following aspects – visibility, symbolism, and display of power. Hallonsten 2016 notes that the politics of Big Science is marked by visibility that far exceeds the financial or administrative magnitude of the endeavour. This visibility is evident in the popular coverage as well as in the official documentation that such endeavours attract. Yet another aspect of its politics is associated with the potent symbolism of nationhood, national pride and national identity that such efforts become invariably entangled with. A final aspect of its politics is the political power that appears to stand behind such efforts. In many instances, Big Science receives approval and attention from the highest echelons of the national government, and this grants such projects importance far exceeding other comparable projects.

Big Science is a concept that has received considerable popular and scholarly attention. But, despite this attention, attempts to conceptualise it has been quite elusive and this has given the concept a polemical nature. Indeed, the historian Peter Galison has noted that this term has a limited analytical capacity (Galison 1992). In this context, Hallonsten 2016 recent framing of Big Science as possessing three dimensions – big organisations, big machines, and big politics is a particularly noteworthy attempt. Rather than mining the term's epistemological or ideological dimensions, he is content to provide a means to think through the ontological distinctiveness of the term. Such an analytical approach is particularly useful to re-purpose the term to analyse the reliance on bigness in other technoscientific contexts.

Building BUS

Big Urban Science and Engineering (BUS) is a practice of urban experimentation writ large that has become lodged in the collective consciousness of making urban change in India. Big Science provides a means to comprehend the enactment of bigness in this emerging practice of making science and engineering serve in enhancing and improving how cities function. As we have seen above bigness in Big Science is manifested through three dimensions – big organisations, big machines, and big politics. We contend that these three dimensions are patently evident in the modern Indian practice of BUS. However, as we shall see the bigness that is articulated in each of these dimensions is quite distinct from the quality of bigness associated with Big Science.

Big organisations: Several recent organisations have been created to facilitate the practice of urban science and engineering. Bigness is evident in these organisations through their reach that is expressed through different aspects – intrusive reform orientation; multi-scalar articulation; and embedding technologies of neoliberal governmentality (Gopakumar 2014). Collectively these organisational aspects marshal a particular regime of urban knowledge with regards to service delivery, project management, and financial management. The primary organisational aspect that leads to bigness is the underlying conceptual orientation guiding it. Organisations supporting BUS are underwritten by a reform orientation that posits that the condition of cities is seriously awry and needs to be fixed. Such a conclusion opens the way for a techno-managerial intervention into the urban condition in the country. In order to do that there is a need for multi-level partnerships and agreements between national, state, and city levels. Reform conditionalities that are tied to project approvals and the release of funding tranches from the national and state levels are the means to ensure the reform orientation guides organisational practices (Kundu and Samanta 2011). Yet another aspect is the construction of a multi-scalar structure that spans national, state and city levels. JNNURM, for instance, was accorded a programmatic reach to cities around the country by developing a multi-tiered organisational structure at the national, state and city levels (Narayan 2018). Each of these levels was tasked with approving, funding, and monitoring project development and implementation. In order to achieve this, JNNURM created organisational units at the national, state and city levels to manage and steer the realisation of programme objectives (Narayan 2018). At the city level, a project implementation unit (usually the city government but also quasi-statal entities) are tasked with the execution of infrastructure projects. A dedicated organisational entity referred to as the state-level nodal agency provided steering and monitoring roles. At the national level too, the Central Sanctioning and Monitoring Committee exerted operational oversight over projects while at the same time appraising and sanctioning funding for individual projects. A final aspect is the incorporation of a host of technologies of governing that together assemble rationality that underlies how JNNURM steered cities in the country. Broadly these technologies of governing can be divided into two – those associated with the project development cycle and those associated with the review and monitoring cycle. Associated with each of these cycles are specific strategies, exercises or techniques. For example, the project development cycle was composed of the City Assessment exercise, urban visioning strategy, Project scoping, capacity building amongst others (Banerjee-Guha 2009). It is another matter that these exercises were not carried out with rigour or sincerity in several cities, resulting in poor participation and buy-ins from the citizenry (Mahadevia 2011). Taken collectively, these aspects of India's recent urban organisational enterprises (exemplified in the JNNURM programme) are extraordinarily intrusive in seeking to alter urban policy discourse by centring a national vision and rationality of how cities around the country should be managed and serviced.

Big machines: Yet another inseparable feature of the current Indian practice of BUS is that it relies on big machines to achieve its objectives. Machines, in this case, are particular technological instruments such as elevated tolled expressways, signal-free corridors, mass rapid transit systems, centralised wastewater systems that are particularly emblematic of Big urban science and engineering (BUS). Such machines are gigantic against most scales of construction and require enormous investments in capital and techno-managerial skills to realise. For instance, elevated expressways often run for many kilometres and require many tonnes of steel and concrete to support the superstructure of the roadway. At multiple levels, such machines have emerged as critical to the practice of BUS. At the scientific level, these big machines represent supply-oriented interventions that further conventional orthodoxies of urban science and engineering. In so doing, urban deficiencies are conceptualised in a fashion whereby bigger and bigger machines are required to address the problem, that would otherwise lead to paralysis in the functioning of cities. This supply-side orientation is particularly visible in fields of urban transport planning and engineering as well as in water supply and sanitary engineering. In the field of urban mobility, for example, the assumption of time-savings in addressing the 'friction of distance' has exerted a hegemonic dominance in how people movement in cities is understood, how knowledge about it is created and addressed. Madhav Badami (Badami 2009) has noted that the high value assigned to time-savings have justified the creation of high-speed highways designed for automobiles that will then reduce travel times, thereby addressing this urban deficiency.

Within this supply-side orientation, given the high priority that time-savings play, scientific findings in urban transportation have invariably sought to address this factor. For instance, a key determinant of traffic studies has been the volume/capacity ratios (V/C ratio) of roadways. A roadway with a V/C ratio less than 1 is considered to be in a state of free flow with automotive vehicles facing a situation of unhindered movement. At the same time, a V/C ratio much greater than 1 indicates a situation of severe traffic congestion where a number of vehicles on the street far exceeds the capacity of that roadway to carry those vehicles uninterruptedly. In order to address the deteriorating V/C ratio on city roads, the preferred response is to conduct a transport demand analysis that is based on transport demand modelling in the current situation and projected into the future. This analysis seeks to understand the city-wide share that different modes of travel possess as residents move about for their needs. Forecasting into the future, a general trend appears to be a rapidly declining use in public transport with a corresponding rise in the use of private vehicles to meet travel demand (Dargay et al. 2007; Bouachera and Mazraati 2007). In order to address this shift towards private automotive vehicles in a manner that minimises travel time, aggressive investment in non-motorised transport, mass rapid transit systems such as metro systems, elevated monorail systems, high-density traffic corridors, bus rapid transit systems and electric vehicles present themselves as the preferred solution (Mittal et al. 2016).

On the operational level, all cities eligible to receive funding as part of JNNURM were required to propose major projects as part of the city development plan (CDP) that each city was expected to develop. Based on a transport demand analysis, the CDP for the city of Bengaluru, for example, proposes a slew of mega projects ranging from metro systems, monorail, elevated road corridors, grade-separated signal-free ring roads, and bus rapid transit systems. Indeed, the plan refers to the vision for implementing these projects in the city as the "Big Picture of Interventions" (iDeCK 2006).

Big Politics: Recent urban interventions by the national government have attracted considerable visibility in the popular media as solutions that will clean up the chaos in Indian cities ushering in an era of world-class urban living. This visibility of urban issues in the popular imagination has been accomplished through two means – first, constructing flexible networks that string together a range of public, political, societal and international groups to advocate for this type of urban change; and second, introducing technical and management consultants as 'experts' who were bearers of legitimate knowledge to specify and conduct the process by which urban change could be executed (Sadoway et al. 2018). Flexible networks brought together a range of public and societal stakeholders who sought to introduce two distinct orientations in urban interventions such as JNNURM – a reform orientation and a civil society orientation by involving private actors with urban technical and managerial skills to fashion cities in a global image. This was especially true in JNNURM, a pioneer in urban interventions writ large. The first orientation was addressed by involving individuals who bring experience working in international financial investment agencies such as World Bank and Asian Development Bank to insert a political-economic reform orientation in urban service delivery. The second, but by far more politically sensitive, orientation arose from civil society who demonstrated an agenda to refashion cities in the image of cities in globalized contexts elsewhere in the world. Actors and groups for this network were drawn from academia, urban practitioners, and think tanks (like Mumbai First, BATF, or Janaagraha) that espoused a reform agenda aligned with corporate visions of urban transformation. The civil society network underpinning JNNURM was institutionalised within its programme architecture like the National Technical Advisory Group (NTAG), chaired by Mr. Ramesh Ramanathan.[17] This flexible network was particularly effective in not only heightening the visibility of this mode of urban intervention in the popular imagination but also gave the intervention its mission-mode capacity. This characterisation allowed the intervention to be branded with an urgency far more immediate than could have been achieved through a government programme 'manned' by bureaucrats. The presence of entrepreneurial corporate and civil society leaders arguing for a greater stake for cities in the public sphere gave the message greater traction and visibility in media, corporate, and civil society sectors (Baindur 2017).

A second means that enhanced the footprint of cities in India is by characterising the work of urban transformation as a professionalised technical field that needs specialised consultants to bring their expertise rather than ordinary citizens to change the status quo (Coelho et al. 2013). Given that such a professional cadre was lacking within government, the important task of re-fashioning cities into engines of economic growth would have to be spearheaded by external technical consultants. In 2010, McKinsey Global Institute – the economic and business research division of the global management consultancy McKinsey – released a report titled 'India's Urban Awakening: Building Inclusive Cities, Sustaining Economic Growth' that diagnosed the absence of technical human resources as one reason for the inability of Indian cities to adequately plan for change. It suggests that till such technical human resources become available within India, the country would do well to "access talent by leveraging global resources… and creating specifications and standards that would allow existing talent to work more effectively" (McKinsey Global Institute 2010: 116). The combination of these factors of flexible civil society and corporate networks combined with specialised technical consultants place a 'big' political imprint on interventions in the technoscientific base of cities. A particular cast of actors have made their entry and have acquired expertise and voice in shaping and developing cities while others such as citizens remain largely unheard. This is a major change ushered in with recent efforts such as JNNURM, Smart City Mission and AMRUT.

Conclusions

In our interconnected global political economy, cities have acquired extraordinary importance as sites of socio-economic advance. Urban science (and engineering) as modes of inquiring into and gathering knowledge about cities have emerged in the present context as, to borrow Vannevar Bush's famous metaphor, the new endless frontier. Attention to the urban science frontier will guarantee a world of plenty and prosperity. In keeping with this global logic of cities, national efforts in the past decade and a half have sought to transform Indian cities to realise the goal of fashioning them into engines of economic growth, powering the country on a path to prosperity and development. These national efforts have orchestrated a particular national footprint of experimentation in putting into practice a body of knowledge about urban services. Given its national scale, we refer to this footprint of urban knowledge as Big urban science and engineering. The practice of making Big urban science and engineering (BUS) in India can be effectively fathomed through the framework that Hallonsten 2016 proposed for describing some key dimensions of how Big Science is being transformed in recent years. The three dimensions of big organisations, machines, and politics we have seen are particularly apt in analysing the recent experience of how the country is intervening in the provisioning of urban India. The three major programmes JNNURM, AMRUT and Smart Cities Mission have fawned big multi-scalar institutional frameworks deploying elite organisations, manufacturing public consent while installing expensive technological solutions to address long-standing service deficiencies. The outcomes of these programmes are, therefore, aligned with the aspirations of the middle-class while low-income groups have suffered physical uprooting and disruption of their livelihoods.

Proponents would argue that the frontier for urban science and engineering in India is endless. The search for solutions and products to address India's intractable urban problems is a task that needs urgent attention and yet is filled with unending opportunities for problem-solving.[18] But at the same time, it is necessary to ask the question of how urban knowledge and solutions are being produced. JNNURM, AMRUT and Smart Cities Mission are examples where top-down technocratic solutions were proposed towards addressing critical deficiencies in service delivery with limited success. In India, this desire to address the urban frontier has solidified into a pathway that we refer to as Big urban science and engineering (or BUS). As we have seen, BUS is realised by instituting particular architectures of politics, machineries and organisations. This architecture of intervention in urban science and engineering, in turn, plays a role in shaping the products and designs used to intervene in cities in India.

[1] [5]World Bank was a pioneer in propagating this metaphor and enjoining nations around the world to take their cities seriously. In the World Bank Development Report 1999/2000, cities are portrayed as engines of economic growth. In India, the uptake of this discourse has gathered steam from the mid-2000's with several popular and policy texts underscoring the critical necessity of cities for transforming the country (Ahluwahlia

[2] 2014; Sivaramakrishnan 2011).

[3] [13] The capacity of systems of urban infrastructure to now respond to using ‘intelligent’ technologies is at the core of the concept of smart cities (Karvonen et al. 2019).

[4] [14] Science and engineering, we know, are products of a particular modernist, enlightenment epoch in Western European history with engineering characterized as the applied alter-ego of science. However, as research in engineering studies has shown, engineering understood as applied science does not quite do justice to the complex interaction and symbiosis there exists between the two fields of engineering and science (Downey and Lucena 1995).

[5] [15] The argument for a “*science of service delivery”* was presented in a recent book titled *Transforming Our Cities* written by the Isher Judge Ahluwalia, an architect of this orientation to urban intervention. Ahluwahlia 2014 makes the case that “to bring our cities anywhere close to world-class, we will need to reform the political environment within which our cities function” (p.9). She argues that political will and associated political impetus is necessary because to achieve a structural transformation of India’s economy, it is necessary to transform urbanization and how cities are managed in the country.

[6] [16] Launched by the United Progressive Alliance (UPA) government in 2006, JNNURM targeted around 67 large cities with a focus on reform-tied development of infrastructure, planned development of peri-urban areas and urban corridors, expansion of access to utilities among urban poor and redevelopment of inner city areas (See Avashia and Garg 2015 and; Gopakumar 2015). Following the victory of the National Development Alliance (NDA) in 2014, the JNNURM was swiftly replaced with AMRUT which is essentially a reformed version of the earlier mission. Its aims included the provision of water supply, sewerage, stormwater drains, public spaces, public transit and nonmotorized transport in the identified 80 (500 eventually) cities (See Smith and Pathak 2018). The Smart Cities Mission focuses on tackling sustainability issues through retrofitting, redevelopment, greenfield developments implemented in identified pockets and across 100 select cities (See Hoelscher 2016).

[7] [17] Mr. Ramesh Ramanathan, an ex-CitiBank executive was a member of the Bangalore Agenda Task Force (BATF) and Agenda for Bangalore Infrastructure and Development Task Force (ABIDE); and founder of *Janaagraha*, the civic governance oriented non-profit organisation based in Bengaluru.

[8] [18] This characterization parallels what Sarewitz 1996 myth of the endless frontier understood as a passive disembodied desire to know more about the natural world, all the while reinforcing its separation from how society chooses to enroll technoscience to achieve their ends.

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