Understanding network societies : two decades of large technical system studies

Chapter 10

Understanding Network Societies

Two Decades of Large Technical System Studies

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In the previous chapters, we saw how individuals and organizations time and again conceived of network technologies as means to construct transnational polities, economies, or societies in Europe, literally by tying peoples and places physically together. It is strange, therefore, that professional historians observe but rarely analyze processes of network building and their entanglement with wider European history. They are not alone. Even scholars analyzing modern societies as 'network societies,' a notion denoting exactly that present-day societal change is deeply intertwined with network technologies (and Information and Communication Technologies in particular), rarely analyze this interaction beyond the trivial.

On closer inspection, this omission may be at least partly due to a poor understanding of technical change. Historiographies of Europe and sociological network society studies are well equipped to describe a variety of social changes, and observe the crucial importance of network technologies in these changes. However, they tend to associate technical change with the invention of artifacts (and occasionally their diffusion) leading to a variety of new possibilities. They take for granted, without further analysis, complex processes of network development and their entanglement with broader societal changes.

The cases presented in this volume, by contrast, demonstrate that the interlacing of Europe did not follow in a straightforward way from the invention and diffusion of the steam locomotive, electric dynamo, or motor car. They show how these technologies were parts of larger networks. The shaping of these networks reflected hopes and agendas of powerful actors, negotiations, and conflict-ridden economic or political contexts. Indeed, network building was a major arena for negotiating relationships between states and for forging transnational societies.

This chapter complements these empirical observations with a conceptual exploration of the entanglement of network technologies and societal change. It searches for perspectives, narratives and concepts that may inform the historical inquiry of network societies in the so-called Large Technical Systems (LTS) literature. This literature constitutes the most important specialization on network technologies in historical technology studies. Moreover, it claims exactly the interaction between technical and societal change as its object of study, and takes into account the constructed, negotiated and contested character of network development. Implicitly or explicitly it serves as a reference for many chapters in this book.

Section one addresses some overall concerns of LTS scholarship. Then I take a thematic approach and map a variety of LTS perspectives on the history, societal implications, and dynamics of large technical systems. The overall idea is to construct a platform of references that may inspire the historical study of network technologies and societies.[1] By way of example, the final section discusses how the LTS concept of 'system building' can be modified and used to spotlight crucial aspects of the intertwinement of network development and transnational society building in Europe.

PURPOSE AND POSITION

At the outset, I find two aspects of LTS scholarship important to emphasize. First, this literature is pretty univocal about its overall research purposes and position in the academic landscape. Second, it hosts a variety of narratives, concepts and research strategies; it is a platform for discussion, rather than the coherent theory of technology and society that some superficial reviews and critiques make of it.

To state their research aims and position in the academic landscape, LTS authors usually refer to the work of Thomas P. Hughes as a point of departure.[2] In particular, Hughes' book *Networks of power* (1983) on the development of electricity supply systems in Germany, England and the United States is often taken as the beginning of a new and promising research field.[3] It is cited for at least three concerns.

First, Hughes criticized the historiography of technology for its focus on the invention of artifacts or machines, such as the light bulb, telephone, motor car or personal computer. Instead, he advocated the study of the technological entireties or 'systems,' of which such elements were integrated parts. His study of electrification took as its unit of analysis not the dynamo or light bulb, but the entire system that made public electricity supply possible. Furthermore, it studied such systems' subsequent diffusion and territorial expansion to society-wide structures. Hughes argued that systems for electricity supply, railway transport, or telephony constitute an often overlooked frontier development in 19th and 20th century technological change. LTS authors picked up this concern to investigate technological systems rather than individual artifacts.

Second, Hughes criticized contemporary history and sociology for overlooking the enormous societal importance of such omnipresent systems. Reviving arguments originally made by authors in the French *Annales* School in socio-economic history, Hughes portrayed large technical systems as new, human-made 'deep structures' in society.[4] These structures have surpassed even natural geography and politics as key drivers of societal change. To a large extent they influence where and how people live, work, play, and wage war. This observation, too, echoes widely in LTS scholarship. It claims to investigate an important category of phenomena structuring individual and social life, yet grossly neglected in earlier academic inquiry.

Third, Hughes advocated a *sociotechnical systems research methodology* to investigate these phenomena. His study of electricity supply systems described the successful alignment of generators, distribution networks and appliances but also research facilities, company structures, licensing strategies, advertising and consumer practices into a coherent sociotechnical whole that made the entire thing work. Furthermore, this working involved the tuning of the system to a wider environment equally sociotechnical in character, including e.g. the development of electrotechnical engineering, emerging international financial markets, and war industry demands. What needs study, then, is the perpetual interaction between technological and societal change. For this task, categories as 'the technical,' the 'social' or the 'political' are deemed too crude. Worse, they may superimpose analytical seams that obscure from view how the sociotechnical fabric is actually woven.[5] Hughes therefore introduced a handful of alternative concepts.[6] For instance, the concept of 'system builders' spotlights privileged actors (Thomas Edison, Henry Ford, the U.S. navy) doing the actual weaving. In Hughes' footsteps, LTS authors often position themselves as investigators of sociotechnical creatures so deeply intertwined with modern societies yet—exactly because of their sociotechnical character—tragically overlooked in the division of labor between the technical and the social sciences.

The LTS literature that emerged in the last two decades shares an identity exemplified by these three concerns, and, of course, a base of standard references.[7]

Then, there is practice. Whereas the programmatic claims are rather univocal, LTS publications diverge considerably in their use of concepts and research strategies. This conceptual and methodological richness has been acknowledged as a crucial asset in exploring the many faces of large technical systems in the modern world.[8] In view of this rich variety, it is most unfortunate that superficial reviews and critiques often reduce this scholarship to a more or less coherent theory with narrowly defined concepts.[9] These not only do injustice to the field, but also suggest a methodological lock-in. This chapter, however, will not outline one privileged theory. Instead it juxtaposes a variety of perspectives into a platform of references, on which historical inquiries into network technologies and societies can draw.

Due to this variety, I cannot offer the reader a strict definition of large technical systems here, simply because there is no consensus. Large technical systems are often defined by example. They certainly include railway systems, telephone systems, electricity supply systems and so on. Factories or hospitals are considered 'nodes' or 'junctions' rather than systems. Some authors work with stricter definitions, but they tend to arrive at crossed purposes. For instance, some define large technical systems as sociotechnical entities and reject any distinction between 'the technical' and 'the social.' Others, by contrast, try to disentangle these systems' technological and social make-up and see large technical systems rather as society-wide *technologies*.[10] Likewise, some presuppose centralized control over all system elements and exclude such anarchistic systems as road and water transport. Others focus on exactly these systems to study self-regulation or 'loosely-coupled systems.'[11] Some define large technical systems by function (communication, transport, energy supply), others investigate their multifunctionality.[12] Finally, one may quarrel about the meaning of words like 'large,' 'technical' and 'system.'[13] This chapter will not be an arbiter on these choices of definition; all may produce insights into the historiography of network societies.

THE HISTORY OF LARGE TECHNICAL SYSTEMS

A first research theme of interest is, of course, the history of large technical systems themselves. Following Hughes' above-mentioned historiography of electricity supply in three Western countries, many studies deal with individual large technical systems in individual countries, say telephony in Germany, the Netherlands, or France.[14] How do such individual stories add up? In a more synthetic vein, one can distinguish several 'grand narratives' of overall LTS history.

LTS History as System Building History

I will start with the later work of Thomas Hughes himself. In several books, Hughes studied modern United States history through the lens of technology and technological system development.[15] In the 19th and 20th centuries, Americans transformed a wilderness into a giant building site. Technological systems allowed for a 'second creation' of the world, man-made rather than divine, the 'American Genesis' (a metaphor used by American settlers, who conceived of technology as a means to recreate the Garden of Eden). This produced a technological nation, in whose footsteps the rest of the world was to follow.

Within this somewhat patriotic framing, Hughes' narratives focus not so much on the development of systems themselves, but on their builders and modes of system building—touching upon the history of management as well as the history of technology. Hughes sees technological inventiveness and system building as central tenets of American character, on a par with commitment to free enterprise and democracy. His narrative spotlights system builder ingenuity, its importance, and its forms. Later, he also studied—especially environmental—problems relating to the American technological culture.

Lumping several books together, one may distinguish four phases in the history of American system building.[16] First, from roughly the 1870s on several 'independent inventors' went beyond the invention process and took their products to the market. These 'inventor entrepreneurs' were the first system builders. Thomas Edison is the chief example; known best for his 'invention' of the light bulb, he actually set up the first public electricity supply systems aligning a number of technical and non-technical elements, ranging from new generator, bulb and distribution network designs to company structures and advertising campaigns.

By the Interwar years, however, the main locus of system building activity had shifted toward large industrial enterprises and their research laboratories. Independent inventors could no longer cope with institutionalized patent battles. Archetypical 'manager-entrepreneurs' of this phase include Samuel Insull, who prepared electricity supply for mass consumption by amalgamating firms and interconnecting their transmission networks. Another example is Henry Ford. Like Edison, he is usually celebrated for a single invention (the assembly line), but he actually integrated mines, shipping and rail transport, iron and glass production, electricity production, and car manufacturing into mass production systems creating flows of energy and materials, managed by a new class of white-collar workers.

From the Second World War, the frontier of system building activity moved to a collaboration of government, university, and industries—the military-university-industrial complex. Apart from several pre-war precursors, three mega-projects constituted the primary learning schools for this type of system building. In the Manhattan Project, General Leslie Groves acted as a kind of top system builder, managing a huge, centrally co-ordinated production system involving government institutions, universities, and many industrial producers to create the atomic bomb. In the 1950s, project SAGE developed a national US air defense system using digital computers (developed by MIT engineers) to process, in real-time, information collected by a fine-meshed network of radar stations. Finally, in the ATLAS intercontinental ballistic missiles project, system builder Bernard Schriever inserted a specialized management department between the commissioner (the U.S. Air Force) and the multitude of industrial suppliers. These helped develop systems engineering as a management tool to micromanage the production of components. In the 1960s, these strategies traveled from the military to the civilian sphere of system building.

In the 1970s, finally, this form of system building stagnated in view of counterculture values and the compromising of military systems in the Vietnam War. Some planners thought the time of large system building was definitely over. Yet new learning schools emerged to develop a new mode of system building, 'post-modern system building,' adapted to counterculture values. Project ARPANET, producing a forerunner to the Internet in the early 1970s, replaced hierarchal organization structures and micro-management by a relatively small, horizontal and flexible management department steering suppliers by specifications. The design of a large, partly underground motorway system in Boston since 1984 developed participative management for infrastructural projects: a form of 'open system building' granted a variety of stakeholders influence on the design process.

Finally, the restoration of the Kissimmee River system and the Everglades in Florida answers to concerns of ecological crisis by 'ecotechnical' system building on a regional scale.

Europe plays a modest role in this narrative. Europeans discovered the U.S. as a technological nation and carried the lessons of Edison, Insull and Ford across the Atlantic. To date, studies of European transnational system building methods are lacking. There are some studies of individual countries. In the Netherlands, for instance, in the late 60s and early 70s national legislation specified extensive procedures for participative, 'open' system building and for including ecological considerations. However, by the 1990s the accompanying bureaucracy and delays were deemed problematic: to speed up decision making on several Dutch branches of trans European rail networks, public participation possibilities were again reduced.[17]

LTS History as Institutional History

While Hughes built his narrative on American system building on a few exemplary system builders and systems, Arne Kaijser addressed the entirety of systems for the case of Sweden from the 17th century until today.[18] He includes grid-based systems (electricity supply, railroads) as well as 'loosely coupled systems' such as postal services, water control systems, air traffic systems, and maritime navigation systems. Jointly these systems constitute obdurate material as well as institutional structures shaping present-day societies. Kaijser's narrative focuses primarily on patterns in the development of institutions governing the construction and operation of infrastructures.

In 17th century Sweden, road system building became exemplary for the institutional embedding of large technical systems. The politically strong, yet financially weak Swedish state combined centralized co-ordination with construction and maintenance by local actors, mostly farmers. Other systems were organized in a similar way. The extensive Swedish postal system, covering most of the Baltic Sea region, mobilized farmers in a kind of an 'estafette-system.'

In the second half of the 19th century, railroads became the new paradigmatic system. A State Board was established to construct the main lines and stations, while other actors constructed secondary lines. This arrangement was also used in telephony (at least initially), electricity supply, road construction, and air transport. In the 1920s, a second element was added to this Swedish 'national institutional regime' for large technical systems. State Boards developed long-lasting cooperations with industrial giants such as ASEA (currently merged to ABB) and Ericsson. Such companies profited from a stable and strong home market to become world leaders in their field. Simultaneously, the State Boards gained access to the most advanced technological capabilities. This national institutional regime for large technical systems declined only with the liberalization wave that started in Swedish telecommunications in the 1970s.

Looking beyond the Swedish case, a series of national comparisons has demonstrated the rich variety of possible institutional or governance frameworks of large technical systems.[19] Furthermore, Kaijser addressed the role of institutional frameworks in European transnational linking processes. For instance, the contested electrical linking of Norway to the rest of Scandinavia and Continental Europe illustrates the pervasiveness of institutional rather than technical barriers.[20] More generally, Kaijser distinguishes between four levels of increasingly tight international infrastructural cooperation: (1) purely technical coupling across national borders; (2) economic and juridical frameworks for transnational exchanges; (3) common technical standards; and (4) harmonized institutional regimes. An increasing number of international conferences dealt with the first two aspects beginning in the 19th century, including the first international postal (Paris, 1863) and telegraph (Paris, 1865) conferences and the international railway conferences. In the interwar years, a number of standardization bodies were founded, such as the CCIF for long-distance telephony and UNIPEDE for electricity supply. Finally, harmonization of institutional regimes was only placed on the agenda quite recently by the European Union, which aims for a common market for LTS services.[21]

LTS History as Material Networks History

A third narrative on LTS history puts the material dimension of large technical systems center stage. No doubt the LTS narrative with the largest span in time and space was developed by the German historian Joachim Radkau.[22] For Radkau, large technical systems are not a specifically modern phenomenon: he dates their genesis to Antiquity. LTS history is not characterized by increasing systematism, but unfolded in three phases with different types of systems. In none of these phases was central planning or coordination a prerequisite for system development; in many cases it simply lacked.

For millennia, water was the most important connecting tissue of large technical systems. Water-based systems include the irrigation systems of the early civilizations along the Nile, Euphrates and Indus, in China and in the Andes. Drainage systems, such as those developed in the Netherlands in the Middle Ages, inland navigation systems constructed during Early Modernity and the Industrial Revolution, and riverine wood transport, are other examples.

Only in the 19th century did a new type of materially 'tightly coupled' systems emerge, starting with railways, which were increasingly perceived as part of a 'nation-wide network of steel.' Paved road and telegraphy networks also reached (trans) national scales, while the late 19th century saw the emergence of electricity supply, sewage, and gas supply systems as urban technologies that would grow spectacularly in the 20th century.

Finally, Radkau suggests three features of 20th century large technical systems. First, information and communication technologies, including radio and television systems, became increasingly important. Second, consumer choices increased. Examples include the rapid diffusion of telephony in the last decades of the 20th century, and motorized road transport, which ousted railway traffic and navigation. In these successful systems users shape network flows.

A third feature is the so-called 'second order' character of many new large technical systems. First noted by the German sociologist Ingo Braun, second order large technical systems are constructed by combining familiar (1st order) systems to create a new function.[23] For instance, from the late 1960s Eurotransplant set up a European organ transplant system by linking up medical nodes (like hospitals, staff, donors and recipients) with links belonging to road systems (mobilized by ambulance or taxi), air transport systems (mobilized by line and charter flights and helicopters), (radio) telephony (mobilized e.g. by beepers calling on doctors at short notice), and data communication systems (comparing donor and recipient data over large distances). This heterogeneous large technical system, many elements of which Eurotransplant neither owns nor controls, conveys flows of organs, people and information over large distances. Other examples include mass tourism, the global exchange market system, and the container transport system, all built on top of transport, energy or communication systems.

While Radkau described a variety of large technical systems throughout millennia, the Dutch national history of technology programme[24] mapped and narrated a veritable proliferation of material networks in the Netherlands in the 20th century. It brings into vogue the shaping of a 'networked nation': By 2000 a multitude of systems materially integrated every house, factory, farm, field and forest into a nearly 100% human-made geography of large technical systems. This transformation involved LTS development in three realms.[25]

First, by the 1970s many infrastructural technologies had reached a national coverage through processes of expansion and branching, integrating even the most remote areas with material networks of stone, steel, copper wire, water, electromagnetic waves, and air corridors.[26] Second, societal domains such as food supply, banking, production, politics and military defense mobilized and used these infrastructures to interconnect farms, factories, or stock exchanges into second order LTS such as food chains, industrial production systems and banking systems.[27]

Third, even 'nature' was integrated into this human-made geography of networks. Since the Middle Ages, water control systems had helped reclaim and cultivate most of the Dutch territory, which was subsequently integrated by multiple LTS: by 1970 a mere 6% of the territory was still counted as 'natural.' By then, water flows through rivers and canals had been mastered in a national fresh water supply system (1941–1970) controlled by strategic weirs and sluices. The capstone of this process of 'networking nature' is the current integration of remaining 'nature' zones by newly built 'ecological corridors' into a coherent National Ecological Network, facilitating the circulation of plant and animal species on a national scale. This network, currently heavily delayed, is to be integrated in a 'pan-European ecological network' coordinated by the Council of Europe.[28]

These two contributions hardly address trans-national linking processes; they focus on LTS developments in ancient empires or modern states. The systematic mapping of transnational infrastructure development is an urgent yet unaccomplished task.

LTS History as History of Ideas

A fourth narrative explores LTS history as a history of ideas. Rosalind Williams has traced the 'cultural origins' of the current human preoccupation with large technical systems in the 'modern ideology of circulation' that emerged with early Capitalism and the Enlightenment.[29] Williams calls for more work to uncover this line of thought, but we should note that it has been studied extensively in communication studies, not in the least by the sociologist Armand Mattelart.[30]

Already in the 17th century French administrators aimed at reorganizing national space by waterway building, while merchants conceived of trade routes as economic circuits, including round trips to the colonies and the 'triangle trade' between European ports, the African coast, and the Caribbean. Simultaneously, Harvey's publication on blood circulation in the body (1628) inspired studies of society in terms of circulation in the emergent field of political economy. For instance, William Petty's *Political Anatomy of Ireland* (1672) described money as the circulating nourishing, equalizing, and beautifying 'body fat,' while tradesmen played the 'role of veins and arteries, to distribute in a circulatory movement the blood of the nourishing sap of the Body-Politick.'[31]

In the 18th century, Enlightenment thinkers further developed this understanding of society in terms of circulating economic value. They added the global circulation of rational knowledge as a means of human progress. Philosopher and statesman Anne-Robert-Jacques Turgot is an interesting junction of thought. With the Physiocrat School he shared the idea that value stemming from agriculture had to be cycled through society as effectively as possible, for which purpose the State ought to construct dense road and canal networks. Turgot also wrote one of the first formulations of the 'ideology of progress' (*Discours sur les progrès successifs de l'esprit humain*, 1750) emphasizing how the gradual and enduring enlightenment of the human mind was proportional to their contacts with other groups. This diffusion of rational knowledge, too, required lines of communication crossing local or national borders to encompass an increasingly large part of the globe. Turgot's ideas passed into Liberalism with Adam Smith (1779), who found transborder routes of transport and communication (especially navigation) pivotal in the progressive transnational division of labor, which would ultimately abolish hostilities in the universal mercantile republic.

The ideological connection between circulation, progress, and infrastructure building culminated with the Saint Simonian cult in the first half of the 19th century. Pleading for a 'universal association' in which men worked in partnership on a common goal, rather than division of labor, Claude Henri de Saint Simon (1814) proposed a European Society run by an industrial government emphasizing infrastructure building (roads, canals, drainage) as well as money reforms (proposing a European confederation, common bank and currency). His follower and French statesman Michel Chevalier saw in network technologies the ultimate means to create a 'circulating civilization,' in which 'spiritual' (credit) and material networks provided cohesion to the social organism. "Railways have more relation to the religious spirit than we think. Never has there existed an instrument of such power to link together scattered peoples."[32] Other Saint-Simonians were involved in preparations of the Suez Canal and set up railway and shipping companies, global industries, and credit multinationals.

The ideology of circulation frequently emerged in 20th century thought. Promises of economic progress and social cohesion accompanied the introduction of electric power networks (Gall, Maier, this volume), motorways (Blomkvist, this volume), radio, television, and, latest, the Internet. Moreover, it surfaced in 20th century urban planning[33] as well as in political attempts to construct an integrated Europe. The notion that infrastructures could promote social cohesion and prosperity for Europe was, for instance, embraced by the United Nations Economic Committee for Europe, the Council of Europe, and the European Union and its forerunners.

It should be emphasized that this ideology should not be taken at face value. Mattelart contrasts these visions of a better world due to infrastructures with a 'reality' of powerful elites using infrastructures to gain an economic, political or military advantage. He is not alone. Already in the 1850s Pierre-Joseph Proudhon observed that social reform depended on the use of networks rather than their construction; "the length of railway lines in operation in France has tripled. Since then, we have not seen the slightest idea circulate."[34]

LARGE TECHNICAL SYSTEMS AND SOCIETAL CHANGE

A second research theme of importance to the historical understanding of (European) network societies is that of the societal implications of large technical systems, taking 'societal' in the broadest possible meaning. LTS authors see these systems as levers of political, economic, social and environmental change, or as 'deep structures' shaping individual or social life. How, then, do large technical systems affect history? How do they change nature and the ways in which people live, work, play, and wage war?

Unfortunately, systematic research into these questions has barely begun. The study of (network) technology's societal consequences was largely abandoned during the 1970s, 1980s and much of the 1990s because of connotations of Technological Determinism, a term denoting a unidirectional and necessary influence of technology on society, which was deemed intellectually and politically incorrect. Only recently it was commonly accepted that the technological shaping of society can be investigated in non-determinist ways, and that this research question is too important to leave to journalists.[35]

Much empirical and conceptual work still needs to be done. However, existing LTS scholarship includes a number of promising approaches and narratives that may inspire further study of LTS-related societal change.

Sociotechnical System Building

A first approach to investigate the societal implications of large technical systems is often regarded as the canonical LTS approach. Studying sociotechnical system building makes visible not only the shaping of systems, but also two kinds of societal changes that are part and parcel of the sociotechnical construction process.

First, non-technical elements constructed in this process may constitute important historical events in their own right. Hughes' account of Thomas Edison's construction of early electricity supply systems illustrates this point. Edison's system included novel technologies, but also a concept of electricity sales to external consumers, a business structure (including a holding company, production companies for light bulbs, tubes, and machinery, and an array of local electric utilities), franchises defining relations between companies and local politics, and advertising campaigns. Hughes' point was that these jointly made up a relatively successful and stable sociotechnical system.[36] In terms of the present research question, however, the latter elements constitute important societal events of their own. Edison's companies, for instance, later merged into General Electric, which together with its competitors would shuffle the U.S. business landscape: the electric industry became a first-rank economic, political, and employment factor in the U.S., as railroad companies did in the 19th century, and ICT companies do today. Likewise, negotiating franchises redefined relationships between private utilities and local, state or federal governments. Private utilities became important public service providers in the U.S., while in many European countries the engagement of states in system building intertwined with an increasing role of the state in economic life and, ultimately, the emergence of the intervention-state.[37]

Second, system builders designed the material core of systems to achieve specific goals and changes. These include the familiar functions large technical systems were designed to fulfill: electricity supply systems made light and power available to consumers with simply a pull of a switch, and railroads constituted fast transportation means between cities. Networks might also be designed to alter power relations. The Swedish government set up the first large state-owned hydropower project to achieve energy independence after the loss of Norway in 1905.[38] The Australian federal government saw the interconnection of different state power grids into an interstate power grid as a means to breaking state-owned utility monopolies that kept prices up, and breaking coal miner strikes that were organized at the state level.[39] Finally, according to the 'splintering urbanism' thesis, private firms, which in recent decades have increasingly taken over system building and management from government bodies, build new infrastructures dedicated to high-end customers. Thereby they are also building a social divide between those with access to state-of-the-art LTS's, and those who are bypassed and have to rely on increasingly outdated, congested and malfunctioning public systems.[40]

This first approach to LTS-related societal change thus simultaneously investigates the 'social shaping of technology' and the 'technical shaping of society'; it emphasizes that large technical systems and their societal effects 'co-evolve' in one and the same sociotechnical construction process.[41] The other side of the coin, however, is that long-term, indirect and unanticipated implications for individuals, institutions, or nature, which may take place far beyond the construction phase, are rarely addressed.

The Intrinsic Properties of Network Technologies

Some authors, luckily, have searched for such indirect LTS-related changes beyond the system building realm. One approach is to study the long-term effects of the intrinsic properties of large technical systems. Kaijser, for instance, addressed the impacts of large technical systems on economic growth, geography, the political/military sphere, and environment and health. Transport innovations enabled the creation of European—and later worldwide—trade systems. Waterways and roads determined where towns were founded; later, access to railway networks, water supply systems, sewage systems, and electricity systems made some towns grow at the expense of others. Electricity supply systems much improved the urban environment as chimneys disappeared from cityscapes. However, in the long run they unexpectedly created new forms of regional and global pollution such as acid rain and the greenhouse effect.[42]

In a more theoretical vein, the German sociologist Renate Mayntz, too, identified four societal implications of large technical systems. Two of these, she argues, are well known and obvious: large technical systems increased the achievements of mankind, and produced a complementary increase in risks. This risk increase stems from the accident potential of ever more complex technologies, but also from the growing dependence of modern societies on large technical systems that function flawlessly. Two other implications are much less known. During the 20th century, large technical systems increasingly structured other societal subsystems such as politics, education, religion, industry and science. These subsystems became increasingly and asymmetrically dependent on infrastructural systems because of the obdurate material basis of the latter. Finally, in much of the 19th and 20th centuries centrally coordinated large technical systems were a driving force towards organizational hierarchisation and centralization in state institutions and industry. Current developments are again characterized by synchronous changes in infrastructures, states and industries towards horizontal organization structures and decentralization.[43]

Finally, several authors have suggested that intrinsic properties of large technical systems may create new consciousness and mental spaces (feelings, knowledge, and hope); they are a powerful cultural driver. For instance, space exploration systems inspired a rediscovery of the Earth: the 'satellite-view' (a Peter Sloterdijk concept) showed a unique yet fragile 'blue planet' in a vast empty space inhabited by scattered bare planets. This view inspired new imaginations, concerns and concepts. It became a widespread icon appearing on environmental report covers, T-shirts, and the daily television news. Two years after the first moon landing, the 'biosphere' concept was coined, denoting the thin, vulnerable layer that contains all terrestrial life and makes the Earth so unique. Environmentalists appropriated it to symbolize and project their concerns, science made it a new domain of scientific inquiry, and it inspired calls for a global politics exemplified e.g. by the influential 'Brundtland report' (1987), the World Commission on Environment and Development report that developed guiding principles for sustainable development.[44]

These authors address important LTS-related societal changes missed by studies of system building processes. However, their approach makes them prone to accusations of Technological Determinism. Some commentators find such analysis so misleading that it should be abolished.[45] Others find it too trivial to merit investigation.[46] Therefore a few comments are in order.

First, the examples of acid rain and the Greenhouse effect suggest that deterministic relationships *do* exist between network technology properties and environmental change. These effects are too important to be excluded from any assessment of technology's consequences. The example of Dutch drainage canal networks shows that deterministic changes may take centuries, but this does not make them less pervasive. From the 9th century AD, massive and successful drainage enabled habitation and cultivation of extensive wetlands behind the Dutch coastline, but also gave oxygen access to organic soil components. These decomposed and the ground level decreased to or below sea level. By the 12th century, catastrophic floods had become endemic and new sea incursions perforated the coastline. The causes behind these landscape changes were understood only in the 20th century.[47]

Second, such 'hard determinism' indeed does not exist in the social world. Studies of waterway or railway effects on city development, economic growth, or perceptions of space and time require more nuance.[48] Still, there is a soft determinism worth investigating. The economic historian John Heilbroner has suggested studying soft technological determinism not as univocal determination of social or psychological changes, but as a 'force field' affecting such changes.[49]

Users

Within the possibilities and constraints set by system building processes and intrinsic system properties, users may use large technical systems in multiple, sometimes surprising ways. Users, too, are agents of LTS-related societal changes.

The point that technology's societal implications are neither fully determined in their construction phase nor by their intrinsic properties, but also shaped in processes of use, was made first by David Nye and Claude Fisher.[50] Usually not considered LTS authors, both made their case for network technologies. Fisher described how American women used telephony to organize families' social life in novel ways, unforeseen and initially discouraged by telephone companies, which perceived and designed telephones as business tools. Nye studied how industry, the farm, the household and the city in the U.S. did not passively undergo a process of electrification. Instead, they actively mobilized and used electricity to support particular developments instead of others. For instance, an American industry concerned with scale increase used electricity to even further increase the scale of production; single drive electric motors made the factory design independent of mechanical transmission, and enabled the assembly line factory. In Denmark, by contrast, small and medium-sized industries and agriculture seized electric drive, which enabled for the first time the construction of very small and cheap motors, to compete with large steam-powered factories and strengthen their position in the business landscape.

User—particularly consumer—studies flourish in technology studies today.[51] Some find this approach antithetical to a systems approach, which they associate with a production perspective. Nye, however, conciliated with Hughes' systems approach; user-studies merely focus on a different (user) end of the same systems.[52] Also, the books on household technology and construction technology in the Dutch national history of technology project look at end-users, not least women, and their organizations shaping the meaning of electricity and gas supply systems in the home.[53]

Institutional Users

Most user studies address uses of artifacts as telephones, arc lights, electric stoves and electric streetcars in local settings such as homes, factories, farms and cities. In addition, in the Dutch national history of technology project we developed a narrative on 'institutional users,' which use exactly the geographically extended features of large technical systems to change society-wide societal institutions—say food supply, finance or industrial production. They built second-order large technical systems.[54]

For instance, actors in the food business used nationally integrated transport and communication systems to alter food chains.[55] From the late 19th century, new Dutch food industries mobilized roads, railways and waterways to tie new factories into the food chains between farms and markets. Lists of factory equipment would typically include barges and trucks adapted for food transport, like beer barges or milk trucks. By the 1950s, concerns of competition and conceptions of a national home market had led food producers to set up such farm-factory chains on predominantly regional and national scales. Likewise, emerging distribution companies inserted central warehouses and satellite shops (later supermarkets) as new junctions in factory-consumer chains. They too established their own fleets of trucks and barges for this purpose, and they too operated increasingly on a national level. By 1960, these players had jointly built a nationally integrated food system: a standardized and affordable food assortment had become available everywhere in the country to all social classes. Later, food chains were expanded to predominantly transnational scales.

Many other institutional users mobilized and possibly adapted large technical systems to build new structures. A flourishing petrochemical industry was organized around chemical complexes, in which factories were mutually connected by rail or pipeline so that the waste of one factory could provide raw material for the next. By the 1970s, the Rotterdam-Antwerp complex was one of the world's largest, interconnecting over 70 plants, and in turn connecting via further pipelines, roads, rails and waterways to other petrochemical complexes in Western Europe. Stockbrokers and their organizations used and built communication infrastructures to set up financial systems governing the trade in stocks and bonds. The Philips company used infrastructures to connect factories into national and transnational production systems.[56]

Such food, production and financial systems are important LTS-related societal developments. Moreover, they in turn had further societal implications. For instance, the national integration of food chains was accompanied by what food historians call the 'unification of the Dutch meal.' By 1960, previously diverging local and regional food habits had converged: Dutchmen and -women across the country and of all social groups ate bread meals twice a day, typically consumed with milk or butter-milk. An evening meal consisted of soup, a main dish of potatoes, salad, and a small piece of meat or fish, and a dessert.

This approach makes visible how large technical system developments affected people's lives, albeit indirectly. Again it should be emphasized that there was no historical necessity involved.[57] In the case of Dutch food habits, moments of agency and choice include system builders constructing nationally integrated transport systems (rather than regionally or socially fragmented ones), institutional users building predominantly nationally integrated food chains (rather than producing for regional, export, or niche markets), and consumers choosing uniformly (rather than differently) from the available assortment. This latter choice was induced by decades of information campaigns, telling Dutch housewives how to select and prepare food for the sake of public health and the Dutch food industry's home market. Notably, food habit homogeneity disappeared when lifestyles diversified in the 1970s.

Debating Technical Change

Finally, in his latest book Thomas Hughes employs a very different approach to study the effects of (network) technologies.[58] Rather than addressing processes of sociotechnical change themselves, Hughes traces comments on technical change by contemporary observers, authors, artists and historians, mainly in the U.S. It is no surprise that this narrative reflects utopian and dystopian discourses that often characterize public debates.

To start with, early settlers in colonial America interpreted technology religiously as a gift of God enabling them to cut forests, drain swamps, reclaim land and ultimately transform wilderness into a new Garden of Eden. They brought this 'Edenic Garden theme' from Europe, where it had a long history in Cicero, medieval Catholic orders (Benedictines and Cistercians), and Puritan theologists perceiving natural philosophy and mechanical arts as God-given means to improve the human condition. The Edenic garden motive peaked in early 19th century America, where observers saw canals, railroads, steam mills and other machinery transform the young country. By the late 19th century, however, technology had not produced a garden but a factory site. Observers deserted the Edenic ideal and described industries' astonishing output, but also poor working and living conditions for the waves of immigrants, accidents, and ecological destruction.

After the turn of the century, newspapers and magazines displayed a new technological optimism. American social critics observed that electrical, internal combustion, and mass production technologies brought economic democracy; all classes could now enjoy material abundance. Inspired by American developments, Lenin gave electrification a key role in his communist utopia. Also, German architects, industrial designers and artists saw technology as a driver of economic prosperity, social change and modern values, witness e.g. the Bauhaus school (1919) and the International Style in architecture and design, and the *Neue Sachlichkeit* and Dada movements in art. Simultaneously, however, modern technology was blamed for disrupting German cultural traditions, spiritual development, and nature, as articulated forcefully in Oswald Spengler's *Decline of the West* (1918–22) and *Man and Technics* (1931). More nuanced thinkers noted material progress and spiritual displacement as two sides of an ambiguous technological change.

Post-Second World War commentators and artists expressed a similar ambivalence. The new systems approach promised to solve complex problems in e.g. urban design. Simultaneously, technology was associated with systematization, large-scale weapon systems and the military-industrial complex. In his 1961 farewell address, President Dwight Eisenhower warned the public of the political, economic and spiritual influence of the latter. Counterculture commentators perceived further dangers of technical change. Rachel Carson's *Silent Spring* (1962) highlighted the loss of natural sounds, smells and sights, and toxic substances displacing nature. Many comments on the environmental crisis followed. Technology was portrayed as 'out of control' and as a source of a potential nuclear catastrophe.

Current information technology is mainly heralded as a social and political problem solver. So far, Hughes concludes, public debates have been decidedly positive, and the Internet has been associated with democracy and equal power distribution. The effects of the crash of dot.com stocks and terrorism are still unclear.

LTS DYNAMICS AND CONCEPTS

A third research theme of interest here addresses the dynamics of large technical systems. Contrary to the synthetic character of the above narratives, this theme delves into the details of system development, specifying and conceptualizing development phases, driving forces and change patterns. Some of these concepts have already been mentioned in passing. Often the underlying aim is to identify opportunities for policy intervention in LTS development, e.g. to improve reliability or sustainability.

Of course, opinions differ on the role of theory and concepts in historiography. Theoretical work is sometimes contrasted to a source-based narrative approach highlighting the specificity of events.[59] Many historians, however, use concepts as devices to focus historiographical attention on important or neglected issues, to organize complex narratives, and to make sense of vast amounts of empirical data. As such, concepts capturing LTS dynamics are an additional resource to the historical inquiry of network societies.

LTS Development Phases and Drivers

Also the discussion of LTS dynamics has its origins in the work of Thomas Hughes. As mentioned above, Hughes argued that it is the successful alignment of technical and non-technical elements into a sociotechnical whole that makes the system work. Presupposed analytic categories separating 'technical,' 'social,' 'political,' and 'economic' aspects of large technical systems tend to obscure this sociotechnical intertwinement. Hughes developed several alternative concepts to spotlight how the sociotechnical fabric is woven and how it works.[60]

Overall, Hughes identifies a 'loosely defined pattern' of LTS development with 'overlapping yet discernable' phases. In the 'invention phase,' radical inventions inaugurate a new technological system. In a 'development phase,' this nascent system is adapted to economic, political, and social characteristics needed for survival in the 'use world,' typically at test sites. The 'innovation phase' adds further system components relating to manufacturing, sales, and service facilities, enabling the system to enter the market. In a phase of 'competition and growth,' the system expands in competition with rival systems. In a 'consolidation' phase, a system becomes less dependent on its environment as it acquires 'momentum.' Now it is difficult to change, creating an appearance of autonomy. Finally, a 'technology transfer' phase may occur at any time during the history of a system. Here it is exported to different environments, for instance different countries, and adapted to new natural, social and technical contexts.

Several concepts specify the driving forces behind such system development. First, privileged actors called 'system builders' mould and align technical and non-technical elements into a sociotechnical whole. System builders work by identifying 'reverse salients'—elements lagging behind that restrain total system development. The trick is to recognize these and translate them into well-chosen 'critical problems,' that is, problems that may be solved. Such problems may be of a technical or non-technical nature; system builders engage in 'transdisciplinary problem solving.'[61] Forging sociotechnical systems, they constantly cross disciplinary borders, fixing problems usually studied separately in technical, political, economic, and marketing analyses. Following system builders as they fix problems, adapt elements to each other and forge them into a working system, historians can reconstruct the shaping of sociotechnical systems. They may also observe that different types of system builders dominate different development phases. 'Inventor-entrepreneurs' such as Thomas Edison are crucial during invention, development and innovation stages, while 'manager-entrepreneurs' such as Samuel Insull and Henry Ford preside over the growth phase. 'Financier entrepreneurs' and consulting engineers are the main players in the consolidation phase. Notably, this strategy of following system builders brings agency into the study of structure development and change—a move that another famous systems theory, general systems theory, never managed to make.[62]

Other concepts point at structural drivers of system development. The concept of 'technological style' expresses how system designs change when transferred to other social, natural or technical environments. Once transferred abroad, Edison's electricity supply systems had to adapt generator and network designs, voltages, supply conditions, or marketing strategies. By contrast, the concept of 'momentum' articulates the apparent autonomy of mature large technical systems, resisting pressures for change. This physics metaphor suggests a 'mass' (in terms of invested capital, commitment of many actors, employment, etc.) traveling with a certain 'speed' in a certain 'direction' (e.g. geographical expansion or scale increase). Large-scale electricity supply had reached considerable momentum by the 1930s; the trajectory of scale increase proved difficult to change since.[63] The momentum concept is akin to concepts of 'path dependency' and 'lock-in' in economic innovation studies.[64]

Finally, several economic factors allow larger systems to oust their smaller predecessors and add to their momentum. Hughes mentions not so much economies of scale, but rather a superior 'load factor' and 'economic mix' of larger systems. Both metaphors stem from the electricity supply world. A high load factor denotes a stable system load, allowing better usage of the available machinery and thus a quicker return on investment. An economic mix denotes the pooling of production facilities with different characteristics so as to optimize production costs at any given moment. Although these concepts were originally invented by system builders, once implemented in system design they exert a 'soft economic determinism' in the direction of system expansion.[65]

Differentiation by Phase

Others have expanded, questioned and adapted this framework, often drawing on additional case studies. Several authors observed that a phase of stagnation or decline was missing.[66] Moreover, phases of innovation, growth, and stagnation can be characterized by fundamentally different processes.[67]

The early phases, for instance, may be characterized less by a visionary system builder than by uncertainty and lack of vision. New systems are often introduced merely as supplements to existing systems: railway lines served to connect waterways, radio communication to expand the telegraphy system to shipping, etc. Indeed, new systems could hardly compete head-on with existing systems. Early telephony could only cover short distances, early rail transport was more expensive but not faster than shipping, and the electric light functioned only for a couple of hours. Therefore, new systems developed primarily in niches.

'Hughesian system building' is a characteristic particularly of the system expansion phase. Strong economic and political actors (central governments in Europe, large private companies in the U.S.) and a strong market demand seem key drivers of such expansion. Besides, several economic factors not mentioned by Hughes come into play: system expansion produces accelerating income flows, learning curves reduce operation costs, and economies of scale and scope. Also, system expansion may increase its intrinsic value for users; an increasing number of subscribers increases the usefulness of telephone networks.

Finally, the history of telegraphy and railroads illustrates that stagnation is part of the LTS life cycle. Mayntz makes a useful distinction in this respect between 'infrastructure domains' such as transport, communication, and energy supply, and the development of individual systems. While infrastructure domains constantly expand, individual systems (like railroads and roads within transport) succeed each other as successive S-curves with a slow start, accelerating growth, and a slow-down or decline (measured in km of railroad track, freight volume, number of subscribers, number of telegrams).

Differentiation by System Properties and Interaction Patterns

In addition, system dynamics seem to vary by system.[68] Kaijser and collaborators developed a typology distinguishing systems by technical, geographical, economic, and institutional properties, with due implications for their development patterns.[69] For instance, systems may technically differ in their network substance. Electricity and railroad systems have *specific* networks, while maritime navigation, air traffic and radio communication use *nature-based* links to interconnect human-built nodes (harbors, airports, transmitters and receivers). The postal system uses *existing networks* to link artificial nodes. The nature of networks has consequences for system development. Specific networks are more capital- and labor intensive, take longer to build, and are more difficult to change.

Likewise, systems have different technical architectures; they may be *distributing* like water supply, *accumulating* like sewage, or *communicative* like navigation canals. Systems vary geographically on their local, provincial, national, or international scale, and their geographical representation by dots (like self-generating electricity units), lines (like railroads), or fields (like radio systems). Economic criteria include financing and pricing methods. Finally, systems vary institutionally regarding forms of government control and cooperation between key actors like operators, equipment suppliers, and users.

A second important addition by these researchers is that system dynamics depends on interaction with other systems. Such interaction can take several forms. Collaboration between systems may improve the position of each. Such collaboration can exist between systems of similar function, e.g. when maritime navigation or air transport are connected to land transport by 'junctions' like harbors or airfields. Alternatively, systems of different function may cooperate, e.g. when railway systems are interlaced with signaling and electricity supply systems. On the other hand, systems with a similar function (e.g. rail, air, and road transport) compete for market shares. They compete on five P's: Price, Performance, Political pressures, legal Paragraphs, and Propaganda.

Stability and Change

A third elaboration of Hughes' framework concerns the issue of system stability and change. Many LTS studies presuppose growth and consolidation of large technical systems characterized by an increasing relative autonomy, or momentum, towards the environment. In Hughes' case of early electricity supply, only extreme conditions like warfare could change the development trajectory. Studies of more recent momentum changes in electricity supply likewise point to external factors as the oil crises, environmentalism, and government interference.[70] Economists of innovation observe similar system stability and resistance to change. They speak for instance of a lock-in on hydrocarbon fuels in energy and transportation systems, implying a lock-out of more sustainable technologies.[71]

This perspective on systems has policy implications. If mature systems resist change, policy makers should look elsewhere to achieve radical changes. One strategy is to set up protected spaces or 'niches' where new systems can be invented and grow, protected from the established system until they are able to compete. Niche activities include developing new technologies as well as new knowledge production structures and new alliances of energy companies, equipment manufacturers, and users.[72] Another strategy is to generate innovative views on future infrastructure developments in the minds of the main stakeholders. To this purpose, participative technology assessment methods—putting stakeholders together to develop scenarios or roadmaps—may be useful.[73] Current policy tools such as Strategic Niche Management and sociotechnical scenario development partly lean on LTS insights.[74]

Others, however, dismiss the assumption that mature systems cannot change. Jane Summerton argues that 'closed systems' can open up and adapt to new internal and external circumstances.[75] She rejects sequential phase models of LTS development and instead distinguishes alternating phases of relative stability and radical reconfiguration. Causes of reconfiguration can be internal or external; internal causes include congestion, 'negative externalities' such as pollution, or changing competitive advantages motivating system builders to find new markets.[76] In this vein, ongoing work on system innovations is developing a taxonomy of transition paths originating either from within or outside existing systems.[77]

Notably, it can be difficult to determine the degree of change, as a discussion on wind turbines shows. Hirsh and Serchuk argued that wind turbines initially challenged large-scale electricity supply, but were subsequently absorbed in the large-scale system in the form of wind turbine parks. In the end, they became a conservative, system-preserving technology. Mathias Heymann replied that combined pressures from wind energy and deregulation *did* change the internal structure, system culture, and momentum of electricity supply systems. Incorporating small and relatively unstable wind turbines, the electricity supply system became a 'hybrid system.' The system culture of consensus between electricity supply companies, technical experts, and legislators was replaced by a reliance on market mechanisms. Finally energy conservation programs drastically slowed down the 'speed' of system development, while its 'direction' changed from centralization and market control towards decentralization and deregulation.[78]

Indeed, a long-term study of system changes in the history of Danish electricity supply—currently a European leader in sustainable electricity generation—suggests that system stability and change can be two sides of the same coin. In periods of radical reconfiguration, some system elements were radically changed (say supply ideals and the degree of centralized electricity production). Simultaneously, however, other elements were tacitly preserved (say the stakeholder playing field, or other technical features. Radical system changes, then, are intriguing mixes of old and new.[79]

EUROPE'S SYSTEM BUILDERS

I have now presented a variety of perspectives, narratives and concepts addressing the history, societal implications, and dynamics of large technical systems. These suggest that infrastructural and societal change intertwine in many ways. Such insights have become commonplace in the history and sociology of technology, and more recently started to inform national historiography in several countries. Since the case studies in this book show how important aspects of European history intertwined with the shaping of network technologies, LTS perspectives could also inspire the historiography of Europe. For this to happen, much work still needs to be done. By way of example, I shall conclude this chapter by discussing how the LTS concept of 'system builders' can be adapted to study the intertwinement of infrastructural and European history.[80]

As noted above, Thomas Hughes developed the 'system builder' concept to spotlight key agents in the development of large technical systems as well as their transdisciplinary approach. To investigate the networking of Europe, the concept needs some modification, partly because it has to do different work, and partly because several criticisms on Hughes' original concept need to be considered and possibly accommodated.

The chief task of a concept of 'Europe's system builders' is to spotlight actors that were centrally positioned in the networking of Europe. Since the object of study is the intertwinement of infrastructural and European history, it should point at actors that had infrastructures as well as 'Europe' as their domain. These include individuals, such as Hermann Sörgel (Gall, this volume) and Gunnar Myrdal (Blomkvist, this volume), who connected infrastructural change to the shaping of a strong or peaceful Europe. These also include international organizations. The League of Nations, the United Nations Economic Committee for Europe (UNECE), and the European Union all sought to create a peaceful and prosperous Europe *and* had committees for transnational system building as part of this effort. In addition, several organizations specialized in transnational system building in Europe, such as the European Conference for Post and Telecommunications (Laborie, this volume), the Union for the Coordination of Production and Transport of Electricity (UCPTE) (Verbong, this volume), or the European Broadcasting Union. Also the International Telecommunications Union and the International Railway Union focused much of their attention on the infrastructural integration of Europe. Such actors did important work on the interlacing of Europe, but have rarely been studied by historians, let alone been included in the canon of European historiography. The concept of Europe's system builders should highlight their existence, their role in the shaping of Europe, and their suitability as a research site for studying the intertwinement of transnational infrastructure and society building.

Studying international organizations such as 'Europe's system builders' immediately prompts two comments. First, Hughes originally used the 'system builder' concept to study individuals such as Edison, Insull, Ford or General Groves. However, LTS authors quickly added that, especially in Europe, it made sense to study state governments as system builders, setting up railway, telephone and electricity supply systems.[81] International organizations, too, are what Hughes later called 'collective system builders.'[82]

Second and more important, Hughes' original concept presupposed central system builder control over all system elements. Others, however, found that system building agency can be distributed over many actors.[83] European transnational system building processes, likewise, involved many actors, most notably private companies and state agencies. Neither visionary individuals nor international organizations built infrastructures themselves. Rather, they had an inspiring, monitoring, or coordinating role. This makes them a methodologically promising research site: Following these actors, historians will encounter how transnational networks were built, how divisions of labor between international organizations, state agencies and private companies were negotiated, and even how transnational linking processes failed. Studying Europe's system builders is a methodological move to get access to the complex game of transnational system building, not a claim that these actually controlled from the top down such system building.

Three Aspects of Transnational System Building

Next to spotlighting key actors in the networking of Europe, the concept of Europe's system builders should also suggest how these actors can be studied. LTS research suggests three important aspects of transnational system building for historians to investigate. These are the ideological, sociotechnical, and contested aspects of system building.

First, more than Hughes' system builders, Europe's system builders might have a distinctly *ideological* agenda or rhetoric. Gunnar Myrdal and his UNECE saw infrastructural integration and trade as means to integrate all European countries, heal the East-West cleavage, and ultimately prevent a nuclear Third World War.[84] The European Union supports Trans European Networks for transport, communications and energy to create an economically strong and socially coherent Europe, as the Maastricht Treaty (1992) specifies.[85] It seems that Europe's system builders often redressed the ideology of circulation described by Williams and Mattelart (see above): infrastructures integrate peoples and thereby create powerful, prosperous, socially coherent or peaceful societies. The research question, then, is how Europe's system builders ideologically connected infrastructure projects to wider political, economic, or cultural goals and to the building of 'Europe,' however defined.

Of course such ideologies may cover over hidden agendas, national self-interests, and disagreement. Nevertheless, they can have great mobilizing power and therefore very real consequences. Perhaps they can be studied as a form of expectations, the contents, articulation, and appeal of which are generally recognized as important drivers of sociotechnical change.[86]

Second, as in Hughes' original concept, the aspect of *sociotechnical* system building should be highlighted. For instance, the UNECE work on road transport not only involved designing the European E-road highway system and its technical specifications. It also included work on financing models, emergency aid services, liability and insurance issues of foreign drivers (leading to a uniform insurance card), uniform rules for freight and passenger transport (e.g. an international waybill), and changing border control formalities.[87] Likewise, to stimulate the free circulation of people, goods and services, the EU supports and co-finances transnational networks, but also abolishment of systematic border control in exchange for increased police and judicial cooperation.[88]

Finally, the concept of Europe's system builder should highlight the negotiated or *contested* character of network building. Several commentators have dismissed Hughes' original system building concepts for lack of social critique: emphasizing success and convergence of system elements implies a 'harmony model' that silences critique and failure.[89] Negotiations and conflicts in system building processes should be made visible.[90] Europe's system builders organized such negotiations and observed cooperation as well as conflict, success as well as failure, winners as well as losers. Despite the high stakes, by the late 1960s Myrdal had to conclude that his UNECE had failed in forging a united Europe. It had been 'bypassed' by 'subregional organizations' such as the Organisation of European Economic Cooperation (OEEC) and the Council of Mutual Economic Aid (COMECON), setting up specialized organizations integrating e.g. electricity networks and roads in Western and Eastern Europe, respectively. Sadly, the term 'European' was increasingly used for a small band of Western countries. To Myrdal, such developments increased rather than relieved East-West tensions.[91]

Studying Europe's system builders thus may bring into vogue important yet neglected actors in contemporary European history, as well as ideological, sociotechnical and contested aspects of their work. In a similar way, other perspectives, narratives and concepts discussed in this chapter and this book may inspire insights into the intertwinement of infrastructure development and societal change, in Europe or elsewhere. Above all, it is important to dismiss misconceptions of a straightforward, uncontested technical change that characterize much historiography and network society theory today.

NOTES

1. The following surveys are not intended to be exhaustive, nor is LTS scholarship narrowly delineated. Personal selections and preferences do come into play. I include scholarship in English, the main language of scholarly exchange, but also contributions in German, Swedish, Dutch and French that are little known beyond language boundaries. Thematically, my focus is on contributions relevant to the historiography of network societies rather than current policy issues. For this reason, the major research-theme of LTS-governance is underexposed.
2. Hughes' contributions are discussed in John Staudenmaier, "Disciplined imagination: The life and work of Tom and Agatha Hughes," in *Technologies of power. Essays in honor of Thomas Parke Hughes and Agatha Chipley Hughes*, ed. Michael Thad Allen and Gabrielle Hecht (Cambridge, MA: MIT Press, 2001), pp. ix–xx; Pierre Lanthier et al. ed., *L'électricité en réseaux. Networks of power. Special issue of Annales historiques de l'électricité* 2004, no. 2. An older review is David Hounshell, "Hughesian history of technology and Chandlerian business history: Parallels, departures, and critics," *History and Technology*, 12 (1995): 205–224.

3. Thomas Hughes, *Networks of power. Electrification in Western Society 1880–1930* (Baltimore: The Johns Hopkins University Press, 1983).
4. See also Thomas Hughes, "Historical overview," in: *Social responses to large technical systems. Control or anticipation*, ed. Todd La Porte (Dordrecht: Kluwer, 1991), pp. 185–189.
5. Thomas Hughes, "The seamless web: Technology, science, et cetera, et cetera," in *Technology and social process*, ed. Brian Elliot (Edinburgh: Edinburgh University Press, 1988), pp. 9–19.
6. Thomas Hughes, "The evolution of large technological systems," in *The social construction of technological systems. New directions in the sociology and history of technology*, ed. W.E. Bijker et al. (Cambridge, MA: MIT Press 1987), pp. 51–82.
7. Including the work of Thomas Hughes, and, in English, at least: Renate Mayntz and Thomas Hughes eds., *The development of large technical systems* (Frankfurt am M.: Campus, 1988); La Porte, *Social responses to large technical systems*; Jane Summerton, ed., *Changing large technical systems* (Boulder: Westview Press, 1994); Olivier Coutard, ed., *Governing large technical systems* (London: Routledge, 1999); Olivier Coutard, Richard Hanley and Rae Zimmerman, eds., *Sustaining urban networks. The social diffusion of large technical systems* (London: Routledge, 2005).
8. Bernward Joerges, "High variability discourse in the history and sociology of large technical systems," in *Governing large technical systems*, Coutard (ed.), pp. 258–290.
9. Many only base their assessment on Hughes, "The evolution."
10. Compare e.g. Hughes, "The evolution" to Joachim Radkau, "Zum ewiger Wachstum verdammt? Jugend und Alter grosstechnischer Systeme," in *Technik ohne Grenzen*, ed. Ingo Braun and Bernward Joerges (Frankfurt: Suhrkamp, 1994), pp. 50–106.
11. Compare e.g. Alain Gras, *Les macro-systèmes techniques* (Paris, 1997) to Arne Kaijser, "Technological systems in the natural world," in *Technological systemic changes and economic theories*, ed. Jan Odhnoff and Uno Svedin (Stockholm: FRN, 1998).
12. Compare e.g. Arne Kaijser, *I fädrens spår.Den svenska infrastrukturens historiska utveckling och framtida utmaningar* (Stockholm: Carlssons, 1994) to Cornelis Disco and Erik van der Vleuten, "The politics of wet system building," *Knowledge, Technology & Policy* 14, no. 4 (2002): 21–40.
13. Joerges, "High variability discourse"; Klaus Kornwachs, "Steuerung und Wachstum. Ein systemtheoretischer Blick auf Grosse technische Systeme, " in *Technik ohne Grenzen*, Braun and Joerges, eds., pp. 410–445.
14. Frank Thomas, *Telefonieren in Deutschland. Organisatorische, technische und räumliche Entwicklung eines großtechnischen Systems* (Frankfurt am Main: Campus, 1995). Onno de Wit, *Telefonie in Nederland 1877–1940. Opkomst en ontwikkeling van een grootschalig technisch systeem* (Rotterdam: Cramwinckel, 1998). Catherine Bertho-Lavenir, "The telephone in

France 1879 to 1979," in *The development of large technical systems*, ed. Mayntz and Hughes, pp. 155–178.

15. Thomas P. Hughes, *American Genesis. A century of invention and technological enthusiasm* (N.Y.: Penguin, 1989); *Rescuing Prometheus* (N.Y.: Pantheon Books, 1998); *Human-built world. How to think about technology and culture* (Chicago: University of Chicago Press, 2004). And, with Agatha C. Hughes, ed., *Systems, experts and computers. The systems approach in management and engineering, World War II and after* (Cambridge, MA: MIT Press 2000).
16. NB I deviate from Hughes' own periodisation in *Human-built world*, which has other concerns than systems development alone.
17. Erik van der Vleuten, "De materiële eenwording van Nederland," in *Techniek in Nederland* Vol. 7, ed. Johan Schot et al. (Zutphen: Walburg, 2003), pp. 43–73. Disco and Van der Vleuten, "The politics of wet system building."
18. Kaijser, *I fädrens spår*. Arne Kaijser, "The helping hand. In search of a Swedish institutional regime for infrastructural systems," in *Institutions in the transport and communications industries*, ed. Lena Andersson-Skog and Olle Kranz (Canton, MA: Science History Publications, 1998), pp. 223–244.
19. Arne Kaijser and Marika Hedin, eds., *Nordic energy systems. Historical perspectives and current issues* (Canton, MA: Science History Publications, 1995). Compare Volker Schneider, "The governance of large technical systems: the case of telecommunications," in *Social responses to large technical systems*, ed. La Porte, pp. 19–41.
20. Arne Kaijser, "Trans-border integration of electricity and gas in the Nordic countries, 1915–1992," *Polhem* 15 (1997): 4–43.
21. Kaijser, *I fädrens spår*, 200 ff.
22. Radkau, "Zum ewiger Wachstum verdammt?"
23. Ingo Braun, "Geflügelte Saurier. Zur intersystemische vernetzung grosser technische Netze," in *Technik ohne Grenzen*, ed. Braun and Joerges, pp. 446–500.
24. This programme ran from 1995 to 2003, involved some 70 researchers and had a budget of some 10 million euros. Its main output is Johan Schot et al., eds., *Techniek in Nederland in de twintigste eeuw* vols. 1–7. (Zutphen: Walburg, 1998–2003).
25. Erik van der Vleuten and Geert Verbong, eds., *Networked nation. Technology, society and nature in the Netherlands in the 20th century. Special issue of History and Technology 20, no. 3 (2004)*. Erik van der Vleuten, "In search of the networked nation," *European Review of History* 10 (2003): 59–78. Van der Vleuten, "De materiële eenwording."
26. Geert Verbong and Erik van der Vleuten, "Under construction: Material integration of the Netherlands 1800–2000," *History and Technology* 20, no. 3 (2004): 195–204.
27. See below.
28. Erik van der Vleuten and Cornelis Disco, "Water wizards," *History and Technology* 20, no. 3 (2004): 291–309; Henk van den Belt, "Networking

nature, or, Serengetti behind the dikes," *History and Technology* 20, no. 3 (2004): 311–333.

29. Rosalind Williams, "Cultural origins and environmental implications of large technological systems," *Science in Context* 6 (1997): 377–403.
30. Armand Mattelart, *Mapping World Communication. War, progress, culture* (Minneapolis: University of Minnesota Press, 1994; French orig. 1991); Mattelart, *The invention of communication* (Minneapolis: University of Minnesota Press, 1996; French orig. 1994); Mattelart, *Networking the world 1784–2000* (Minneapolis: University of Minnesota Press, 2000; French orig. 1996).
31. Petty cited in Mattelart, *The invention*, 19.
32. Chevalier cited in Mattelart, *The invention*, 103.
33. For the 'modern infrastructural ideal' in urban planning see Stephen Graham and Simon Marvin, *Splintering urbanism. Networked infrastructures, technological mobilities and the urban condition* (London: Routledge, 2001), chapter 2.
34. Proudhon cited in Mattelart, *Networking the world*, 17.
35. For discussion and references see Erik van der Vleuten, "Infrastructures and societal change. A view from the Large Technical Systems field," *Technology Analysis & Strategic Management* 16, no. 3 (2004): 395–414; Erik van der Vleuten, 'Étude des conséquences sociétales des macro-systèmes techniques: une approache pluraliste.' *Flux. Cahiers scientifiques internationaux réseaux et territoires* 43 (2001): 42–57. Also the conceptual purist's argument that the interrelatedness of the social and the technical makes phrasings like 'technology's societal consequences' meaningless no longer prevents such inquiry. As Robert Merton knew, the real dangers to academic scrutiny stem not from wrong answers, but from the failure to ask crucial questions.
36. Hughes, *Networks of power*.
37. Dominique Barjot and Ginette Kurgan, "Les réseaux humains dans l'industrie électrique Europeène," *Annales historiques de l'électricité* 2004, no. 2: 69–88. Johan Schot and Dick van Lente, "Techniek als politiek: ingenieurs en de vormgeving van de nederlandse samenleving," in *Techniek in Nederland* Volume 7, ed. Schot et al., pp. 196 ff.
38. Mats Fridlund, "De nationalistiska system. Konstruktion av teknik och svenskhet kring sekelskiftet 1900," in *Den konstruerade världen. Tekniska system i historiskt perspektiv*, ed. Pär Blomkvisk and Arne Kaijser (Stockholm: Brutus Östlings, 1998), pp. 77–104.
39. Stephen Salsbury, "The Australian electric power industry and the politics of radical reconfiguration," in *Changing large technical systems*, ed. Summerton, pp. 141–162.
40. For this thesis see Graham and Marvin, *Splintering urbanism*; Stephen Graham and Simon Guy, "Internetting downtown San Francisco: Digital space meets urban place," in *Sustaining urban networks*, ed. Coutard et al., 32–47. The thesis and its policy implications are discussed and contested in Olivier Coutard, "Urban space and the development of networks: A discussion of the 'Splintering Urbanism' thesis," ibid. 48–63.

41. Olivier Coutard, Richard Hanley and Rae Zimmerman, 'Network systems revisited: The confounding nature of universal systems,' in *Sustaining urban networks*, ed. Coutard et al., 1. This capacity of LTS research was already observed in Wiebe Bijker, "Sociohistorical technology studies," in *Handbook of science and technology studies*, ed. Sheila Jasanoff et al. (London: Sage, 1995), pp. 229–256.
42. Arne Kaijser, *I fädrens spår.*
43. Renate Mayntz, "Grosse technische Systeme und ihre gesellschaftstheoretische Bedeutung," *Kölner Zeitschrift für Sociologie und Socialpsychologie* 45 (1993): 97–108.
44. Wolfgang Sachs, "Satellitenblick. Die Ikone vom blauen Planeten und ihre Folgen für die Wissenschaft," in *Technik ohne Grenzen*, ed. Braun and Joerges, pp. 305–346. Sachs' study strongly reminds one of Wolfgang Schivelbusch, *Geschichte der Eisenbahnreise. Zur Industrialisierung von Raum und Zeit im 19. Jahrhunderd* (Frankfurt am M: Ullstein, 1979. orig. 1977).
45. Claude Fischer, *America Calling. A social history of the telephone to 1940* (Berkeley: University of California Press, 1992), p. 12
46. Bernward Joerges, "Do politics have artefacts?" *Social Studies of Science*, 29 (1999): 411–431 on p. 424.
47. Van der Vleuten and Disco, "Water wizards."
48. Hypotheses on the economic leverage of railroads and the immanent demand for centralized control of LTS have been contested. See, respectively, Lucy Firth et al. "Infrastructure concepts and classifications," in *The infrastructure playing field in 2030*, ed. M. Weijnen and E. ten Heuvelhof (Delft: Delft University Press, 1999), 21–40; and Radkau, "Zum ewiger Wachstum verdammt?"
49. Robert Heilbroner, "Technological Determinism revisited," in *Does technology drive history*, ed. Meritt Roe Smith and Leo Marx (Cambridge, MA: MIT, 1995): 67–78 on 70. For instance, Joerges argues that a wall erected to keep people out does not absolutely determine behaviour, for, "what if one is armed with a tank?" However, most people do not have a tank. The wall would simply invite them to go elsewhere. Joerges, "Do politics have artefacts?," 413.
50. David Nye, *Electrying America. Social Meanings of a New Technology* (Cambridge, Ma.: MIT, 1990). Fischer, *America Calling.*
51. Nelly Oudshoorn and Trevor Pinch, eds., *How Users Matter: The Co-Construction of Users and Technology* (Cambridge, MA.: MIT Press, 2003).
52. David Nye, "Electricity and culture," *Annales historiques de l'électricité* 2004, no. 2: 125–138.
53. R. Oldenziel, ed., "Huishouden," in *Techniek in Nederland* Volume 4, ed. Schot et al., pp. 11–151. E. Bervoets, ed., "Bouw," in *Techniek in Nederland*, Volume 6, ed. Schot et al., pp. 111–242.
54. Van der Vleuten, "De materiële eenwording"; Van der Vleuten, "In search of the networked nation"; Van der Vleuten, "Infrastructures and societal change."

55. Ibid. and Albert de la Bruèze and Van Otterloo, "The milky way," *History and Technology* 20, no. 3 (2004): 249–270.
56. Ibid. and Janneke Hermans and Onno de Wit, "Bourses and brokers," *History and Technology* 20, no. 3 (2004): 227–248; Mila Davids, "The fabric of production," *History and Technology* 20, no. 3 (2004): 271–290.
57. Erik van der Vleuten, "Introduction. Networking technology, networking society, networking nature," *History and Technology* 20, no. 3 (2004): 195–204.
58. Hughes, *Human-built world.*
59. For a canonical debate in the history of technology see Robert Angus Buchanan, "Theory and narrative in the history of technology," *Technology & Culture* 32 (1991): 365–376; John Law, "Response," Ibid., 377–385; Phil Scranton, "Comment," Ibid., 384–392; R.A. Buchanan, "The poverty of theory in the history of technology," *Polhem* 15 (1997): 187–193.
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