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The Hybrid Nature of Infrastructures

Until a few decades ago, the study of infrastructures was confined to a few areas of engineering, economics, transport and urban planning. Today, however, it has become the focus of a vast multidisciplinary debate that also includes the humanities and in particular history. As often happens with such kind of keywords, while the concept gained in currency it accumulated a multiplicity of definitions, sometimes resulting in haziness. The term “infrastructure” was originally coined in the second half of the nineteenth century to describe the French railway system and it was translated into other languages over the following decades. After the end of the Second World War, it became more widely used thanks to its adoption in military terminology (particularly in NATO programs) and it subsequently became a commonly used term in many different sectors, to the point of identifying virtually any element enabling the operation of modern economies and societies¹.

Dirk van Laak, one of the historians most committed in recent years to analyzing the significance and role of infrastructures, defines them as: “the stable or immobile elements that are necessary to enable fluidity, movement, and communication. They produce a networked and circularly organized society that generates trade and change, peace and prosperity”². He identified their emergence in the eighteenth century, within the first developments of state modernization.

Given the central role that infrastructures played in shaping the ‘built environment’, it is no surprise that this concept enjoyed growing popularity within the sphere of environmental history, also in relation to two interconnected dynamics. Within the academia, the last decades have seen a convergence between

1 A. Carse, *Keyword: Infrastructure: How a Humble French Engineering Term Shaped the Modern World*, in P. Harvey / C. Jensen / A. Morita (eds.), *Infrastructures and Social Complexity: A Companion*, London 2016, p. 2739; P. Högselius / A. Kaijser / E. van der Vleuten (eds.), *Europe's Infrastructure Transition: Economy, War, Nature*, Basingstoke 2016.

2 D. van Laak, *Infrastructures*, in “Docupedia-Zeitgeschichte”, 20.05.2021, http://docupedia.de/zg/Laak_infrastructures_v1_en_2021, <http://dx.doi.org/10.14765/zzf.dok-2215>.

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environmental history on the one hand and the history of technology and STS (Science and Technology Studies) on the other³. In more general terms, since the start of the new millennium these themes have been profoundly shaped by debate on the concept of the Anthropocene, one of the characterizing aspects of which is the progressive overlapping of ecological and social dynamics, including those related to technological factors⁴. As a consequence of these developments, infrastructures have come to be considered principally as hybrid socio-ecological systems, or according to a definition proposed by Sara Pritchard, *envirotechnical systems*, that are “historically and culturally specific configurations of intertwined ‘ecological’ and ‘technological’ systems”⁵.

Among the many methodological and thematic perspectives through which environmental historians have analyzed infrastructures, it is worth mentioning at least three particularly relevant fields of research, which are closely interconnected with each other and widely discussed also in the essays that comprise the present volume. The first is urban environmental history, as is already clear in one of the texts considered seminal to this historiographic genre: William Cronon’s *Nature’s Metropolis*. In this work, the large infrastructures realized over the course of the nineteenth century, like railways and navigable canals, are considered the linchpins around which dynamics emerged linking the urban development of Chicago to the transformation of a hinterland that extended from the Great Lakes to the Great Plains⁶. At the same time, the studies in urban metabolism that were taking shape in those years also identified the construction and operation of large infrastructures (aqueducts and sewage networks, transport and communication systems, etc.) as elements that oriented the materials and energy flows, both within the urban context and between the city and the surrounding territory⁷. A turning point in these processes was identified, at least for Europe and North America, in the nineteenth century, when the development of modern industrial-scale infrastructures provided new opportunities for urban growth through a series of improvements in sanitation, mobility, and energy

3 Cf. M. Reuss / S.H. Cutcliffe (eds.), *The Illusory Boundary: Environment and Technology in History*, Charlottesville 2010; D. Jorgensen / F.A. Jorgensen / S.B. Pritchard, *New Natures: Joining Environmental History with Science and Technology Studies*, Pittsburgh 2013.

4 K. Hetherington (ed.), *Infrastructure, Environment, and Life in the Anthropocene*, Durham 2019.

5 S. Pritchard, *Confluence: The Nature of Technology and the Remaking of the Rhône*, Cambridge MA 2011, pp. 19–20. On this see also A. Carse, *Nature as Infrastructure: Making and Managing the Panama Canal Watershed*, in “Social Studies of Science”, 42, 2012, 4, pp. 539–563.

6 W. Cronon, *Nature’s Metropolis: Chicago and the Great West, 1848–1893*, New York 1991.

7 J.A. Tarr, *The Metabolism of the Industrial City: The Case of Pittsburgh*, in “Journal of Urban History”, 28, 2002, 5, pp. 511–545; S. Barles, *Urban Metabolism of Paris and Its Region*, in “Journal of Industrial Ecology”, 13, 2009, 6, pp. 898–912.

transport and consumption. The result of these dynamics was the emergence of the so-called “networked city”⁸.

The concept of a *networked city* had been developed by environmental historians starting from that of “large technological system” proposed by the historian of technology Thomas P. Hughes, when referring to the construction of large electrical infrastructures⁹. This genealogy leads to our second field of study, in which the ecological aspects of infrastructures have been frequently studied over recent years: history of energy. This dynamic area of research developed around the concept of energy systems (or regimes), a term that does not refer simply to the sum of energy sources and the necessary converters, but instead includes the social, economic, technological, and environmental aspects associated with specific models of energy exploitation. In this perspective, the study of energy systems and their transitions becomes a way to examine, through the lens of energy, the most significant ecological, economic, and social transformations of a given historical phase¹⁰. For example, recent research has demonstrated how modern energy transport infrastructures (canals, oil pipelines, transmission lines, etc.) are not simply connections linking supply and demand, but through the logic of economies of scale and the dynamics of path-dependence, they first ‘created’ new energy demands and consequently determined particular energy consumption models¹¹. These transformations also redefined relations both between social actors at local or national scale, and between areas of the globe connected by the energy infrastructures on a geopolitical scale¹².

The third and final field of study, particularly well covered by environmental historians who have analyzed infrastructures, involves the management and control of water resources. A famous – and contested – reference in this respect is the theory of “Oriental despotism” elaborated by Karl Wittfogel, postulating that the transition from sustenance agriculture based on local irrigation systems, to a model based on large scale infrastructures for irrigation and flood control in Asia

8 J. Tarr / G. Dupuy (eds.), *Technology and the Rise of the Networked City in America and Europe*, Philadelphia 1988; D. Schott, *Die Vernetzung der Stadt: Kommunale Energiepolitik, öffentlicher Nahverkehr und die ‘Produktion’ der modernen Stadt. Darmstadt-Mannheim-Mainz 1880–1918*, Darmstadt 1999. See now S. Haumann / M. Knoll / D. Mares (eds.), *Concepts of Urban-Environmental History*, Bielefeld 2020.

9 T.P. Hughes, *Networks of Power: Electrification in Western Society, 1880–1930*, Baltimore 1983.

10 C.F. Mathis / G. Massard-Guilbaud (eds.), *Sous le soleil: Systèmes et transitions énergétiques du Moyen Âge à nos jours*, Paris 2019; I.J. Miller et al., *Forum: The Environmental History of Energy Transitions*, in “Environmental History”, 24, 2019, 3, pp. 463–533.

11 C.F. Jones, *Routes of Power: Energy and Modern America*, Cambridge 2014.

12 T. Mitchell, *Carbon Democracy: Political Power in the Age of Oil*, London 2011.

encouraged the emergence of “hydraulic societies”, characterized by powerful bureaucracies and centralized, authoritarian state systems¹³. Wittfogel’s thesis was adopted and adapted by one of the founders of environmental history, Donald Worster. In *Rivers of Empire*, Worster analyzed the political and social dynamics linked to the realization of large-scale irrigation infrastructures, not in relation to the development of “Oriental despotism”, but instead of “Western capitalism”. Worster focused on the infrastructures that transformed the arid lands of the American West into one of the richest agricultural regions on the planet. The process was fuelled with massive public support, both in terms of invested resources and technical-administrative expertise, with an equally important contribution from large scale agrarian capitalism. This created a new typology of “hydraulic society” based on an interweaving of state intervention and private interests¹⁴.

In recent decades one of the most effective ways to integrate water, energy, and urban issues has been the study of rivers. Regarding infrastructures in particular, research has shown that water courses should not be considered only in relation to the impact of large-scale infrastructures on water flow rates or the morphology of river basins. Instead, rivers should be understood as integral parts of more articulated infrastructures, in which technical elements interact with natural ones. This is an idea that already emerged in a text considered to be a turning point in the historical study of rivers, *The Organic Machine* by Richard White¹⁵. The author considered the Columbia River to be a sort of organic machine, in which human and natural labor were interwoven and influenced each other, transforming the surrounding territory through irrigation, energy generation, and the development of transport systems. White’s methodological approach has been adopted frequently and further elaborated in subsequent decades, like for example by Sara Pritchard in her study of the Rodano River, with the aforementioned concept of *envirotechnical systems*¹⁶.

Water courses can thus be considered as nodes in more articulated and hybrid infrastructures that have played an essential part both in urban contexts and for

13 K.A. Wittfogel, *Oriental Despotism: A Comparative Study of Total Power*, New Haven / London 1957.

14 D. Worster, *Rivers of Empire: Water, Aridity, and the Growth of the American West*, New York 1985. On this, see now G. Parrinello / S. Neri Serneri, *Water, Power, Politics: Introduction*, in “Contemporanea”, 2, 2022, pp. 171–183.

15 R. White, *The Organic Machine: The Remaking of the Columbia River*, New York 1995.

16 S. Pritchard, *Confluence*. See also G. Parrinello, *Systems of Power: A Spatial Envirotechnical Approach to Water Power and Industrialization in the Po Valley of Italy, ca. 1880–1970*, in “Technology and Culture”, 59, 2018, 3, pp. 652–688.

providing energy¹⁷. Rivers were the preferential routes of communication between urban and surrounding areas and, at least until the end of the nineteenth century, they were used for importing raw materials and exporting value added or industrial goods. A more recent use emerged from the second half of the nineteenth century, with the creation of modern aqueducts and drainage systems¹⁸. Water courses also played a key role in harnessing energy within more extensive infrastructural complexes. In the early modern period this included the production of hydromechanical energy, and above all rivers' role as means of transport for the main source of energy of that period: wood. The development of hydroelectric energy represented a quantitative leap in the energy that could be extracted from water courses, while the dams, generation plants, and conducting systems changed also the rates of flow, adapting them to the most varied social and economic needs through a process that has been defined as the "industrialization of rivers"¹⁹.

Based on the brief observations and associated examples discussed so far, it is clear that in the study of the relationship between environment and infrastructure, a turning point can be identified in the technological innovations and energy regime introduced through industrialization. This observation becomes even more telling if infrastructures are considered from a 'cultural' perspective. However, the majority of studies cited so far highlight how the material and energy flows that characterized the metabolism of preindustrial societies were already organized through complex infrastructures (or *envirotechnical systems*) based on interwoven social and natural elements²⁰. This framework influenced the adoption of an extensive periodization for the present volume, making it possible to identify the undeniable changes caused by industrialization, as well as the persistence of preexisting features and dynamics.

The essays presented here are the outcome of the academic discussion that emerged from the 62nd Study Week, "Environment and Infrastructures from the Early Modern Period to the Present", organized by the Istituto Storico Italo-Germanico of the Fondazione Bruno Kessler in Trento. The first essay, in the

17 M. Evenden, *Beyond the Organic Machine? New Approaches in River Historiography*, in "Environmental History", 23, 2018, pp. 698–720; G. Bonan, *Riflessi sull'acqua. Ricerca storica e biografie fluviali*, in "Contemporanea", 22, 2019, 2, pp. 317–328.

18 S. Castonguay / M. Evenden (eds.), *Urban Rivers. Remaking Rivers, Cities, and Space in Europe and North America*, Pittsburgh 2012; M. Knoll / U. Lubken / D. Schott (eds.), *Rivers Lost, Rivers Regained. Rethinking City-River Relations*, Pittsburgh 2017.

19 E. Jakobsson, *Industrialization of Rivers: A Water System Approach to Hydropower Development*, in "Knowledge, Technology & Policy", 14, 2002, 4, pp. 41–56; G. Bonan, *Le acque agitate della patria: L'industrializzazione del Piave (1882–1966)*, Roma 2021.

20 See also T. Soens et al. (eds.), *Urbanizing Nature: Actors and Agency (Dis)Connecting Cities and Nature since 1500*, New York 2019.

section “Overview”, provides insight into the methodological and thematic context in which the most recent historical studies on the relationship between environment and infrastructure have developed. This is the broader debate on the concept of Anthropocene that has characterized the last two decades, inducing new interactions between different disciplines within the humanities (like the previously mentioned convergence of environmental history and STS) and between the humanities and the Earth System Sciences. In *Provocations to Environmental History and History of Technology: The Anthropocene*, Helmut Trischler and Fabienne Will trace back the history of the concept that defines the recent continuous transformation produced by mankind, the *Anthropos*, on the Earth system. A process of change that in recent decades has assumed such a massive and powerful scale as to compete with some of the great natural forces. The term was introduced in 2000 in geological studies and soon spilled over into the Earth System Sciences, becoming a discussion point in the human and social sciences. There was reflection on its heuristic and analytic features, debating, among many other things, causes and responsibilities for the ecological crisis and its effects, from climate change to environmental pollution and other issues. Through analysis of the Anthropocene as a geological and cultural concept and the interest it raised as a social phenomenon, the two authors investigate the positions of scientists and anthropologists as regards technology and its impact on the transformations of the planet, examining the idea of the Technosphere or Technocene. This alternative perspective considers mankind as a technical subject and part of a new stage of evolution on the planet. It thus requires a new narrative framework and a different periodization for environmental history and the history of technology in an interdisciplinary and transdisciplinary dialogue.

The role of technology and infrastructures in increasing the consumption of natural resources, and the environmental impact of human activity are the common threads that unite the essays collected here. This also applies to the ones addressing the preindustrial era and not only those regarding more recent decades. Historical analyses reveal the strategies adopted by societies and states to transform and adapt their surrounding environment in a continuous, delicate, and difficult equilibrium of diverse interests. Various means and technologies were applied according to the period, but the environmental impact over time expanded to a global scale, to the extent of necessitating collective reflection and reconsideration.

The volume is organized into three macro sections, with the first dedicated to “Urban Metabolism and the Transformation of Hinterlands”, the second to “The Multiple Scales of Envirotechnical Systems”, and the third to “Hybrid Landscape: Infrastructures of Water Control”.

The first section starts with an essay by Georg Stöger, *Urban Environmental Infrastructure in the Eastern Alpine Region (Sixteenth to Eighteenth Century)*, with

research focused on the infrastructures required for the operation of the urban metabolism in three different cities in the eastern Alpine region: Salzburg, Linz, and Vienna, all administrative and commercial centres, and transport hubs of different sizes. He considers the resources sent into the cities, how the raw materials and manufactured goods were used or transformed there, and then the final outcomes, which included unwanted by-products like effluents, waste, and emissions. The author analyzes in detail the commercial networks that supplied the cities with firewood and cereals, the water infrastructures, and finally the socio-environmental systems for fire control and floods. A system of cooperation is identified between actors inside and outside the city to sustain the urban metabolism with infrastructures, which could differ significantly in each case and were sometimes substantially transformed over time, with smaller simpler networks existing alongside or even within larger more complex systems. These infrastructures could be permanent or temporary and normally involved areas outside of the city. There was often the coexistence of a “plurality of hinterlands”, which might evolve substantially over time as a result of political decisions, crises, or economic and technological developments.

The second essay, *From Stues to Çates. Infrastructures for Timber Transport in Friuli in the Early Modern Period*, is dedicated to the history of lumber transport in Carnia, one of the most critical forestry basins supplying the extensive Venetian emporium and mainland settlements. Claudio Lorenzini reconstructs the complex stages in the production chain, with a detailed description of the constructional techniques for the dams used in timber floatation. This system was already well established in the late Middle Ages with substantial changes only occurring from the start of the second half of the nineteenth century, during the period of industrialization of the main river in the region. This involved draining and irrigating the plain, and exploiting the mountain catchment basin for hydroelectric power in the early decades of the twentieth century. The essay reveals essential aspects of the infrastructural system, including some related legal issues regarding the status of collective forest property, associated organizational issues like the recruitment of specialized workers who were often foreigners, and the supply of staple foodstuffs to the forest worksites. No less important were the environmental aspects linked to the tree felling cycle and the seasonal water availability, which served to transport the logs downstream, exploiting the capacity of rivers and mountain streams to the maximum.

This is followed by a temporal leap to postwar Germany and the case of Wismut, where the largest Soviet company operated for over forty years, a sort of “State in the state” involved in the extraction of uranium during the Cold War. The essay by Astrid Mignon Kirchhof, Yaroslav Koshelev, Florian Manthey, Anna-Katharina Pelkner, Judith Schein, and Christiane Uhlig, *Uranium Stories. Making*

the Wismut Narrative Visible, deals with the infrastructural systems implemented to transform Wismut. After reunification, this component of the Soviet nuclear system, and one of the biggest environmental disasters on the planet, was converted directly into a German ecological remediation company. The intervention work enabled the reconstruction of the thermal baths in Schlema with a series of associated infrastructures, reconverting a disaster zone into one of the most successful remediation projects of the ex DDR, all within a few years of the reunification of Germany. The remediation works also included conserving the memories of witnesses with the support of the Bochum Mining Museum in collaboration with other German academic institutions. Interviews were recorded with workers and their families, and these are available today in an online archive, intended to raise awareness of the social and cultural consequences of East Germany's environmental and mining history. Uranium mining transformed the economic and social profile of the area, as emerges from the testimonies of Russian and German citizens, even if there are aspects that require further research, like, for example, the associated medical consequences and the Wismut health system.

The second section, “The Multiple Scales of Envirotechnical Systems”, starts with Giacomo Parrinello, who in *Water as Infrastructure and the Scalar Mismatch* shows how pollution and climate change have such a severe impact on river flows that they challenge the technical knowledge and predictive ability of those designing infrastructures for irrigation or generating hydroelectric power.

The author describes the first attempts to forecast flow rates based on historical data applied to individual water courses, with the aim of developing new irrigation canals. The Cavour Canal is used as an example, this being the most extensive hydraulic infrastructural development of the 1840s, designed to irrigate the fields of western Piedmont with the waters of the Po River. It turned out to be a failure due to incorrectly forecasting an adequate flow rate in the river to supply the irrigation canal. As the author underlines, it is predictability that transforms water into an infrastructure and this is fundamental for the existence and operation of any water-based environmental system. This emerges again in the second case study regarding the hydroelectric stations established across the entire Po River basin in the twentieth century.

Frédéric Graber addresses the relationship between infrastructures and citizens in *The Ideal Public for Infrastructures. Towards a Long-Term History of the Environment-Infrastructure-Participation Nexus*. He investigates the importance of public participation in infrastructure projects, conducted in France through public enquiries, the so-called *enquête publique*. Participatory procedures were first implemented in the eighteenth century with the public called upon to assess projects for mining, river management, drainage, production sites that created pollution, and other more general issues. Everyone was free to express an opinion

of any kind, and these were recorded in a register and then assessed by a commission based in a municipality or prefecture. The author notes that there was very little public interest or participation right from the start. However, the institution survives to the present day when it remains a necessary mechanism for authorizing infrastructural developments. In the second part of the essay, this phenomenon is considered alongside what emerged from the end of the 1960s through the 1970s, when environmental issues entered the political debate, and civil society claimed a more active role in the decision-making process for major infrastructure projects.

Simone Müller's contribution *Dirty New Natures. Infrastructures and the Global Waste Economy* shifts the observational perspective to an emerging theme in environmental history: the waste economy. The author provides an interesting reconstruction of the infrastructural development project of Puerto Castilla in Honduras, arising after a tightening of environmental rules in the United States that opened the way for the exportation of hazardous waste to Central America. The drainage and consolidation of humid zones, and the creation of artificial land for the expansion of the port, combined with road construction projects, were offered in exchange for disposal facilities for waste from the Philadelphia rubbish incinerator. Some local inhabitants interpreted it as an opportunity to relaunch the local economy, but instead it rested on a heritage of colonial exploitation of areas with unstable political regimes and weak national economies. An emblematic but hardly unusual case, and the consequence of an unequal trade system that highlights the contradictions and unbalanced nature of the global environmental protection processes between the North and South of the planet.

The theme of the third part of the volume is water infrastructures, titled "Hybrid Landscape: Infrastructures of Water Control". An essay by Matteo di Tullio, *Coping with Water. Managing a Living Infrastructure in Early Modern Lombardy between Economy, Ecology, and Conflicts*, concentrates on the Po River plain, particularly in the area between the State of Milan and the western provinces of the Republic of Venice, from the fifteenth to the eighteenth century. Countless drainage and land domestication measures in the area promoted by local communities or private individuals made it possible to exploit this land effectively, enabling stable settlements to grow through a complex system of ecological, economic, and social interventions. The study reveals clearly how the water network required constant attention since human intervention had given rise to a new ecosystem that had to be constantly kept in equilibrium by the inhabitants, who were an integral part of the infrastructure itself. The example demonstrates the importance of constant cooperation between users, united in consortiums that coordinated the use of the various canals. The consortiums were also relegated to resolving disputes, which

were particularly numerous in moments of climate, demographic, or economic crises threatening the efficient exploitation of these living infrastructures.

The role of local people in looking after a territory and environment is taken up again in *Slow Infrastructures, Flood Protection and Extreme Weather Events. A Historical Perspective* by Tim Soens, a study dedicated to the marine coastlines of the Netherlands and Belgium from the Middle Ages to the end of the eighteenth century. The essay details the protective structures, considering the different levels of investment that indicate small somewhat *ante litteram* accelerations, with a transition from “slow” models towards increasingly “heavy” levels of capital and technological intervention. This approach is inspired by the concepts of *slowness* and *deceleration* of the *degrowth* movement, which has emerged in response to the rapid transformations of society and the environment since the second half of the twentieth century. The author underlines how the rapid climatic changes we face today oblige reflection on the need to find innovative technological solutions to protect areas once again threatened by catastrophic flooding. It is crucial to involve the inhabitants of coastal and humid regions, increasing their awareness of risk and moving beyond the model of large-scale infrastructures imposed on them from above.

In the final essay in the section, *Decadent Infrastructure? Representations of Water in the Kingdom of Naples in the Early Nineteenth Century*, David Gentilcore examines water management in the Kingdom of Naples in the nineteenth century, starting from two complementary sources. The first is a work by Teodoro Monticelli, *Sull'economia delle acque da ristabilirsi nel Regno di Napoli*, a discreetly successful volume published in 1809 by the director of the Jesuit College of Naples. It explores political issues and landscape studies, merging proto-environmentalism with concerns for the material condition of the state. The second source volume is *Statistica Murattiana*, started in 1811 on the initiative of Gioacchino Murat, brother-in-law of Napoleon and King of Naples, with the aim of gaining a deeper understanding of the natural, physical, demographic, social, and economic dimensions of the realm. This text is considered a seminal event in the so-called Franco-Neapolitan colonialism. Drawing on these two volumes, the author offers an interesting perspective on the twelve provinces of the Kingdom, based on the results of a heterogeneous study group that included Abbot Monticelli himself. Although no sections are dedicated specifically to water resources, there are numerous references to the condition and supply of water for drinking or power use. What emerges is a water policy in the Kingdom that favored the city at the expense of the countryside and with a disparity of infrastructures in the various areas. The overall situation of the local communities nevertheless appears to have been in equilibrium, thanks to their ability to maintain self-sufficiency and ensure adequate water supplies for agriculture, textile production, and sanity purposes.

John McNeill provides the *Concluding Remarks*, which retrace many key thematic ideas considered in the essays covering different historical periods. Some insightful observations are also offered on the “environment and infrastructure” binomial and its heuristic potential for environmental history.

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