Unboxing Urban Infrastructure: Three Methodologies for infrastructure-oriented Urban Design and Architecture Education

D Bauer

1 Habitat Unit, Chair of International Urbanism and Design, Institute for Architecture, Technische Universität Berlin, Strasse des 17. Juni 152, 10623 Berlin, Germany
bauer@tu-berlin.de

Abstract. Although the exploration of infrastructure has become a main focus of urban-centered studies and urban theory over the last decade, it has only been partially adopted into design and planning education. Here, the traditional curriculum of architecture, urban planning, landscape architecture, and urban design offers emerging professionals limited guidance and tools for exploring and analyzing the complex assemblages and constituting systems that create, run, and shape cities. However, in times of dramatic need for systemic transformation, the critical and research-based analysis of the city's externalities and the flows underlying urban life will become more relevant by the day. Thus, the following article outlines three teaching methodologies for analyzing “infrastructural regimes” as key levers and contexts to embed a reflected and responsive design work directed at transformation towards global sustainability.

Keywords: infrastructure, architecture, urban design, research-oriented design education, transformation towards sustainability

1. Objective
With the global urgency to decarbonize our operational systems by 2050, the current decade presents a critical juncture and a period of pressing vital hinge points that demand resolute decision making and rapid transformation. According to the latest IPCC Report, the desirable mitigation scenarios believed to avoid yet unseen environmental degradation and prevent irretrievable crises in the earth system will require most of the transitional framework in many sectors in the eight years up until 2030 [1]. Continuous global urbanization is one of the critical threats to achieving desired planetary sustainability, as it unfolds along the trajectories of fossil-fuel-powered and extractive industrial logics extending far beyond cities' morphological footprints. In order to not fall short from our ambitious goals, we, therefore, need to look at the world from the eyes of modern, borderless city life.

This is primarily constituted through the existence of its underlying networked infrastructures. They regulate and order urban activities and connect the ever-growing number of needy and highly specialized inhabitants with more distant landscapes from which they draw their resources and goods. Socio-technical systems as they are, urban infrastructures actively (re-)construct and govern urbanized societies, respectively. They constantly enable, enforce, connect, and divide as they operate - or fail to operate. They form the pulse and metabolism of cities by producing and distributing their provisions,
by geographically concentrating global and local resources, by regulating their complexity, by shaping the physical and material surroundings, by conditioning their inhabitants’ feelings and beliefs, by acting as political technologies and forces of administration, but also as hidden power beyond governmental elites [2].

In the last decade, the study of infrastructure has been a great focus and interest for urban-centered studies [3]. However, in the designing and planning professions, it has only just started to become a topic for investigation beyond its purely techno-managerial and engineering context. Although the designer and planner class is confronted more than ever before with the need for thorough reflection on the systems and regimes in which most of their work is embedded, the contemporary curriculum of the architecture and urban design disciplines is only slowly beginning to tap the potential of critical and research-based analysis of local and trans-local material circulation and their impacts on built and unbuilt environments. In this, the engagement with infrastructure can be powerful in scope. As Jochen Monstadt noted: “It is thus argued that we need adequate conceptual approaches which reflect the complex interdependencies between cities, networked infrastructures, and urban ecologies and which broaden our understanding of the ways we can develop, govern, and renew our infrastructures in cities in a sustainable way [4].”

This paper presents three different teaching methodologies developed for graduate students in Urban Design and Architecture. They aim for the analysis of “infrastructural regimes” [5] as key levers and contexts for embedding reflected and responsive design work directed at transformation towards global sustainability. Each approach investigates aspects of these regimes in the description of (1) their existing physical technostructure; (2) the flows of resources mediated by them; (3) their spatial/geographical embeddedness into (4) a local social structure and institutional framework and; (5) lastly, forms of spatial governance as well as (6) their historical contexts and coevolution. The first method follows the path of a selected infrastructure through its geographical course and focuses on on-site studies of interaction with its context. The second approach monitors the commodification process of a selected consumer object and portrays the various landscapes and places underlying the involved global supply chains. Finally, the third teaching layout frames the coming about of a particular urban technology and illustrates the coevolution of socio-technical trajectories and city expansion. The paper does not wish to quantify and compare different methods and their impacts. Instead, it seeks to present alternative frameworks that apply to those who teach and engage with research-based design processes for trans- and interdisciplinary groups of students.

2. Terminology
The expression “infra-structure” is an assembly of two words of Latin origin - the first “inf(e)ra”, meaning underneath, and the second “structura”, which could be translated as constituting. This contraction - originally derived from late 19th ct. transnational railroad engineering jargon - was first used to signify the underlying roadbeds needed for the construction and ceaseless extension of train tracks through the terrain [6].

The term remained limited in use within the formative influence of an increasingly powerful class of transportation engineers and began to see a significant expansion of meaning in the wake of the Second World War through its adoption in supranational military and economic development [7]. In this, it would serve to describe a particular vision of worldwide modernization and progress through the production of commanding technical systems, buildings, and machines and the implementation of unitary formative standards, norms, and codes.

Today “infrastructure” has been widely adopted by a variety of scholarly discourses in order to integrate, assemble, and amalgamate a plurality of material and immaterial artifacts, ideas, standards, and actors into a relationship of depth, meaning, and hierarchy. Infrastructures in their current meaning are “modular, multi-layered, [and] rough-cut […] and consist of numerous systems, each with unique origins and goals, which are made to interoperate by means of standards, socket layers, social practices, norms, and individual behaviors that smooth out the connections among them [8].” They represent powerful instruments for establishing long temporal and spatial continuities in a highly fragmented
world while simultaneously helping to amplify the very same disintegration and divides [9]. If “decentralization is one of the greatest, structural forces reshaping patterns of urbanization today,” [10] then infrastructure is its willing agent shaping the material nature of a globalized planet - a tool to organize the landscape of the Anthropocene [11]. On the other hand, they serve as the “material mediators between nature and the city” and often form the constitutive interfaces between industrialized society and the ecosphere [12]. Infrastructures form an instrumental landscape of essential resources, processes, and services that constitute the foundations of communal life in an urbanized society – a landscape that enables connections and opportunities, but also tends to produce specific spheres of influence and inequalities through embedded hierarchies and order. Far from being neutral objectivizations of materialized circulations, they reveal relationships of power between citizens and state, or between various state and non-state entities, and are the result of complex transdisciplinary, multi-scalar negotiation processes. Because so many regions in the world have been thoroughly transformed through the implementation of modernizing infrastructure to become integrated and connected to the regimes and desires of 20th-century transformation, it is essential to understand the complex causalities and interplays between the spheres that they amalgamate. Without this, forthcoming attempts to shift towards a more inclusive, equitable, and ecologically sustainable future will, in many cases, fall short.

3. Methodologies to trace and display infrastructural regimes

As infrastructures form spatially and temporally extended systems of high complexity, they are hard to be perceived in their entirety. Therefore, to compose an understanding of their nature, the construction of descriptive narratives and images is necessary. The following three methodologies approach the exploration of infrastructural regimes through different scales and scopes and have been developed and inspired by a group of colleagues in and outside of the Technical University Berlin concerned with infrastructure-centered research and design education for years [13]. They all depart from studying material underpinnings of vital systems that allow contemporary cities to exist. Concentrating on tracing visible components, interfaces, and spatial arrangements, they fall into the discipline’s inherent objectives of organizing, forming, and negotiating program in space and allow the students to break down complexity through an incremental investigation with the tools available to them (measuring, drawing, modeling, photographing, and interviewing). Furthermore, they seek to inspire opportunities for complementing these disciplinary approaches with research methods adopted from other disciplines.

3.1. Along the Lines - Tracing Infrastructural Routes

Figure 1. KlubKanal by P. Strobel, D. Jeremias, C. Lichtenstein, T. Imsirovic, T. Rawson.
The first approach examined focuses on following, describing, and analyzing the course of a specific directional urban infrastructure and the impacts of its existing physical technostructure on the surrounding in which it is embedded. This methodology is designed to investigate relatively local and visible systems that follow a vector (e.g., train lines, streets, waterways, electric transmission lines, etc.) and combines in-field study with computer-aided mapping. It is suitable for undergraduate and graduate design studios and allows larger and trans-disciplinary teams to incorporate transdisciplinary methods and viewpoints.

3.1.1. Description. As a first step, students embark on a field trip to trace the continuity of a specific urban infrastructure on foot. The target is to follow the course of a train line, a river run, a particular street, an electric transmission cable, etc., either from end to end or, if that is impossible, within a limited frame of time (e.g., a whole day). Next, the group is requested to document their pathway via physical maps or geo-tracking applications (komoot, wikiloc, etc.). They are invited to consciously perceive the composition, breaks, interfaces, changes, and impacts of the material structure and to document and describe interactions and effects on the fluctuating surroundings it is embedded in. Regular patterns and unique situations are marked and documented through photos, videos, sketches, and drawings to be later evaluated. Back at the computer, large-scale mappings of the route are incrementally built up around a phenomenological perception of the experienced trip. Combined with CAD- and GIS-supported graphical representations, this artery will serve as a venture point and backbone, ready to be combined with fragments of accessible data sets on various layers like vegetation, public buildings, open spaces, future construction projects, wildlife habitats, and others that the groups deem relevant. Once this is established, the classification and comparison of sites can be used to select case studies and typologies for deeper investigation with different ethnological, ecological, and sociological tools. This could include (1) more extended site observation on interaction, accessibility, and frequentation between human and other-than-human actors and the technostructure, (2) more profound research into ecological habitats, (3) a deep dive into the historical transformation of a particular site, or (4) interviews with different actors and encountered individuals. A recourse to methods from other disciplines will help breach the tendency to focus on built structures as autonomous technical entities solely.

To incentivize a complex understanding of the impacts of the objects of study on spaces, it is necessary to experience usage, needs, and responses beyond birds-eye perspective or virtual simplifications. Tracing interfaces can help identify the blind spots and potentials in the often-rigid corridors of designed interaction, as dynamic systems tend to re-configure their parts and oscillate back and forth between informal and formalizing actions, inclusion, and exclusion. With this in hand, several transitions into design-oriented tasks, e.g., through proposed conflict statements and design challenges, are possible.

3.1.2. Advantages. Studying the path, access, usage, and design of infrastructures can be grounded in extremely domestic and mundane situations common to anyone. This makes it especially useful when working with international and trans-disciplinary groups from various contexts. Questions of urban metabolism and its infrastructures are translatable and comparable across different personal backgrounds and biographies. Identifying common themes and variations, e.g., the visibility, availability, and access to water in the streetscape of a particular site can be suitable as a very approachable initial task without requiring exuberant initial background information. Furthermore, the travel along a route offers new ways of reading and interpreting space as it forms connections between elements, landscapes, and practices in the territory that may not usually be perceived in direct relation to one another [14].

3.1.3. Limitation. Unless being able to afford long periods and having large teams, it is advisable to exercise restraint in the range and length of the route in order to be able to consciously experience and primarily focus on qualitative study and field research. When working with mobility infrastructure, it
can be helpful to encourage the students to change their mode of travel at least once and experience the same route by e.g., bicycle, car, train, or boat, to change perspective.

3.1.4. Summary. In our experience over the last years, enviro-technical systems in general and especially waterscapes and rivers have proven capable of binding and combining ecological, cultural, industrial, social, and historical facets through the exploration of a continuous but likewise ambiguous spatial entity [15]. Most urban rivers run through various parts of a city - often traversing a rich series of places and ecosystems. Moreover, they tend to be highly designed and regulated landscapes of historical intervention that present significant resources of urban mobility, leisure, production, livelihood, and environmental zones. In this, they form a common ground in various disciplines to understand the long interaction between ecological transformation and anthropocentric needs and will most likely face increasing challenges and restructuring due to their vulnerability to accelerating climate change impacts.

3.2. Following Objects - Tracing Global Circulation

![Figure 2. Tracing Berlins Gas by E. Soylu, K. Koschany, M. Leuschner, Y. Navatskaya](image)

The second teaching approach is created to analyze the spatiality and architecture of global commodity circulation. It often covers different geographical contexts (in the Global South and North) and helps students to understand and illustrate local and trans-local urban impacts as well as long-distance relationships between different sites and scales. Although the methodology centers around the case study of mundane objects, it requires large portions of virtual and computer-based work, desktop research, and reading to accumulate knowledge and is therefore mainly suitable for graduate courses. It is helpful to offer students key theoretical debates on infrastructures of connectivity and urbanization through a series of readings in architecture and urban studies, political economy, human geography, and anthropology.

3.2.1. Description. The exercise begins with selecting a specific material object (e.g., a consumer good, food, energy carrier, construction material, etc.) and asks the students to follow its production and commodification path from beginning to end. Before being put on shelves and used, most goods travel considerable distances, sites, facilities, and intermediaries. This travel and production route is often obscured, disconnected, and alienated from the final product and the consumer. The exercise is intended to establish connections between involved spaces and understand the trans-local complexities and interplay behind urban centers and highly controlled, often monofunctional extraction, production, and distribution landscapes. To guide the exploration of these global regimes, a series of scopes are defined.
in (1) the description of product properties, (2) the description of the production networks, (3) the description of the involved actors, and (4) the description of the physical infrastructural network. This is supplemented by a profound spatial analysis of different sites integral to the supply chain (e.g., extraction sites, production clusters, transportation hubs, etc.).

The systemic analysis of infrastructures is usually not linear and tends to become an iterative process that needs constant re-evaluation and bounces back and forth between the different scales. To formalize complex systems in selected drawings requires discipline and a clear focus. It is recommended to work with simple, predefined graphical layouts that define limits and help students communicate and represent essential findings.

One of the fundamental challenges encountered is to limit the extent of research. In this, the definition of system boundaries divides the object of study from basically everything else. One practical tool to establish an overview of the given systems is the application of an organizational breakdown structure (OBS). These organigrams are created to capture and order the production steps, sites, and temporalities as well as the constituting actors (human or other-than-human) in their relations and interplay. Although partially abstract and incomplete, these drawings have proven extremely useful in understanding the logic and interfaces of the production processes and help to uncover the obscurities, the relevant blind spots, and missing links in the research itself.

Once the production path is understood and mapped out, the visual description of crucial nodes can start the investigation on a smaller scale. Site research aims to display the relation between technical requirements, production processes, and necessary physical structures on the one hand. On the other, it can relate to significant questions of production backgrounds, labor conditions, environmental impacts, and inclusivity/exclusivity to be formulated and further investigated.

3.2.2. Advantages. This method can produce highly comprehensive research that can serve as a critical analysis on which to set up design studios. Furthermore, it offers ample reflection on the backgrounds and impacts of the profession as well as individual consumer choices. It is very well suitable for international groups and has the potential to include personal biography and background in the selection of goods.

3.2.3. Limitations. The method is intense and very dependent on reading, desktop research, and computer-aided drawing. It requires an openness to various other disciplinary discourses, as the mere evaluation of, e.g., morphological figures and concepts is too limited to understand why places turn out to be as they are. The reduction of information will necessitate a strict layout structure that tends to become technical. Many of the gathered information must be reduced to a minimum and will not give, e.g., interviewed actors' voices and tone without considerable extension. This could be altered through the display via web-based formats that allow the integration of video and audio to form more atmospheric narratives.

3.2.4. Summary. Regarding our main question tracing global commodity chains and their spatial impacts is a crucial exercise to make sense of our current world. The operational regimes of the global factory that maintain and advertise western middle-class comforts of affluence are not only extremely labor and resource-intensive and the main drivers of global inequality and environmental degradation, but they are also in jeopardy. In the face of global circulatory distortion and the long-term need to decarbonize, this exercise can make students more aware of the often-invisible backgrounds, spaces, and hidden externalities of objects of everyday use.
3.3. From the past - Tracing Historical Evolutions

Figure 3. East-Berlins Energy Systems by J. Grambow, S. Hossain, Y. Liu, A. Mega, Y. Navatskaya

Infrastructure usually does not grow from nothing but binds back to long genealogies and transformation paths [16]. The last proposed methodology outlines the historical coevolution of urban infrastructure, large technical systems, and the cities they are embedded in. It is designed to help students immerse themselves in infrastructures' palimpsestic nature and embed current configurations into a chain of developments and decisions that originated in their respective historical backgrounds. They develop an understanding of the relationships and interdependencies between the gradual implementation of infrastructural provisioning and its effects on natural features, architectural typologies, and urban growth of a particular city/region. Primarily driven by the study of selected literature from various academic fields (science and technology studies, political ecology, urban governance, etc.), it can be combined with a survey of historical maps, drawings, and complimentary field trips.

3.3.1. Description. The approach requires selecting a particular urban technology and asking the students to portray its evolution from their usually very concise origin to the complex contemporary configurations. The course can be split into smaller groups focused on defined historical periods that vary from e.g., political categorization to the shift in technological regimes or even ecological phases of local transformation. These temporal categories may be subject to change throughout the class. They can develop into more “biographical” epochs that align closer to the defined object of study. Each period represents a time when infrastructural regimes and respective systems find stable configurations.

Students are asked to provide a variety of portrayals: (1) a cartographic description of the physical extent of the given infrastructure; (2) a comprehensive timeline comprising milestones, events, and relevant statistics; (3) a brief written socio-economic and political background; (4) a description of selected artifacts and their interfaces displayed within their functional context and their geographical embeddedness and finally (5) a diagrammatic overview of the configuration of the system including relevant actors and agents. As in the preceding methodology, this exercise requires iterative interaction supported by the interplay of various graphical tools, text-based analysis, visual overviews, and mappings. To give a systemic overview, a shared map of adequate scale may be defined for the entire course to allow students to trace and compare what came and went throughout time. Due to the extent and complexity, this mapping may represent a mainly quantitative picture with large-scale morphology, values, and locations. This, however, will help define and recognize areas of significance to be
investigated in detail through plans and isometric drawings of artifacts with vital importance to the system. This could be centered around the growth of a district, the implementation of new infrastructural typologies, or emerging and adapting building types that were made possible due to technological advancement. In the progression of the course, this will become especially interesting when brought into connections with other scales. This can be established through the description of the interplay between e.g., building typologies and machines, vehicles, tools, and sometimes animals.

Furthermore, as history requires perspective, a thorough reflection of the different socio-economic backgrounds of exemplary individuals is necessary. For example, the availability of electricity in Berlin in the late 19th century varies considerably between the affluent areas of the wealthy southwest and the northeastern boroughs home to the working class. While the former had early access to electric devices, and consumer durables, to the latter, electricity was practically not available beyond the electric lighting installed in the factories to illuminate the extended work hours.

In the last stage, the individual group works can be assembled and overlayered to define paradigms and narratives of transformation and change. This exercise addresses when and how infrastructural regimes find stability and find reasons for change. Through the example of urban infrastructure, the students explore how the social, political, technical, ecological, and ethical choices were made and were put into action through their design.

In the last step, the groups are asked to team up and to describe the relevant transformation between their respective periods. In this, they question the cause and origin, how transformation was managed by whom and which parts of the system were prone to reconfiguration while others remained intact and untouched. This transformation knowledge could be assembled to provide the basis to embark on more speculative future-oriented scenario design and exploration.

3.3.2. Advantages. As the American historian and sociologist James R. Beninger noted, “One tragedy of the human condition is that each of us lives and dies with little hint of even the most profound transformations of our society and our species that play themselves out in some small part through our own existence [17].” The comprehensive study of historical developments in infrastructural design is an excellent laboratory for incrementally understanding the path toward the contemporary conditions. Furthermore, it can help recognize patterns of change and leverage points vital to transformation.

3.3.3. Limitations. Depending on the temporal frame, this methodology is heavily desktop-oriented and heavily reliant on sources. Although students can be equipped with a limited body of literature and archival material to guide them through periods, it may require time, tenacity, and robust preliminary background knowledge of historical context. Language skills and availability of English documents may also limit the success of international groups.

3.3.4. Summary. With regards to the pressing and heavily disruptive changes of the upcoming decades that are posed by decarbonization, climate change adaptation, technological advancement, and demography, studying historical transitions and shifts offer considerable potential, as infrastructural systems will become (partially) obsolete, and will be subject to reinvention, adaptation, and reform. The analysis of vital metabolic systems such as the coevolution of sewage and freshwater systems, the study of electrical provisioning, or the evolution of rail infrastructure offers ample opportunity to learn not only about the past, but to build up robust insights to speculate into future conflicts needs and transformation.

4. Conclusion
Infrastructure, characterized by the following series of crucial features, is no easy topic to address via teaching methodologies. They are:

- Complex: Infrastructural systems often comprise immense behemoths of byzantine complexity. They are multi-scalar and multi-temporal and tend to form long-lasting palimpsests that evolved
through many stages, sites, and places. Tracing system boundaries and taking stock of involved artifacts and actors is vital - but often involves detailed research with potential dead ends.

- Invisible: In many cases literally underlying, infrastructures are largely invisible or opaque, exclusive, and only approachable through highly regulated interfaces. Thus, their study often involves a multifaceted amalgamation of approximations, abstractions, and virtual representations to be perceivable to their extent.

- Relational: Infrastructures are fundamentally relational as they bundle and materialize connections between different actors, artefacts, and organized practices [18]. They, therefore, must be studied in their embeddedness, context, and interaction rather than as singular material entities.

- Expertocratic: Infrastructures tend to be created and operated by experts and specialists. Because their frictionless functionality is often critical, their way of operation is primarily framed as technologically benign realms outside of human interaction. Although many of these experts are generous in giving insights and explaining the complexity and workings of systems, gaining access and formal understanding requires a broad knowledge base.

- Monofunctional: Infrastructures tend to be monofunctional in their usage, which on the one hand has to do with complexity (and partially also with the crude simplification of complexity), but also with the description of their aim. Some of these systems do not show much capacity for engagement: High voltage overhead power lines aim to transport electricity over considerable distances, safely and reliably.

- Resistant and Conservative: Built infrastructure is a conservative field that involves long-lasting and rigid structures tied to substantial sums of money. Nothing changes quickly as planning and implementation require the involvement of numerous and diverse actors and may easily stretch beyond a single person’s professional work life.

- Not a “design” field per se: Although the construction and implementation of infrastructure require an incredible amount of planning, this comes accompanied by the thick and constraining undergarments of norms, rules, regulations, and codes to be implemented and followed.

The goals for a teaching approach centered on urban infrastructure, therefore can be framed in the following:

- To open the “black box [of] infrastructure” [19] through the systemic analysis and display of their functional, historical, geographical, and structural extent, their network of involved objects, actors, agents, and their inherent aims, qualities, chokepoints, and problems that telescope through different scales and temporalities.

- To “flatten” infrastructure to understand and represent their workings & politics by explaining their physical, operational realities, and materiality without losing sight of depth, hierarchy, and layers of the systems manifest in their design, management, maintenance, and accessibility.

- To address infrastructural design and implementation not as a merely “technological” problem, bound to other professions, but as a common ground to achieve trans-disciplinary cooperation between research, planning, design, and the civil spheres of users.

- To elevate infrastructure as a key context to embed architectural and urban design and through which to address existing and future problems, systemic transitions, and shift.

- To confront the concept of uber-human, monofunctional and inadaptable, techno-superstructures through the approach of integrated and hybridized infrastructural planning and design for multi-coded and urban and rural landscapes. [20]

References
[1] For a suitable introduction see Klein, Naomi. 2019. On Fire: The Case for the Green New Deal.
New York: Simon & Schuster.

[2] Amin, Ash, Nigel Thrift, and Katarina Nitsch. 2017. Seeing like a city. Cambridge: Polity.

[3] For a comprehensive overview of the current infrastructural discourse see chapter 2 in: Moss, Timothy. 2020. Remaking Berlin: a History of the City through Infrastructure, 1920-2020. Cambridge, Massachusetts: The MIT Press.

[4] Monstadt, Jochen. (2009). Conceptualizing the Political Ecology of Urban Infrastructures: Insights from Technology and Urban Studies. Environment and Planning A. 41. 1924-1942. 10.1068/a4145. P1924.

[5] Monstadt, Jochen. (2009). P. 1937-38

[6] Carse, Asley. 2017. Keyword Infrastructure: how a humble french engineering term changed the modern world. In: Harvey, Penelope, Casper Bruun Jensen, and Atsurō Morita. 2019. Infrastructures and social complexity: a companion. P. 29

[7] Carse, Asley. 2017. P. 31

[8] Edwards, Paul N.; Steven J. Jackson; Melissa K. Chalmers; Geoffrey C. Bowker; Christine L. Borgman; David Ribes; Matt Burton; and Scout Calvert (2013). Knowledge Infrastructures: Intellectual Frameworks and Research Challenges. Ann Arbor: Deep Blue. http://knowledgeinfrastructures.org/. Accessed 16 December 2015. P. 5

[9] For a concise introduction see: Graham, Stephen, and Simon Marvin. 2001. Splintering urbanism: networked infrastructures, technological mobilities and the urban condition. London: Routledge & Kegan Paul.

[10] Bélanger, Pierre, and Rosalind H Williams. 2016. Landscape As Infrastructure : A Base Primer. Abingdon, Oxon: Routledge. P. 5

[11] Tsing, Anna Lowenhaupt, Jennifer Deger, Alder Keleman Saxena, and Feifei Zhou. 2020. Feral atlas: the more-than-human Anthropocene. http://bibpurl.oclc.org/web/95602.

[12] Kaika M, Swyngedouw E, 2000, Fetishizing the modern city: the phantasmagoria of urban technological networks. International Journal of Urban and Regional Research 24, P. 120

[13] For important and inspirational work within the context of the TU see: Beyer, Elke, Elsner, Lucas-Andrés, Hagemann, Anke, and Misselwitz, Philipp. 2021. Industrial Infrastructure: Translocal Planning for Global Production in Ethiopia and Argentina. PRT.

[14] For further elaboration on the study of routes as paradigms for urbanism see: Bruyn, Joeri de, Maarten van Acker, Filip Buyse, Frédéric Rasier, and Peter Vanden Abeele. 2014. In via veritas: route as a paradigm for urbanism.

[15] One of the most complex and inspirational projects worth mentioning here is the HKW The Anthropocene River Project. https://www.hkw.de/en/programm/projekte/2018/mississippi_an_anthropocene_river/mississippi_an_anthropocene_river_start.php

[16] Star, Susan Leigh. 1999. The Ethnography of Infrastructure. In: AMERICAN BEHAVIORAL. SCIENTIST, Vol. 43 No. 3, November/December 1999 377-391. Sage Publications, Inc. P. 382

[17] Beniger, James Ralph. 1986. The control revolution: technological and economic origins of the information society. P. 1

[18] Star, Susan Leigh. 1999. P. 381

[19] Carse, Asley. 2017. P. 35

[20] Bélanger, Pierre, and Rosalind H Williams. 2016.