



# How to Study Infrastructure: Methodological Remarks in the Context of the Pandemic and its Impact on City Design

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Received 14 September 2020; tentatively accepted 16 December 2020; published 28 August 2023.

## Abstract

The paper is an introduction to the anthropology of infrastructures. We define how infrastructure is understood on the grounds of anthropology and science and technology studies. We show what is the significance of various infrastructures for the functioning of modern and late societies. The text discusses extensively the methodological challenges of studying infrastructures. We not only explain why analyzing infrastructures is difficult but also discuss several methodological tricks we can resort to when trying to uncover infrastructures. We elaborate the methodological guidelines on the margins of two research projects. The first dealt with social aspects of epidemics, and the second with urban clusters of innovative companies.

**Keywords:** anthropology of infrastructure; ethnography of infrastructure; inverse infrastructure; epidemic; innovation district; breaching experiment

## 1. Introduction

The article is an introduction to the anthropology of infrastructures and focuses on the methodological challenges associated with the field research of infrastructures of late modern societies. In the social sciences, by infrastructure we mean the set of factors—social, institutional, material, cultural, etc.—that are

necessary for a given practice or technology to function smoothly. Studying infrastructures can be difficult, as infrastructures most often remain transparent to many actors, including researchers. Often, we become aware of a given infrastructure when it collapses: when it ceases to perform its functions as a result of a breakdown or disaster. This doesn't have to be a natural disaster like an earthquake that destroys physical technical infrastructures like roads or sewers. Corporate bankruptcies, personnel strikes, or the collapse of states can also come into play. Yet another non-natural factor that can trigger infrastructure collapse is an outbreak of emerging infectious disease.

The COVID-19 pandemic led to a series of breakdowns of various infrastructures. The pandemic was an opportunity for us not only to appreciate the importance of infrastructure as a theoretical category but also to rethink strategies for studying various late-modern infrastructures. Studying infrastructures is not easy. Even before the COVID-19 pandemic, infrastructure as an object of study posed quite a methodological challenge. There are two main reasons for this, which are closely related to the characteristics of infrastructures. First, the infrastructures we know were created and evolved over decades in the course of a build-up of local, often non-obvious solutions. As a result, virtually every infrastructure we know contains "stopgaps," obsolete solutions, various "contradictions," etc. Infrastructures are not only heterogeneous (they contain technical, social, and symbolic elements, etc.), but also very eclectic: within a single infrastructure, we are dealing with artifacts, procedures, and institutions developed in very different, distant temporal contexts. Second, crucial to the maintenance of infrastructures is the skilled but often underestimated work of various specialists and professionals. We are talking about the people who design, service, and "patch" infrastructures. The efforts of these people are most often noticed and appreciated only at the moment of crisis when a broken infrastructure needs to be restored to working order. Hence their work is referred to as invisible work (Star & Strauss, 1999; cf. Daniels, 1987). This invisibility means that when we start to study some infrastructure, it is not obvious who should be interviewed first. Meanwhile, it is the doers of invisible work who have the deepest and broadest insight into the infrastructure and its richness. The default method of researching infrastructures (cf. Star, 1999) assumed that we had to reach many places (the spatial dimension, related to the vastness and eclecticism of infrastructures) and cover different periods in our analyses (hence the need to reach out to people operating infrastructures and witnessing infrastructure redevelopment). Thus, mainly intensive, multi-sited, often longitudinal ethnographic studies came into play. However, the pandemic confronted infrastructure researchers with the following paradox. On the one hand, it significantly impeded, and often even prevented, field research. On the other hand, it revealed many elements of infrastructures and the hitherto invisible work of many specialties.

We demonstrate this paradox using as an example our research on innovation spaces, which we refer to as innovation districts (cf. Katz & Wagner, 2014). Here we show how it is possible to try to take advantage of an upcoming research opportunity by reaching for research methods other than ethnography. We argue that the study of infrastructure does not have to be reduced to intensive field research alone.

The plan of the paper is as follows. We begin by discussing the concept of infrastructure and outlining the field of anthropology of infrastructures. In the second part of the text, we discuss the infrastructure elements of modern Western societies that the pandemic crisis reveals, pointing out the importance of pandemics as a kind of breaching experiment. In the third part, we focus on urban infrastructures related to innovation. We pay particular attention to inverse infrastructures, that is, infrastructures created from the bottom up. Referring to our research, we present as an example of inverse urban infrastructure the innovation districts that are currently emerging in Poland. The article closes with our thoughts on the methodology and research tools that anthropologists and infrastructure anthropologists can turn to.

## **2. Anthropology of infrastructures**

Infrastructures are not only things but also people, including the invisible work they do and the institutions they maintain (understood as formal and informal rules of conduct). Infrastructures also include "conceptual" elements, for example, classification systems or conceptual ontologies (see Bowker & Star, 1999a; Star & Ruhleder, 1996). The quotation marks are justified since even concepts most often have some kind of social or material media, without which it would be impossible to use and reproduce them.

Infrastructures are often layered, one on top of the other. Infrastructures also have their historicity. They are created gradually, in the course of successive innovations. This is related to the importance of infrastructures to various social practices, organizations, and institutions. We are not in a position to suspend the operation of infrastructures for a significant overhaul. Infrastructures are also most often vast and complex. Therefore, they are rebuilt gradually, without interrupting their operation. Old elements are combined with new ones. As a result, infrastructures can (and most often do) contain suboptimal solutions, such as entrenched stopgaps. Such contingent elements of a given infrastructure can make it difficult to rebuild a given system in the future.

In the introduction we already mentioned the transparency of infrastructures and invisible work. It should be emphasized that invisible work is an integral part of various infrastructures. The work of service people is just as important as the bundles of cables, concrete elements, valves, and seals. It should also be remembered that invisible work is not just about maintaining infrastructures.

For certain things to work efficiently, you need a variety of resources. Among other things, classification systems, conceptual ontologies, systems of weights and measures, and metrological standards are needed (O'Connell, 1993). In other words, symbolic entities are also an important part of infrastructures (see Bowker & Star, 1999a; Star & Ruhleder, 1996).

To tie the above threads together, let's use the example of the power grid. The fact that we have electricity in our outlets is due not only to transmission networks, and power plants, but also to various policies, metrological standards, and markets. The work of engineers, regulators, controllers, designers, electricians, and even users is also significant. Failures such as the 2021 Texas power crisis (Busby et al., 2021) expose energy infrastructure, showing its heterogeneity, eclecticity, and vastness. The energy distribution and production system is also resistant to change due to various entrenched solutions and surprising interactions of components that emerged at different times and in different contexts.

Democracy, the culture of innovation, and public health—all of these domains have interesting infrastructures that are difficult to study and rebuild. Not surprisingly, infrastructures are of interest to various social scientists (see, for example, Harvey, Bruun & Morita, 2017). The term infrastructure is used by representatives of science and technology studies (Furlong, 2014), anthropologists (Larkin, 2013), and architecture scholars (Easterling, 2014). Social research on infrastructure draws inspiration from studies in the history of science and technology devoted to large technical systems (LTS), in particular the history of electrification of Western societies studied by Thomas Hughes (1983). Among other things, his work inspired the concept of socio-technical transitions (see Geels, 2019). The ethnography of infrastructure developed within STS, which we now want to focus on, also drew from Hughes' research.

The concept of ethnography of infrastructure is mainly associated with the work of Susan L. Star and Geoffrey C. Bowker (Bowker & Star, 1999a, 1999b; Star, 1999; Star & Bowker, 2006). They point to the collective work *The Right Tools for the Job* (Clarke & Fujimura, 1992) as the first work to address the issue of infrastructure. However, this book does not develop the concept of infrastructure and should be considered as an inspiration for Bowker and Star's concept. The essence of the ethnography of infrastructure is an attempt to "unpack" the internal complexity of infrastructures, showing their heterogeneity and eclecticity. Ethnographers of infrastructure are interested in a broad spectrum of systems. Infrastructures here are not just material or social objects, but conceptual ones as well. Ethnography of infrastructure, for example, examines the classification systems that underlie how we know things about the world. In *Sorting Things Out*, Bowker and Star show how classification systems can shape not only our visions of the world but also our social interactions. Ethnography

of infrastructure also explores the basis of aesthetics or the sense of self (Larkin, 2013). It also doesn't shy away from examining the other invisible foundations of the modern world, no matter how we would classify them ontologically.

Instead of writing about the ethnography of infrastructure, we prefer to use the term "anthropology of infrastructures." Writing about anthropology is justified because infrastructures as discussed here are central to understanding humans and their culture. Anthropology does not seek to offer a theory of infrastructures. Rather, it is a research strategy. It provides us with neither a description of what the world is made of (ontology) nor how these components work (mechanisms), it only shows us how to track and describe these things. We do not intentionally use the term "ethnography", because we are convinced that to understand infrastructures we do not have to limit ourselves to field observations combined with a specific, narrative way of reporting the results. Ethnography, in our view, is one of several available approaches to the study of infrastructures. Let's move on to the second term. We deliberately use the plural, wishing to emphasize that there is a plurality of infrastructures. At the same time, certain infrastructures may be more basic than others. Infrastructures can also be interdependent; for example, the expansion of railroads in North America required telegraph lines, with cables stretched along the tracks as they were built.

The anthropology of infrastructures does not offer a ready-made ontology, but it still provides us with some useful distinctions and concepts. We want to highlight two of them.

The first concept that is particularly important to us is inverse infrastructure. Not every infrastructure has to be an LTS. In late-modern societies, there is a growing role for infrastructures created from the bottom up, by users, with as little expense as possible, instead devoid of standardization, unification, and centralization (see Egyedi & Mehos eds., 2012). They are an alternative to the top-down and large-scale infrastructures of the modern era. The difference between LTS and inverse infrastructures can be explained by going back to de Leat and Mol's (2000) concept of liquid technology. They describe the use of a water pump in Zimbabwe, which is supposed to (or rather was supposed to) solve the problem of access to potable water. The standard solutions to this problem are pipelines hauled by corporations or wells drilled with heavy equipment provided by the state. Both solutions are characteristic of modern ways of thinking about technical infrastructure. The Type B water pump is a relatively simple device that the local community can not only operate but also modify and repair based on available materials. The installation itself doesn't require heavy equipment or training either: the borehole is drilled by the community using a hand drill operated by the community. The authors refer to the pump as a fluid technology, as each pump in use is different: the differences between units are the result of constant adaptation of equipment to local conditions and needs. It is not a-modern: the device—though simple—is not the result of unskilled cottage work, its maintenance also requires technical

knowledge and the community has to learn the technology. Nor are Type B water pumps anti-infrastructure: this is merely an alternative to large-scale, top-down, and centralized infrastructure.

Type B water pumps, because of their fluidity, can be described as eclectic, makeshift, and "fractal" (cf. Mol & Law, 1994). In practice, however, LTS also have these characteristics. They too have a history, they too are eclectic, and they too may contain makeshift solutions, although this is generally difficult to discern. Within the LTS, there are usually elements that Hughes called reverse salient (Hughes, 1983). These are elements of a system that slow down or prevent the development or redevelopment of an entire system. Reverse salient can be attempted to equate with the weakest link that fails to keep up with the rest and thus slows down change. Anthropology shows the limitations of such an approach, pointing out situations where a single weak link cannot be identified. The factor that constitutes a reverse salient could be an outdated procedure, but it could be legal regulations or the language in which an entire computer program is written. The problem with change could also be how the various components of the system interact with each other. Another weakness of the weak link metaphor is that something blocking social or technological change may be beyond our reach: changing it may require an intervention that will be too costly or the element in question may be deeply rooted in other infrastructures, in the culture, or the logic of our work.

Since the anthropology of infrastructures is a research strategy it would be appropriate to explain what exactly this strategy consists of. Bowker advocated using the infrastructural inversion technique (Bowker, 1994). He and Star recommend learning "to look closely at technologies and arrangements that, by design or by habit, tend to fade into the woodwork" (Bowker & Star, 1999, p. 34). The directive to look out for the obvious is not particularly revealing to those familiar with the STS literature. Much more helpful is the guidance provided by Star in the paper *The ethnography of infrastructure*. She recommends identifying dominant narratives about how the system works and looking for moments when they are negotiated and perpetuated. These narratives very often play a role in making infrastructure-relevant work invisible. She also encouraged attention to people whose work is downplayed or overlooked, such as secretaries, nurses, and technical workers. It is among these people that hide those who deal with infrastructure daily and have a better insight into it than, the people who designed it and manage it from the top down. Finally, she sensitized us to the various paradoxes of infrastructure, which sometimes reveal themselves as specific, seemingly illogical, or makeshift solutions (Star, 1999, pp. 384-387). The 'expert tricks' that Star formulates are useful, but they will be beneficial for those researchers who are already well-versed in the implementation of ethnographic research. Following Star's advice we must consider the social study of infrastructures an activity with a high entry threshold, like any other

full-scale ethnography. However, there are situations when this threshold is lowered. And this is precisely the situation we faced during the pandemic.

### **3. Pandemic as a natural interruption experiment**

In the era of the fight against COVID-19, various infrastructures have been recognized. They have become visible, regardless of scale or location. Disinfectant dispensers placed at store entrances, personal glove sets, disruption of global production and distribution chains, methodological annotations to incidence statistics, and epidemiological models. The generally invisible work of public health agency personnel and, representatives of various scientific was also revealed. The work of identifying and seeking solutions to the various problems caused by the crisis also became visible: at the level of the globe, countries, cities, neighborhoods or buildings, and even specific offices. Even at the level of individual households, it became apparent how much it takes to work remotely (Gądecki et al., 2017). Some dominant narratives about modernity and the risks it poses have also been disrupted. All of this can be viewed as a natural breaching experiment.

In ethnomethodology, a breaching experiment is a research strategy devised by Harold Garfinkel (cf. Scambler, 2020). He proposed to deliberately disrupt the normal course of social interaction to reveal the mechanisms controlling it and the strategies for re-establishing the social order. Sometimes interruptions occur spontaneously, but there are several procedures used by social actors to maintain interaction and the feeling that its participants live in the same social world. During the pandemic, various social practices, organizations, and institutions were disrupted. The extent of tacit knowledge and tacit assumptions that underlie our normal functioning were revealed. This is well illustrated by the forced shift from stationary work and education to various remote formulas. The fact that working and learning remotely was a challenge was not just a result of that we had to learn a new model. Attempts to transfer the communication model familiar from stationary conditions to the remote sphere often failed. The way we gave each other feedback was not available remotely. It was difficult to build and sustain teams. This led to many “breaches” in the flow of interaction.

We argue here that the breaching experiment can serve not only to reveal ethnomethods (procedures for maintaining the sense that we live in a shared world), but also material, technological, conceptual, and symbolic infrastructures. This applies to invisible work.

In the course of the pandemic, quite a few inconspicuous elements were revealed that guaranteed modern and late-modern societies a relatively high degree of protection against infectious diseases (cf. Afeltowicz & Wroblewski, 2021). To understand to what extent we are free from the burden of contagion,

we need a relevant historical perspective. Infectious disease epidemics did not exist in hunter-gatherer societies. They appeared only with the transition to a sedentary lifestyle when spatial concentrations of humans and domesticated animals emerged. Concentration allowed pathogens to jump between hosts and between species (Scott, 2017). Presumably, it was during that period that the deadly toll of infectious diseases was greatest in human history and prehistory. Later, as early empires developed, pathogens began to play a positive role: the populations of many city-states acquired a collective immunity to pathogens, while invaders were still susceptible to them; the result of this was that invasions and sieges of city-states often ended in outbreaks in camps of invaders. Early urban centers were able to take advantage of “herd” immunity, provided they had adequate sanitary infrastructure. The Roman Empire, at the height of its power, had several sanitary devices and facilities, such as aqueducts, sewers, vomitoria, latrines, and baths. The inhabitants of the empire were well nourished, which also had a positive impact on population immunity. This health infrastructure was no less crucial to the functioning of the Roman Empire than roads and legions. Interestingly, the fall of Rome was also linked to the decay of the health infrastructure in question, as well as to malaria endemics (Harper, 2018).

It is worth noting the clear connection between the development of modern forms of organization of social life and our successes in the fight against infectious diseases. On the one hand, taming microbes is a condition for the rationalization of social life. On the other hand, security against infectious agents itself is, to some extent, the result of the development of modern institutions such as urban planning, bureaucracy, public health, science, and technology. The institution of the modern state was crucial to the control of infectious diseases in the 18th and 19th centuries. It was important to recognize health not as an individual good, but as a public good. Along with the institutionalization of public health came the modernization of sanitary infrastructure, the reorganization of cities to make them less susceptible to cholera epidemics, the reorganization of homes, which was important in the fight against tuberculosis, and finally better diet and personal hygiene. Universal vaccination and antibiotics are important inventions, but they came at a time when European societies were already quite successful in avoiding infectious disease epidemics (cf. Afeltowicz & Wroblewski, 2021).

Infectious diseases were considered a marginal problem in Western European societies until the 1980s, at which time epidemics of new infectious diseases began to be recorded, as well as old ones that were thought to be defeated or residual. As early as the early 1990s, epidemiologists and virologists argued that this “return of infectious diseases” was a consequence of human activity rather than a natural process: global transportation, urbanization, decline in biodiversity due to human activities, and climate change. Some of these factors were



related to infrastructure. The anti-epidemiological infrastructure was deficient: there were staffing shortages among infectious disease physicians, procedures and organizations monitoring emerging infectious threats were inefficient (or absent altogether), and epidemic crisis communication procedures were nonexistent. Yet another problem was related to so-called "developing" countries lacking modern public health infrastructure: new infectious threats could emerge in Asian and African countries and easily spread globally. The lack of standardization of measurements and poor conceptual ontology was also a problem. For example, an attempt to operationalize the term "pandemic" was not made until shortly before the swine flu pandemic (see Abeysinghe, 2013). In the 1990s the anti-epidemiological infrastructure was systematically strengthened and expanded: organizations such as CDC and WHO received support to face emerging infections, emergency procedures were designed, epidemiological scouts began to systematically search the field for new pathogens, research on emerging infectious diseases was resumed, and tools like Global Disease Burden appeared.

The development of those global and national public health infrastructures remained transparent for more than two decades. Only the threat of COVID-19 made it possible for almost everyone to see the enormity of the previously invisible work. Without this research and monitoring infrastructure, we would not have been able to tell that a pandemic was beginning. COVID-19 revealed an even deeper infrastructure: the infrastructures that make modern medical technologies work. The distribution and use of antibiotics, vaccines, and many modern therapies require a social and cultural infrastructure. An obvious example of this would be the mass behavior of citizens in many countries who distanced themselves physically and socially during a pandemic, wore masks, and washed their hands. This was not only a means of personal protection, but also to "flatten" the curve of COVID-19 cases in such a way that medical systems could keep up with treating new cases. There's a good chance that, after time, dominant narratives will develop that attribute the credit for bringing the situation under control to healthcare workers and vaccine developers, with the result that the work of citizens will become invisible. To appreciate its importance and scope, let's look back to the test-and-trace system, well described in the literature, which was successfully used in the first months of the pandemic in South Korea to reduce the number of cases.

The approach was developed and tested during the 2015 MERS outbreak (Yang et al., 2020). It required (1) producing and distributing a large number of tests, (2) identifying and isolating patients, and (3) identifying people with whom they had contact and reaching out to nothing to test them. The approach also involved (4) informing the general population about specific areas to avoid, and (5) encouraging people who came into contact with potential carriers to get tested voluntarily. Information technology played a sizable role, but the system was not just about digitally tracing contacts. The work of citizens and officials

was key. Citizens had to keep track of notifications, be extra careful in selected places, or simply avoid them by modifying their routines. The entire electronic system was able to work because of the consent of citizens for officials and politicians to use their private data. Citizen mobilization requires appropriate political leadership and skillful crisis communication (Budd et al., 2020; Moon, 2020; Oh et al., 2020). In other words, trust played an important role: citizens' trust in the authorities that their data would be used only to fight the epidemic; and officials' and politicians' trust in citizens that they would comply. These expressions of trust are the infrastructure for the test and trace system. The Korean case inspired many analogous initiatives, and contact tracing applications were developed, but often their designers forgot about the citizen components, making them invisible again.

COVID-19 was also an opportunity to rethink urban policies. Above all, in the course of the pandemic, the work of the people who make it possible for cities to function at all has become apparent. Drivers, store workers, delivery and letter carriers, maintenance workers, construction workers, waste pickers, gardeners—these are just some of the professions whose representatives could not afford the comfort of remote work and physical distancing. Many of the people who could be categorized as blue-collar could not stop working: for others to distance themselves socially, they had to work stationary. Here we come across one of the dominant narratives. The dominant narratives of the pandemic focused on how hard it was to work and learn remotely. Meanwhile, huge numbers of people could not isolate themselves even if they wanted to. If we realize that in European and North American countries, social distancing was not an option available to many professional categories, but also to many vulnerable groups due to various forms of socioeconomic inequality, we will be able to make our expectations of anti-epidemiological designs for post-pandemic cities and offices more realistic. Any calls to redesign our cities and our offices to expand the scope of opportunities to provide work remotely should also take into account the needs of the people who will establish infrastructure. For this to happen, their efforts must first be made visible and appreciated.

A separate, specific remote work infrastructure worth mentioning is the household. During the pandemic, when some of us had to work from our homes, many of us have witnessed the extent and importance of the unpaid work at home that must be done to meet the needs of household members, especially the younger ones. It's also generally invisible work. Someone has to take charge of childcare, fetching, and creating conditions so that others can participate in teleconferences and focus on professional tasks. It also requires arranging the physical space in the household accordingly (Gądecki et al., 2017).

There is another grand narrative that has begun to unfold in the trope of COVID-19: a new version of the myth of the countryside as an idyll. The city has become a source of risk for many of us, a technological system that drives microbial traffic. For many, countryside life even before the pandemic appeared

peaceful and healthy. This is a mythology of sorts, as it is in large cities that people have a more comfortable life and better access to the public health system. Residents of large cities are often exposed to more stressors or forms of contamination typical of big-city physical infrastructure. However, those cities that are growing rapidly economically tend to resolve health-related problems more quickly. At the same time, economic prosperity itself makes for a higher quality of life. This is why large cities that prosper continue to grow and therefore attract more residents. In the course of the pandemic, many urban residents, especially those in densely populated cities, have begun to reconsider the advantages of living in the countryside or small towns. The physical infrastructure that had hitherto made their lives easier, including airports, ventilation, subways, and railings, was seen as a source of danger to those lives. This is a fairly typical pattern: throughout European history, evading an epidemic by visiting the countryside has been a popular strategy opted for by the upper class. Alongside the growing appeal of the countryside and suburbs, narratives developed driven by pandemic fears about the need to rebuild the architecture and morphology of cities to prepare for the next epidemic. But is it really necessary to physically rebuild cities or consider fleeing them? Our cities are fundamentally modern, centrally planned structures that are difficult to rebuild. As LTS, they can seem resistant to change, which is a problem during a health crisis. However, the pandemic showed that urban dwellers can compensate for deficits in large physical infrastructure by creating inverse infrastructures.

Sometimes urban inverse infrastructures are material. An informal urbanization (Baumgart & Kreibich, 2011) is an example. If urban policy fails to meet citizens' needs, if they feel excluded or completely abandoned by the authorities, they may start erecting their makeshift physical structures. In a book on Brasilia, Scott (1985) shows how an invisible and disordered city functioned alongside the new and modern capital for the workers erecting the new capital. People may also engage in tactical urbanism, which is not so much about permanently modifying the architecture or morphology of cities as it is about temporary and rather punctuated interventions (Silva, 2016). During the pandemic, many cities to solve various problems and meet new needs relied on such informal and tactical interventions. Sometimes these efforts were grassroots, and sometimes they were supported or initiated by the authorities. Cities—contrary to various fears—often acted very efficiently during a pandemic: residents were able to provide social infrastructure to help selected individuals isolate themselves, providing emotional and logistical support, etc. One should not succumb to the vision of viruses as miasms: they are not and they do not operate on a similar principle. Living in the city, we can use its resources or provide support while maintaining proper hygiene. We don't have to move out beyond city corners, walk around in hazmat suits, put disinfection stations everywhere, or isolate ourselves in our households. We just need to modify our daily practices or organize our grassroots infrastructures.

Inverse infrastructures are not new. Crises like pandemics, armed conflicts, or power grid failures often force us to create them. But this type of infrastructure is also being created outside of crises. Examples include urban energy cooperatives, decentralized waste, water and wastewater management systems, or citizen servicing of Wi-Fi networks. The key point is that inverse infrastructures have coexisted with large-scale infrastructures for a long time, although they differ from them in many ways and most often operate in their shadow. Most of today's LTS, such as railroads, power grids, and road networks, date back to the late 19th or early 20th century. This large-scale infrastructure model has had a major impact not only on our idea of what modernity is but also on our perception and expectations of solutions to various problems: when a need arises, we expect it to be met systemically, centrally, universally, top-down. But not all needs have been met this way. For decades, in various social niches, in the shadow of the LTS, as it were, people met their needs by building inverse infrastructures.

Science and policy are increasingly recognizing and appreciating inverse infrastructures. User- and citizen-created solutions are not in competition with large infrastructures. They not only coexist with LTS but complement them. Very often the developers of inverse infrastructures are those who initiate various technological changes. The synergy between large and inverse infrastructures can be seen in the example of pandemic cities. When traditional urban structures are complemented by bottom-up solutions—remotely operated cultural institutions, home-arranged workplaces, or public pocket parks set up by residents—cities can create life-enhancing social networks that help people isolate themselves and mitigate disasters.

#### **4. Innovation infrastructures before and during the pandemic**

Our team's research interests lie at the intersection of urban planning and epidemiology and concern the aforementioned innovation districts. For several years we have been involved in the study of innovative industries, including the high-tech sector. These sectors are interesting for two reasons. First, innovative industries have a significant local multiplier effect: one job in such a sector generates several in others, which is of great importance for modern economies (Moretti, 2012). Second, companies representing innovative industries tend to form denser geographical clusters than companies representing other branches of the economy and this clustering is considered crucial for creative processes and innovation (see, for example, Motoyama & Watkins, 2014).

When analyzing clusters of innovation actors, we pay attention to the specific infrastructure of innovation. In particular, it is about the various social and cultural elements that are crucial to the technological and market success of these entities. This social infrastructure of innovation is most easily demon-

strated by the history of Silicon Valley. The concentration of people and companies was key in the 1970s and 1980s when Silicon Valley was still a place focused on innovation in electronics. Potentially competing companies shared technological knowledge and risks. This was all made possible by trust. Many modern clusters offer high-tech companies not only the opportunity to share knowledge and risk but also access to a dense labor market, specialized complementary services (legal, marketing, etc.), or investment capital. A small geographic distance not only enables faster knowledge transfer but also allows better coordination of activities within work teams and between different organizations. It is easier to build trust, and generate and develop ideas, within the framework of direct contacts innovators can support themselves with various visualizations, models, mock-ups, etc.

The advent of the pandemic and the need to work remotely disrupted clusters of innovation companies. Due to the degree of technological advancement and work culture, entities in this sector were more receptive to hybrid and remote forms of work. Still, these entities were seriously affected by the lack of access to traditional workspaces.

In the following paragraphs, we focus exclusively on Polish clusters of innovation companies, which we define as innovation districts. Our observations on the role of innovation infrastructure are at (1) the urban level (entire neighborhoods and quarters) and (2) the architectural level (specific buildings and headquarters of innovation companies). We make our observations based on expert interviews conducted during the pandemic with innovation experts (employed by Polish government agencies, local governments, and universities) and designers (in particular, architects involved in the design of office spaces). We also refer to interviews conducted before the pandemic with employees and managers of innovation companies.

In Poland, we are very often faced with a situation in which creative and innovative entities establish themselves in locations that were never designed as innovation hubs. Such innovation districts as Jeżyce (Poznań) or Zabłocie (Kraków) form without top-down coordination: gentrifiers adapted various dilapidated buildings and premises to their needs. Therefore, these innovation districts can be viewed as physical inverse infrastructures: they develop spontaneously and were not planned top-down.

The process of bottom-up formation is contrary to modernist planning. According to modernist planning, a given district should have one dominant function. An example of this modernist approach is the design of Polish science and technology parks, which we studied in parallel with grassroots innovation districts. Those parks are typically large-scale, top-down infrastructure projects. According to their managers, the architecture of the parks does not fulfill its role of stimulating innovation. The original designs did not take into account the specific needs of high-tech companies. Innovation districts, unlike science and

technology parks, are very diverse and have many functions, and these functions are shaped in response to the current needs of innovation companies and their employees. They are not only workplaces. By its very definition, an innovation district is a space where one lives, works, relaxes, and meets most household needs. This approach to mixing functions is not standard. Such multifunctional planning requires architects and urban planners to change their way of thinking about urbanity. And this is by no means easy.

If one has an innovation center—a zone of office buildings outside the city—then often this zone lacks basic services needed by people who spend a great deal of their time there, hence the attempts to bring those parks closer to the city. There is another approach: to build a large building, where inside we will have all the functions needed for life. This model can be viewed as an attempt to captivate employees. You can also look at it as a convenience because employees can take care of all their needs in one place. In my opinion, this is certainly a right theory, but can it be realized? (A1\_ex).

Innovation districts are not only clusters of headquarters of IT companies, research and design agencies, or software houses. Other services relevant to developing innovation are also emerging within them: coworking spaces, maker spaces, business incubators, specialty stores, bookstores and restaurants, and public transportation networks. Not all of those facilities are not directly related to innovation activities, however, all of them form a base of innovative industries. Interviews conducted with employees of the industries of interest proved that even before the pandemic, these places and those services were an important part of their mental spatial maps. Access to public transportation, including bicycle infrastructure, made it possible to arrive at work. The physical infrastructure in the form of cafes, and restaurants allowed teams and clients to meet outside the company's spaces, but also to establish collaboration between employees of different companies. Such places also gave rise to ideas for creating entirely new entities. A variety of studios and workshops make it possible to prototype new products.

An important finding for us was that in Poland there are many constraints on the bottom-up formation of innovation districts. This is related to the level of horizontal mobility in Poland, the real estate market dominated by residential developers, and the existing urban policies. Very often there was a shortage of premises to which a company could move. The premises that were available most often had to be adapted (for example, offices are created by combining adjacent residential premises by demolishing walls). Besides, there was also often a shortage of premises for entities that create facilities for innovative companies.

In situations where the existing urban physical infrastructure effectively hinders spatial concentration, many actors attempt to compensate for this by temporally bringing people together. Managers of science and technology parks

often acknowledge that the architecture of the buildings they manage is incompatible with the needs of tenants, and try to compensate for this tactically:

I assume that everyone wanted to work in a place where there are swings, where everything is behind glass and on the other hand is so a bit industrial, but on the other hand is cozy. Our space looks like a mental hospital: a long white corridor from which you enter offices or meeting rooms. And there just pouring in stimuli, different things, it does the job though and it attracts you, it's an effect of that. (E1\_ex)

In the case of innovation districts animators of start-up community try to make up for hindered concentration by deliberately organizing a series of events, such as conferences, workshops, and hackathons. This is made possible by physical "event infrastructure": these are spaces and entities that are elements of the organization of a variety of large events for specific innovation industries. These events can compensate for the lack of fully developed innovation districts. Interestingly, the locations of these events are more concentrated than the locations of corporate headquarters themselves.

Let's go down to the office level. When it comes to stationary work, there is an infrastructure in the form of specific office architecture solutions. It is important to recognize and appreciate the contribution made here by office and furniture designers, architects, office managers, and various types of networking specialists. The role of the latter two categories is particularly important from the perspective of the functioning of innovative industries in Polish conditions. This is because Poland's urban infrastructure has many features that make it difficult for this type of business to function daily.

A long-standing trend in office design has been that workplaces should resemble informal home spaces. When observing the offices of creative and innovative companies, attention is drawn to the infrastructure associated with leisure and "domestication" functions. Regardless of the degree of its use, resulting from the organization's culture, the office space was supposed to be one more attractor—to attract new employees, being an advantage for the company. Such spaces—as one expert put it—are typically "Instagram spaces." Play spaces are associated with the headquarters of innovative companies, but in practice, it is difficult to attribute to them functions related to solving design problems and creating new products. They certainly play a role in creating a company's image. Let's give the floor to the person designing such spaces.

More and more companies are pumping cash into interiors, and these are often things that aren't super necessary for work. Sometimes these are interior touches that are 80% for marketing: so that the company can brag that they have a slide for employees, or whatever else looks super. You can slide down there from 2-3 times, but an employee is not going to go down from the 3rd floor to the first floor every day to leave the building [...]. The fun room can be used so that when an employee has nothing to do or is off work, he

can indulge in playing PlayStation or some foosball there, or simply organize a meeting in such a room and on comfortable sofas or recliners to talk about work-related problems. So it varies, but we try at the very beginning to find out how the company works and whether it makes sense at all, because some companies would like to have a fun room of some super, and employees can't use it at all during the day, because the boss will look at them crossly, that they are playing on PlayStation and not sitting in front of the computer. The culture of the company has to determine that. Sometimes we do such things because we simply have such requirements specified by the investor, but then it works differently (A1\_ex).

Even before the pandemic, many employees of innovative companies approached this type of office equipment, and the atmosphere of "playfulness" and "homeliness" communicated through it with great caution. One reason is that these types of solutions can seriously disrupt the work-life balance. With the COVID-19 pandemic forcing many people to work remotely, a significant number of people have come to appreciate office spaces for the peace and privacy they offer which allows them to focus on their work.

The distancing forced by the pandemic has caused many companies to fundamentally rethink their work model, not only in terms of the crisis but also in terms of what comes after it. As various studies have shown (see Afeltowicz 2022), not all creative tasks require face-to-face interactions. Even some team tasks require a period in which team members and members will work in isolation. Still, working in a shared physical space proves essential, if only during the formation of work teams. As one of our respondents notes:

Starting with our work, in our particular company somehow I can't imagine too much that we can work remotely. It happens, but there can't be a main emphasis on the fact that we now divide the work and partly work for ourselves remotely and partly in-house, because our work is so interdisciplinary, that's one thing, and two, that it simply requires constant rethinking and constant analyzing, and coming up with new ideas, and checking so many things, that without a person next to you, with whom you design, and without being able to exchange free thoughts, somehow I can't imagine that architecture can continue to function (A\_1\_ex).

Thanks to information and communication technologies, we can transmit a lot of information over long distances, but we are not always able to transfer knowledge in this way. It is difficult to solve technical problems cooperatively at a distance. Then there is the issue of building trust, motivating employees, and possibly supervising them. Any experimentation with the transition to permanent remote work would require not only the fine-tuning of many technological solutions but most often also a deeper change in organizational culture. Therefore, planners during the pandemic assumed that companies would try to encourage employees to return to their offices.



[After the pandemic] the office space will be shaped differently. A lot of emphasis is being put on making this space even more attractive, to encourage that employee to come back to the company, though. I don't know what the research looks like, but it seems to me that when it comes to people's productivity, well, it's the case in many industries that you have to be with each other and work in the company for it to make sense and produce good results because we know how it is at home (A 1\_ex).

The physical and social distance of the pandemic period has made us more aware of the meaning of what office space understood as a meeting space is. The pandemic—as a natural breaching experiment—has reframed the experience of office work and creative processes. Our research, but also the daily pandemic experience, shows that it is these informal interactions that are key to building atmosphere and creativity in the workplace. It's not about fun rooms and office gadgets, but what is defined by the category of buzz (see Bathelt et al. 2004). It is office buzz that makes employees come to work motivated. It's the buzz that causes employees to unknowingly acquire originally irrelevant information that becomes relevant when solving specific problems. The buzz is the medium for exchanging new ideas. Buzz consists not only of what people feel and hear but also of what they see and what they can touch. Documents and visuals lying on a neighboring desk can inspire us. We may come across a prototype in a storeroom, elements of which we will use in our design (see Hargadon & Sutton, 1997). On top of that, we can get quick feedback from coworkers or even perform hallway usability tests. All these opportunities offered by office work are obvious, but we only began to appreciate them during the pandemic. It's also important that buzz doesn't appear on its own. Specific people research and design office spaces so that the buzz stimulates and inspires, rather than distracts from work. But many of the solutions conducive to the emergence of office buzz are nothing more than local inventions of employees themselves, which have been copied and transferred to other places, with more or less success.

In conclusion, both at the level of innovation districts and the offices of innovation companies, one can see how important are inverse infrastructures. Thanks to their characteristics, they allow better organization of processes and people, including in pandemic conditions. When analyzing inverse infrastructures, we should note that the initiators of their creation are the users themselves and companies that understand the needs of users better than management institutions, including those in the business sector. These solutions are motivated by the needs of the user, not the owners or municipal authorities.

## 5. Conclusions: a few more tricks of the trade

When studying infrastructures during the pandemic we are faced with a kind of paradox: on the one hand, we cannot conduct field research and on the other hand, the pandemic exposes elements of infrastructures and makes us appreciate (at least for a while) the invisible work. The experience of the pandemic and the methodological observations we have made on the margins of our research on innovation districts allow us to develop the list of methodological guidelines proposed by Star. Let us start, however, by recapitulating her ideas and showing how some of her tips assisted us in our research.

### *Pay attention to the paradoxes!*

The biggest paradox for us as anthropologists and sociologists was that high-tech companies with advanced remote working capabilities still value geographic proximity. It also seemed paradoxical to us that there is a co-location of companies that are in direct competition with each other. This is where our interest in clusters of innovation came from in the first place. It quickly became clear that there are several reasons, well described in economic geography, why geographic proximity is important to the process of technological invention and innovation.

### *Watch out for dominant narratives!*

The important narratives for us were (a) the concept of the death of distance, (b) the vision of remote work during the pandemic as something universal, and (c) the city as a source of epidemiological risks. As economic geography and mobility studies show, distance has not died at all, but has begun to play different roles for us than in the early stages of modernization. Despite the revolution in information and communication technology, direct contact is still valued. An analysis of people who could not distance and isolate themselves in the course of a pandemic tells us a lot about the foundations of our modern world and the state of our society. Cities are not necessarily environments where we are particularly vulnerable to infection due to urban architecture, morphology, or spatial concentration of people. The risk of disease has more to do with how we use urban infrastructure (tactical interventions) and how we manage it (urban policies).

### *Look for people doing trivial work!*

Often trivial work turns out to be infrastructural work. During the pandemic, one could see how blue collars maintain the system. As for clusters of innovation, a closer look reveals the work of people who do not come up with ideas

themselves and implement them, but organize and facilitate the work of others, creating the necessary facilities for them. These could be managers of science and technology parks circumventing the inadequacies of material infrastructure, or organizers of remote hackathons where people who design and implement digital solutions can come together.

We suggest supplementing the above guidance with the following methodological tips.

*Pay attention to temporality!*

When we write about temporality, we don't just mean that infrastructure changes over time (Simonsen et al., 2020). What we mean is that strange as it may sound, elements of infrastructure can be temporary and ephemeral. An important consideration when it comes to the operation of high-tech industries in Poland is that Polish companies have a problem with geographic concentration. This infrastructural deficit is compensated for by the multitude of events where those involved in the management, design, and implementation of various digital products have the opportunity to meet and network. The locations of these events are much more spatially concentrated than corporate headquarters. That is, when wanting to explore infrastructures, we not only need to be in the right place but also at the right time. Also evident in our pandemic experience is the role of temporality. After all, many of the tactical interventions used to cope with the challenges of the "new normal" were temporary.

*Remember about the localities!*

The concept of infrastructure should be used with caution: there is a trap here in that infrastructure seems to us to be something beyond the local. This is not surprising, since we associate infrastructure mainly with the LTS of the modern era. Even social studies of infrastructures very often present them as delocalized phenomena. In practice, each infrastructure is created and constituted by specific individuals, embedded in specific cultures, coping with resources and constraints specific to certain contexts and places. And often these initial solutions are contingent (cf. Carse, 2016). Only later does the infrastructure grow, and the various socio-technical systems are combined and made coherent. Taking into account locality makes it easier for us to understand some of the paradoxes of infrastructures. But locality also matters in the context of infrastructure development. Nowadays LTS are being combined with local, grass-roots solutions that originate from various niches (see Lopolito et al., 2011), and these by their nature are very local and contextual.

The process of re-localizing elements of infrastructure also seems important. During the pandemic, we witnessed attempts to transfer between contexts various local solutions such as test and trace approach. Attempts of this type allow us to scientifically unpack what is usually hidden under the term "broader socio-cultural context." Often it turns out that a given solution cannot be implemented elsewhere due to infrastructural deficiencies. By tracking unsuccessful attempts to transplant solutions, we are better able to determine what exactly was missing.

*Follow grassroots innovation!*

While researching infrastructures we can be on the lookout for a variety of innovations emerging from local niches. These innovations may represent challenges thrown at large-scale systems, but they may also represent attempts to adapt existing infrastructures to the needs of residents, citizens, or users. Analyzing such attempts at bottom-up change will not only tell us quite a bit about the communities that rely on particular infrastructure but also about the infrastructure itself: its deficits, its limitations, who the infrastructure empowers, and who it excludes. In short, by following attempts at grassroots change we will more easily understand the political dimension of infrastructures.

*Look for the infrastructural gurus!*

Not every invisible job has the same importance for the functioning of the infrastructure. Often the work in question is simply part of the infrastructure. Sometimes, however, there is invisible work that goes beyond maintaining and repairing infrastructures. These are situations where managers and technical staff actively monitor the infrastructure for various problems and attempt to solve or circumvent them in such a way as to ensure that the problem does not recur in the future. Such activity presupposes not only knowledge of various aspects of the infrastructure but also a specific cognitive mindset and practical competence. It requires not so much fixing a specific defect but aligning different aspects of the infrastructure: social, technical, symbolic, etc. (cf. *window aligning*; Fujimura, 1987). We can refer to such a set of competencies and knowledge as infrastructural entrepreneurship. STS has recognized the role of various handymen and technological gurus, who not only restore efficient work in laboratories but even enable the implementation of experimental research and actively participate in solving scientific problems (see, for example, Shapin 1989, 1995). Similar handymen and gurus take an active part in shaping infrastructures, including large ones. If we follow attempts at changing an LTS from the inside out, we have a good chance of hitting upon this infrastructural guru.

*Use a participatory approach!*

The original anthropological study of infrastructures required a competent, professionally trained person to carry out intensive field observations. Whether we were dealing with single-site, multi-sited (Marcus, 1995), or strategic (Pollock & Williams, 2010, p. 536) ethnography, trained researchers were still necessary. They were the ones tasked with spotting the paradoxes of infrastructures, reaching out to the various people operating and designing infrastructures, and finally, they were the ones who analyzed narratives and the politicization of infrastructures. They were the ones who drew scientific conclusions and formulated design proposals. The contemporary development of inverse infrastructures shows that more and more nonprofessional researchers and designers are noticing and understanding infrastructures in depth. At the same time, crises such as pandemics, but also climate change, are causing breaches as a result of which a wide range of citizens are beginning to notice and appreciate the infrastructures that determine their lives. By exploring infrastructures, we can capitalize on this potential by incorporating a variety of participatory techniques into our toolboxes (cf. Karasti et al., 2010). Since the pandemic has sensitized all of us (if only briefly), we can gather this knowledge not only through a variety of diaries but also through a variety of survey tools. The sensitivity and insight that citizens gain make it possible for us to collectively explore the politics and poetics of infrastructures. In particular, various workshop procedures and selected tools from the field of participatory action research, such as futures and scenario workshops, seem to be helpful here.

### **Funding**

The paper results from the “Innovation Districts? Creative Industries and Urban Changes” project financed by the National Science Centre, Sonata BIS 6, number 2016/22/E/HS6/00144. The publication was created as part of the implementation of the Minister of Science and Higher Education program under the name of the National Program for the Development of Humanities in 2016-2018.

### **Acknowledgments**

The authors thank the reviewers, for their critical reading of subsequent versions of the text and helpful suggestions. After the first round of reviews, the text was rewritten with the intention of better achieving its intended methodological goals. Revisions included the inclusion of extensive new literature and a complete revision of the text's structure. The most important change, however, concerned the argument itself: instead of exposing the deficits of ethnographic methods in infrastructure research, we decided to expand the list of research advice given by Susan L. Star. We formulated this advice largely based

on the empirical material and research experience we gained after submitting the original version of the manuscript.

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