Records of Disaster:

Media Infrastructures and Climate Change

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Infrastructures in Time and Anthropogenic Climate Change

Gabriele Schabacher

Infrastructures are material traces of climate change in a threefold sense. They are major contributors to climate change, they represent forms of coping with and combating climate change (more sustainable energy or transport systems), and they economically affirm and exploit it. To understand these interrelationships, this paper takes a closer look at the temporal constitution of infrastructures. It discusses the relationship between infrastructure and collapse as a form of their fundamental processuality, and distinguishes four ways in which infrastructures can be said to be "in time": their everyday fragility, their overlapping lifetimes, their status as remnants and ruins, and their relevance in the horizon of the Anthropocene. The example of Arctic shipping is discussed to show how climate change and the resulting navigability of the Arctic region are fundamentally altering the global geopolitical network of supply and exchange relationships.

Keywords: Infrastructure, Climate Change, Anthropocene, Temporality, Disruption, Ruin, Lifetimes, Care, Arctic Shipping

Infrastructures play an important role with regard to anthropogenic climate change.[1] Heuristically, at least three respects can be distinguished in which they do so. For infrastructures can be considered equally as causes, handlings, and profiteers of climate change. Insofar as the establishment of infrastructures has been linked to industrialization and urbanization since the beginning of the nineteenth century, for whose success the use of fossil energies was primarily responsible, they must first be seen as the cause of climate crisis. Second, they provide opportunities for dealing with climate change, whether in the form of scientific methods or through the development of new climate-friendly technologies. And third, infrastructures can also be seen as the winners of climate change, specifically calculating with the consequences of it. To better understand the different relations between infrastructures and anthropogenic climate change, this paper proposes to focus on the temporal dimension of infrastructures. For not only is anthropogenic climate change a temporal phenomenon, this applies equally to the infrastructures that interact with it.

Low water levels of the Rhine and other rivers, uncontrollable forest fires in Spain and Portugal, the faster melting of alpine glaciers and resulting landslides (for example in the Marmolata massif), these are only some of the "records of disasters", as this volume calls them, that characterized the European summer of 2022. But we can also look back to 2021 and think, for instance, of the flooding in the Ahr valley in Rhineland-Palatinate, the heat waves in North America, the hurricane season or the Corona pandemic, for which the crossing of the animal-human boundary (zoonosis) as a result of the destruction of natural habitats as well as excessive animal use is being discussed as a possible cause – in all these cases we receive pictures and videos, reports from eyewitnesses, scientific data and problem analyses of the ecological crisis events in question. Here, infrastructures are involved in the sense of processing telecommunication (transmission of data) or storage media providing such records. These records, in turn, are assessed scientifically, for example, in the context of attribution research (Otto 2020), which statistically evaluates the relative contributions of various causal factors to climate change, paying particular attention to the relationship between anthropogenic climate change and extreme weather events. But not only the images and reports are records of disaster; in a certain sense, the destroyed bridges, flooded roads, burned houses themselves must be considered to be such records, namely as material traces of climate change.

1 The research literature on anthropogenic climate change is extraordinarily extensive. In particular, the concept of the Anthropocene has been widely discussed in this context. Initially informed by the natural sciences (Crutzen 2002; Will et al. 2011), it then became central to the humanities as well (Chakrabarty 2009; Horn and Bergthaller 2019). For critiques of the term, especially in light of its implicit assumptions and exclusions, see, for example, Harraway 2015; Moore 2017; Yusoff 2018. On the relationship of infrastructure and environment specifically, see Hetherington 2019. For further literature, see the references in section 2.

In this context, the concept of "material witness" as developed by Susan Schuppli is relevant. This term, in its operative sense, as opposed to its legal usage (a person "*pertinent*" to the outcome of a lawsuit), emphasizes the testimonial capacity of nonhuman actors, quite literally in the sense of "material *as* witness" (2020, 10), which provides traces *of* and *to* a history of political violence. Materials, however, are not witnesses per se. They only become such "when the complex histories interwoven in the objects are unfolded [...] and put up for public consideration and discussion" (2020, 18), lending relevance to the conditions and procedures that turn such eventful materials into testimonies (2020, 20). Such a perspective on the testimonial quality of matter, however, is not self-evident. Only an interest in the mediality of personal witnesses and the transmission of knowledge carried out by them brings to the fore the ambivalence between personalization (the authentic witness) and depersonalization (the witness as a 'neutral' recording device) associated with this process (Krämer 2015, 152). It is then above all the "*forensic turn*" (Däumer, Kalisky and Schlie 2017, 14), exemplified, along with Schuppli, by the work of the research collective Forensic Architecture in particular, which focuses on the potential of objects and findings to bear witness to events and experiences, establishing a close connection between media and forensics by means of the concept of the trace (Rothöhler 2021).

What do we gain by applying the concept of material witnessing to the connection between infrastructures and climate change? Seeing infrastructures as material witnesses of anthropogenic climate change, that is, to understand them themselves as records (inscriptions) of ecological disaster, thus means considering them not only as transmission networks that make climate change traceable. Rather, the infrastructures of energy, transport, and production represent essential causal factors for the emergence of anthropogenic climate change. At the same time, they are substantially involved in reshaping existing conditions, with two diametrically opposed tendencies: for the "good" (establishing sustainable forms of transport, production, energy supply, etc.) and for the "bad" (economic exploitation of the very opportunities created by anthropogenic climate change, which further accelerates it). From this perspective, infrastructures can be understood as active mediators of climate change. We will see in the following how and at which levels this understanding is related to the specific temporality and materiality of infrastructures.

The argument will unfold in four steps. At first, I will discuss the connection between infrastructures (especially "critical

infrastructures") and breakdown and address its epistemological relevance. In the next section, I will outline four different ways in which one can speak of "infrastructures in time," namely, their everyday fragility, their aging (not their obsolescence), their status as leftovers after they are no longer in use, and finally their geo-temporal dimension with reference to the Anthropocene. The temporality of infrastructures in the horizon of the Anthropocene is unfolded in more detail in the third section with reference to the recent example of Arctic shipping. I will show how economic actors are building a new shipping infrastructure in deliberate preparation for the fact that anthropogenic climate change will have intensified to the point that the Northwest and Northeast Passages will be navigable without ice by 2040. A brief conclusion will summarize the main arguments and provide an outlook.

Infrastructures and Breakdown

What is the significance of disasters and accidents for infrastructures? If we take a look at the history of railroad development in the nineteenth century, for example, we are first struck by the immense frequency of devastating accidents (derailments, head-on collisions, bridge collapses, etc.), especially in the first decades (Aldrich 2006). Only towards the end of the nineteenth century does the severity and frequency of accidents decrease. In between lies what I have elsewhere called "infrastructural learning" (Schabacher 2022, 175; 2019, 194), which underscores the epistemic importance of accidents and disasters for understanding technical processes and events (Kassung 2009). This is because such disruptions allow infrastructures to emerge from their black-box state; in a sense, they disintegrate again into individual actors (*mediators*) that are coordinated in the infrastructural state (*intermediaries*) (Latour 1996, 176f.). Thus, functional relationships of infrastructures can be analyzed and subsequently changed; for example, derailments draw attention to how track beds must be fixed to withstand various weather conditions, or how railroad crossings must be secured to prevent people from being run over. The state of being deblackboxed is also conceptualized in Science and Technology Studies as the visibility of infrastructures; Susan Leigh Star and Karen Ruhleder, for example, speak of infrastructures becoming "visible upon breakdown" (Star amd Ruhleder 1996, 113). What is meant is the fact that they come to the forefront of attention in the face of disruption (not that the actors and agents mentioned are not actually visible), that is, they become explicit, "bulky," and uncomfortable in their materiality and non-functioning. I use the term disruption here in a broad sense in terms of media theory (Schüttpelz 2002; Neubert 2012), referring to disruptive phenomena in the broadest

sense, ranging from technical defects to system accidents (Perrow 1984) to natural disasters and terrorist attacks, and including the cultural imaginaries and anxieties that accompany them (Horn 2016; Koch, Nanz, and Pause 2018).

As a present example, the war in Ukraine makes abundantly clear that infrastructures first and foremost have the task of providing what is known as "services of general interest" (German: *Daseinsvorsorge*): they supply us with what we need to live – energy, water, food, but also communications, cultural and transport facilities.[2] And because this function is essential, they are referred to as critical infrastructures (Rinaldi, Peerenboom and Kelly 2001; Engels 2018). If they fail, this has serious consequences: Europe no longer receives gas; the Middle East no longer receives wheat. The Ukraine war has put the spotlight on the otherwise inconspicuous axes of global supply and exchange relationships. Pipelines, ports, power plants, and railroads are becoming visible in their regulating function of guaranteeing or preventing access to certain resources.[3] Infrastructures are thus always threatened, they represent vulnerable points of communities and states and are thus possible targets of attacks.

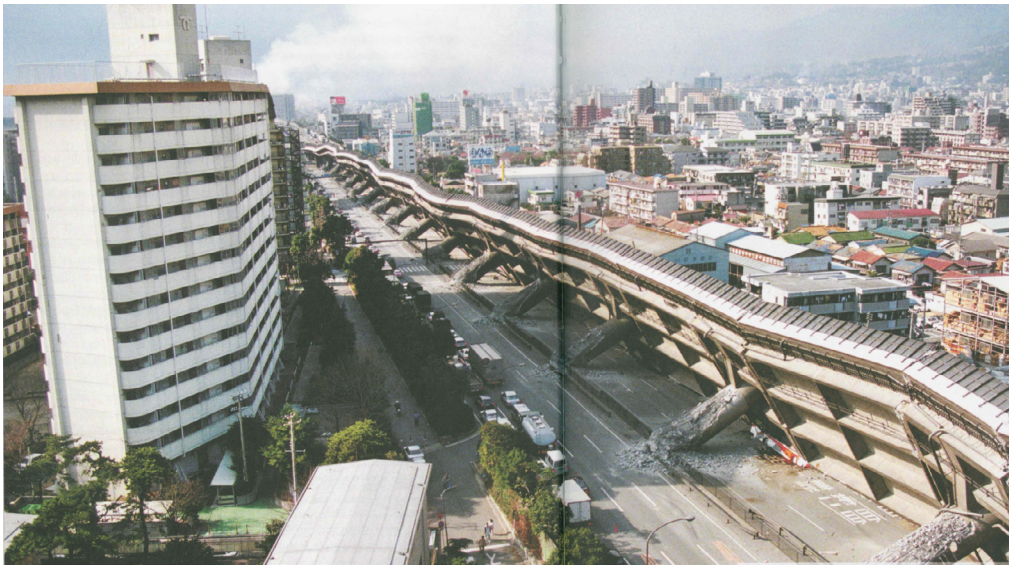
2 This concept, coined in 1938 by the constitutional lawyer Ernst Forsthoff, assumes that man exchanges the individual securing of livelihood for a spatial expansion of his living relations. In this way, however, he becomes fundamentally dependent on what the state can provide (Forsthoff 1938).

3 For example, the well-developed Ukrainian railroad system was targeted by Russian attacks because it is logistically crucial for transporting weapons, aid, and supplies (Latschan 2022).

But infrastructures are not only fragile when attacked in times of war. Already in the early 2000s, Paul Virilio curated an exhibition explicitly dedicated to questions of the accident. Titled *Ce qui arrive,* it was dedicated to the exposition (read: making visible) of accidents to analyze what threats the modern world faces (2002). Virilio was thinking of the deforestation in the Amazon region, meteorite impacts, the effects of radioactivity (atomic bomb/atomic power), chemical accidents, oil tanker accidents, airplane crashes, 9/11, wars, and natural disasters. Frequently, the illustrations center around the disastrous impact on urban infrastructures. For example, we see roads and houses destroyed by earthquakes (→ 1), flooded motorways, electric poles bent by ice loads (2002, 10–20, 34, 35).

One of the central insights of Virilio's accident theory is that every technology generates its own accident (2007, 10). While Virilio focuses on the fortunes of the respective vehicles (the shipwreck, the derailment, the pileup), I want to emphasize the infrastructural dimension of such accidents and disruptions. For when the Ever Given is stranded in the Suez Canal for six days (→ 2), this is essentially not a singular local occurrence. Rather it is an event of global scope that makes logistical trade linkages palpable and shows that the insight Latour formulated for the railroad network applies even more in this case: a global network is local at each of its points (Latour 1993, 171).

1 Collapsed highway after an earthquake, Japan 1995 (Source: Virilio 2002, 10–11)

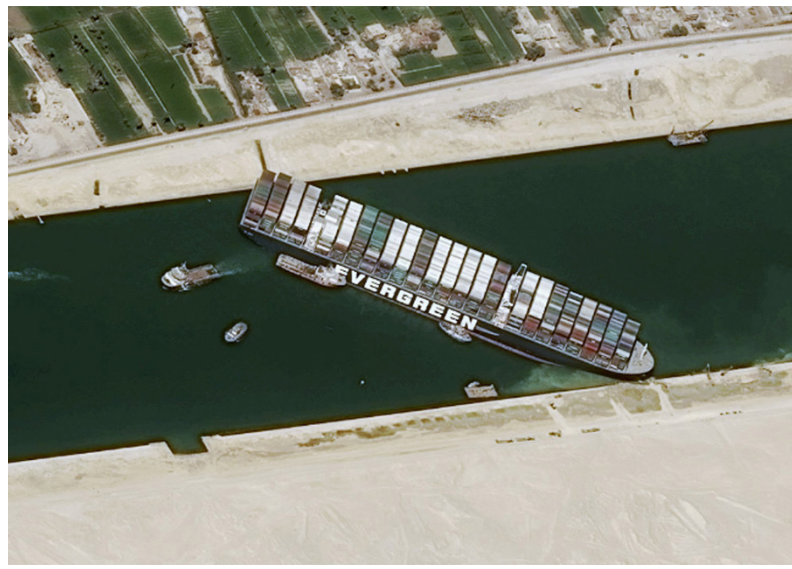


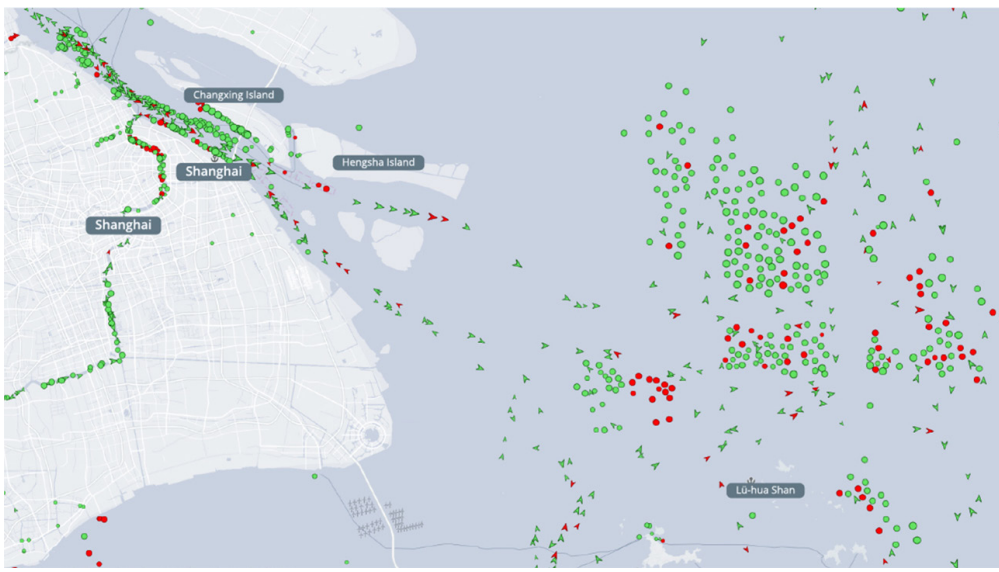
If the Ever Given is stuck or the port of Shanghai cannot handle goods (→3), as was the case during the two-month Covid lockdown in spring 2022, this immediately has noticeable effects everywhere. Accidents and disasters thus make us aware of infrastructures insofar as they show what we assume (and expect) as their normal functioning.

But focusing on the catastrophic states of infrastructures is not without problems. For it implicitly assumes that a calm, balanced, and ultimately accident-free normal state exists on the flip side of catastrophic situations (Graham/Thrift 2007, 9f.). However, closer examination of concrete working environments of large-scale technical systems (Potthast 2008; Wynne 1988), but also intercultural studies (Larkin 2008) have unmasked this idea of a supposedly "calm" normal operation as a specifically Western illusion that unquestioningly presupposes certain properties of technology. Now this does not at all mean that a more unsettled normal operation can only be found in the Global South, but rather that the Western notion of technical normal operation has long prevented us from even taking a closer look at the supposedly stable state of technology and infrastructures. In addition, catastrophes often do not take the form of major events alone. Instead – and this is particularly relevant with regard to climate change – they consist of a large number of small changes, none of which is serious in itself, but which build up in such a way that at a *tipping point* (Gladwell 2000; Horn 2016, 148–56) they catalytically set in motion an irreversible catastrophic development.

2 **Ever given stuck in the Suez Canal, March 23, 2021 (Source: Detail from a satellite image by Pleiades, Airbus, © CNES 2021, Distribution Airbus DS. Accessed August 23, 2022. https://intelligence-airbusds.com/en/5751-image-gallery-details?img=65560#.YwTAQE9CTmg)**

3 **Traffic jam off Shanghai, April 28, 2022. Symbols: cargo ships (green), tankers (red), anchored/ moored (circles), on the move (triangles) (Source: Chart. "Shanghai Ship Jam Spells Out Supply Chain Trouble". *Statista.com*. April 28, 2022. Accessed August 23, 2022. https://statista.com/chart/27343/container-ship-backlog-off-shanghai-port/)**





Beyond catastrophes, however, the "normal" functioning of infrastructures is already more susceptible to disruption than is generally assumed. It therefore makes sense, as I will elaborate below, to assume a fundamentally precarious relationship between fragility and stability for infrastructures, that is, to reformulate their materiality and organization as a temporal issue.

Temporal Regimes of Infrastructures

Infrastructures are indeed "in time" in a specific way. Heuristically, (at least) four different temporal regimes can be distinguished: first, the already mentioned everyday fragility of infrastructures; second, the phenomenon of aging infrastructures, where a kind of overlapping of temporal layers occurs; third, the temporal constitution of infrastructures when they are no longer in use and we encounter them as remnants; and fourth, finally, their temporality in geological terms related to the Anthropocene debate.

Processuality of Infrastructures

To understand the precarious relationship between fragility and stability more precisely, it is important to focus on two opposing processes. For on the one hand, infrastructures are determined by processes whose goal is to stabilize fragile states. On the other hand, however, supposedly stable or, better, stabilized states are always destabilized again. I refer to these two processes as "infrastructure work," as the work *on* and *of* infrastructures (Schabacher 2022, 20–1). What is important here is the following paradox. The processes of stabilizing infrastructures involve, for instance, activities of maintenance, repair, cleaning, that is, in the broadest sense, forms of care and concern that take place recurrently over a long period of time to ensure their functioning. Such repairs after minor or major disruptions, however, are always accompanied by changes – new parts are connected to old parts, different people treat systems and technologies in different ways, new regulations require changed ways of handling them, etc. Thus, the activities aimed at stabilization always have transformative effects whereby they contribute to the transformation of infrastructures. I understand this temporal quality as the processuality of infrastructures (Schabacher 2022, 133).

The fact that the fragility of infrastructures also has to do with climatic factors is part of the everyday knowledge of the modern age. Every year in spring, asphalt road surfaces that have been cracked by winter frost have to be repaired. In the fall, squares, sidewalks, and other traffic routes must be cleaned of fallen leaves, after heavy rains slopes must be resurfaced and filled, and iron elements prone to rust must be repainted

4 ASCE's Report Card on U.S. infrastructures 2021 (Source: American Society of Civil Engineers 2021, 4)

regularly. In addition, of course, there are other forms of disruption, such as vandalism, wear and tear of components, etc. Thus, "material fragility" (Denis and Pontille 2015, 341) characterizes all artifacts and infrastructures. Only when this vulnerability is taken into account can order and stability be established. In the maintenance of the wayfinding system of the Paris subway, for example, the respective technicians have to regularly repair damage, wear and tear, and mold on the signboards, but also update information and make adjustments related to the standardization policy (Denis and Pontille 2015,

355). In doing so, their work cannot be normalized, as part of their job is to cope with very heterogeneous environments and situational problems. In contrast to the subway users, who mainly perceive the standardization of the signage, for the maintenance staff the signboards exist in a fragile and vulnerable state. Repair and maintenance are thus not marginal activities; rather, they represent the heart of modern economies and societies, their "engine room" (Graham and Thrift 2007, 19). And this is the case in economic terms as well, because repair and maintenance activities represent a large part of economic activity (many jobs), even if this is often not considered (Graham and Thrift 2007, 7). For even if the fragility of infrastructures is an economically relevant factor, the activities directed at them are themselves often comparatively invisible (Star/Strauss 1989; Illich 1981). This is because repair and maintenance work belongs to the large field of care work (Degeling and Haffke 2021; Puig de la Bellacasa 2017), which is no longer profitable in the horizon of industrially produced mass and disposable products. It is especially the environmental movement that make cultural techniques of care (Schabacher 2020) relevant again. The relative invisibility of care work also has to do with the fact that it is often not paid or paid less (domestic work and foster care) and partly carried out by less recognized groups of people. It is therefore always about the "politics of repair" (Graham and Thrift 2007, 18) – who repairs, how this is paid for, and whether repair knowledge is provided or prevented.

What happens when repair and maintenance work is not carried out can be illustrated by a look at the situation of U.S. infrastructures. For the failure to make necessary repairs leads to costs rising year by year as problems continue to mount. Since 1998 the American Society of Civil Engineers (ASCE), a professional association of civil engineers concerned with planning, designing, constructing, and operating the built environment, has been assessing the condition of U.S. infrastructures every four years, using the format of an A to F school report card. According to the 2021 infrastructure report card (→ 4) the "infrastructure investment gap," that is, the costs that would be due to repair the ailing infrastructures (read: reach grade B), is put at about 2.59 trillion U.S. dollars (ASCE 2021, 5).

If appropriate investments are not made now, it is projected that by 2039 the funding gap would already be about $10 trillion, costing each U.S. household the equivalent of $3,300 a year or $63 a week (ASCE 2021). Although the report acknowledges that "some incremental progress" (ASCE 2021, 2) has been made, in long-term perspective the investment gap still

grows (ASCE 2021, 5). While the condition of bridges, drinking water, and energy, for example, has improved minimally since 2017, with the grade point average (G.P.A.) for all 17 categories assessed rising from D+ to an average grade of C-, this is still a long way from the targeted B.[4] Of the 617,000 bridges, for instance, 42 per cent are at least 50 years old and over 46,000 are in very poor condition, yet these bridges are crossed 178 million times per day. If the current investment rate were to be maintained, it would take until 2071 to carry out all the necessary repairs, not including further deterioration caused, for example, by extreme weather events (flooding, washouts, storm damage), to which ailing bridges are particularly susceptible (ASCE 2021, 19 and 23). So, unlike consumer goods, which according to the product life cycle calculated for them are to be discarded at the end of their (short) lives and replaced by new goods (Stark 2015),[5] this is not the case with large-scale infrastructures. Since the investment costs are very high, they are not taken out of service in the event of a malfunction but must be continuously repaired and kept running.[6] This is also the reason why the ASCE, in addition to sufficient funding, recommends preventive maintenance programs as solution strategies (ASCE 2021).[7]

Life Age Stratifications

A second perspective on infrastructures in time concerns the fact that they themselves age. Unlike the first case, this is not a matter of materials becoming porous or signs yellowing that need to be replaced or repaired to ensure the functioning of the infrastructure in question. Rather, in this case the infrastructure is functioning smoothly, but its components stem from different ages. In the case of very long-lived and complex infrastructures, the resulting temporal layering is particularly noticeable.

For example, the space mission to explore Saturn and its moons, conducted by NASA in collaboration with the European Space Agency (ESA) and the Italian Space Agency (ASI), lasted about 35 years. Accordingly, not only the spacecraft itself, but also the technical infrastructure that supported the operation and maintenance of this mission in a laboratory on the ground had to be operated for a correspondingly long time. The space craft was planned and constructed since 1982, launched in 1997, reached Saturn in 2004 and began collecting data. In 2010 it was extended for a final phase till 2017. The system thus consisted of "multiple lifetimes of different parts of the system – hardware, software, code, organizational processes, programming languages, institutions, careers – all of which are entangled and are aging or obsolescing at different

4 For an overview of the overall development in the various categories, see ASCE 2021, 167.

5 Turned positive, this is called *circular economy* in the sense of the *cradle to cradle* principle (McDonough and Braungart 2002; Borrion, Black, and Mwabonje 2021); turned negative, it appears as planned obsolescence (Slade 2006).

6 Such cascades of use of things familiar from the pre-modern economy of scarcity (Stöger 2015) can be found today as the reuse of bicycles, cell phones, computers and second-hand clothing in West and East Africa (Hahn 2018; Malefakis 2018).

7 The situation is quite similar to that of Deutsche Bahn. Here, too, repairs are urgently due. In 2022 alone, 13.6 billion are to be spent on renovating the ailing rail infrastructure (1,800 kilometers of tracks, 2,000 switches, 140 bridges, and 800 stations) and 4,800 new jobs are to be created for this purpose (Deutsche Bahn 2022). For this reason, the German federal government and Deutsche Bahn have already agreed on a package of measures for 2020 (BMVI 2020), according to which around 86 billion euros will be invested in modernization by 2030.

rates" (Cohn 2016, 1513). Maintaining the functionality of such a space probe thus meant that a system of several-decades-old technology and software must be kept running by people who in turn must know to handle this 'old' technology. In this case, the maintenance technicians aged with the technology they supported: "Infrastructural decay is a process that emerges through the ways that different parts of the system, aging at different rates are entangled with each other. What decays or ages are the relations across multiple parts of the infrastructure and among people, the organization, and its technologies" (Cohn 2016, 1519). In a similar way, old machines (in museums, for example) can only be kept running (for demonstration purposes, let's say) if there are still people around who know how to operate them.

Such temporal stratifications of life ages are very often also found in the infrastructures of public administration. Unlike in a high-tech company (and even here this applies only with restrictions), public institutions increasingly have devices of different ages (some of them drastically outdated) alongside each other (PCs, copiers, printers, telephones, etc.). In addition, there are people of different ages who are correspondingly adapted to newer or older technologies; likewise, manuals, routines, legal regulations, and forms of organization often originate from different times. One only has to think of the excessive demands made on the health authorities at the beginning of the Corona crisis, when the need to track contacts digitally came up against a process handling system that was still largely oriented toward paper and fax (Kinkartz 2020). In each of these cases, 'keeping it functional' means: dealing with the imponderabilities of the specific local circumstances, including variously aged machines, regulations, and people, and balancing them so that the desired processes work to some degree. In this respect, then, infrastructures are in time in the sense of the heterogeneous ages of things, people, regulations, and processes that are embedded and intertwined within them.

Infrastructure Remnants

But infrastructures are also "in time" in a third respect. Unlike products that decompose or get recycled, infrastructures are often characterized by a high degree of resistance, which can also be understood as their "obduracy-in-obsolescence" (Cairns and Jacobs 2014, 111). What is meant is the fact that they remain marked as remnants even in the state of abandonment (for a more detailed analysis Schabacher 2018). What can generally be stated for the space-time relationship of building ruins therefore also applies to abandoned infrastructures: they are "regularly out of time [...] but still very

5 Rotten swimming pool in Poland (Source: Szary Burek. 2011. *My visit to an old swimming pool in an abandoned hospital in Legnica, Poland*. May 7. Accessed August 25, 2022. https://reddit.com/r/AbandonedPorn/comments/ce31hm/my_visit_to_an_old_swimming_pool_in_an_abandoned/?utm_source=ifttt)

much in place" (Cairns and Jacobs 2014, 58). This is because, unlike infrastructures in operation, which tend to fade into the background as a taken-for-granted part of routines of action, abandoned infrastructures are still there, even when they are no longer in use (→5).

Concerning the nostalgia or *ruin porn* (Lyons 2018; Whitehouse 2018) that is inspired by these abandoned infrastructures, it can be shown how, in a way, they become landscape again. For we often find photographic representations of built structures that are reconquered by nature, which thus reside in a peculiar intermediate "zombie" status between nature and culture (Schabacher 2018, 129). They function as "material witnesses" of historical conditions, be it in an economic sense (think of former industrial sites),[8] be it in an imperial context as lasting traces of colonial structures of governance (*ruins of empire*) that have lasting effects on the present (Gordillo 2014; Stoler 2016), or be it as signs of military conflicts (*ruins of wars*) (Virilio 1994).

8 Detroit has become iconic for this (Levine and Moore 2010; Apel 2015).

This applies not only to the material side of infrastructures, but equally to their social, cultural, and organizational aspects. The *obduracy* of infrastructures can thus be understood as their resistance to change, which is expressed both in the "fixed" views about them, the embeddedness of their components in the environmental space, and in the traditions persisting through them (Hommels 2008, 21–39). One could say that

these aspects become even stronger when the infrastructure in question is no longer used. Its very existence marks limitations of people's life realities, but also refers to the historical and affective ruptures that accompany such debris (Gordillo 2014). Ann Laura Stoler addresses these connections as the "duress" (2016, 7) of imperial leftovers, understood in the threefold sense of their hardness or constraint, durability, and duration which she also frames as the "colonial *presence*" (2016, 33) of imperial debris. Her question is how people "live *with* and *in* ruins" (2016, 353) in order to address the toxic effects of imperial remains on actual living realities. Particularly relevant are the ecological legacies of empire, which express a form of "environmental racism" (2016, 351), for instance when it comes to the unequal distribution of pollution and waste disposal with regard to impoverished population groups (Carruthers 2008; Nixon 2011): "Imperial ruins are [...] *racialized markers on a global scale*" (Stoler 2016, 353). The reading proposed for the term "ruin" is crucial here. For the focus is not solely on the condition of a thing, but rather also on the process of "ruination" that affects it: "Ruination is an *act* perpetrated, a *condition* to which one is subject, and a *cause* of loss" (Stoler 2016, 350). With reference to the relation between *matter* and *mattering* (Cairns and Jacobs 2014, 49; Thompson 1979), it can therefore be emphasized, with reference to Stoler, that in the case of abandoned infrastructures not only the material remnants are relevant, but also their respective positioning and valuations within current political discourses.

Infrastructures in the Anthropocene

The fourth and last respect in which I want to discuss the temporality of infrastructures relates to the horizon of the Anthropocene. As with the discussion of infrastructure ruins in the previous section, this also concerns effects of infrastructures, but now on a different scale. For now, it is the planetary dimension of the geological implications of infrastructures that is at issue, which changes the relations of man and environments in long-lasting ways.

This situation has been referred to as "anthroturbation" (Zalasiewicz, Waters, and Williams 2014), as the disturbance of the Earth by human activity. The term is derived from the geoscientific term "bioturbation," which describes fossil traces, such as burrows and feeding tracks, that invertebrates (such as worms and clams) left in rocks as early as the Cambrian period, 600 million years ago. Applied to humans, it is also a matter of tracing their feeding tracks and burrows, so to say. And these permanent traces are the infrastructures created by humans, which massively transform our planet at the latest

with the Industrial Revolution and have lasting (and often irreversible) effects on the geography of the earth.[9] This affects three levels (Zalasiewicz, Waters, and Williams 2014, 4–5): Anthroturbation changes the Earth's *surface* by engineering landscapes, soils, oceans, and the atmosphere (human constructions, excavations, and other interventions in urban and agricultural environments). It alters *subsurface* layers through structures built at shallow depths, such as systems of energy supply, sewerage, and transportation like subway urban networks, subways, and tunnels. And it alters the earth through *deep anthroturbation* such as mining and drilling in particular.

9 As mentioned at the outset, however, speaking of "the Anthropocene" has certain biases. For both questions of causation and how it affects us are not equally distributed across all of humanity (Yusoff 2018). A term like *capitalocene* takes this unequal distribution into account (Moore 2016).

Against this backdrop, different actors and activities are held responsible as prime movers and drivers of the Anthropocene. The concept of the *plantationocene*, for example, emphasizes the extensive conversion of farmland and forests into enclosed plantations through slave labor (Haraway 2015); the *oleocene* emphasizes the general importance of fossil fuels and the infrastructures of the oil drilling industry; and the *anthrobscene* refers to the "obscene" economics of all materials necessary to produce the contemporary media world (Parikka 2014). Moreover, the global disposal of waste which generates nuclear waste repositories as well as satellite debris orbiting the Earth (Parks 2013; Damjanow 2017; Clormann and Klimburrg-Witjes 2022), the Great Pacific Garbage Patch (Vehlken 2020; Reichle 2021), should also be mentioned here.

As I outlined at the beginning, three respects can be analytically distinguished in which infrastructures are related to the Anthropocene. In the anthroturbation phenomenon just discussed, infrastructures turn out to be primary causes and "material witnesses" of climate change in the Anthropocene. In a second respect, however, they can also be encountered as forces and structures responding to climate change. Here, too, a connection between infrastructures and the Anthropocene emerges, but now insofar as they are transformations and treatments of existing constellations that seek to minimize the effects of climate change: "new" infrastructures, so to speak, that treat "old" infrastructures. We might think, for example, of the transformation of energy production, that is, the closure of lignite mining sites in favor of decentralized, renewable forms of energy (wind farms, solar power plants). We might also think of the transformation of mobility infrastructures through electric vehicles of various types (scooters, cargo bikes, e-cars), which make corresponding supply infrastructures necessary (charging stations, etc.) and a reconceptualization of urban space possible (Doheim, Farag, and Kamel 2020), such as the repurposing of areas previously reserved for parking

(Nieuwenhuijsen and Khreis 2016, 254, 258). But there is a third analytical respect in which we encounter infrastructures in the context of the Anthropocene. This refers to cases where infrastructures are created and planned in direct and positive response to the effects of the Anthropocene. Again, temporality is a crucial factor. However, economic value creation is now no longer based on combating the consequences of climate change, as in the case of changes in mobility and energy infrastructures, but rather on affirming these consequences profitably and exploiting them to create new infrastructures.

Artic Shipping

The example of Artic shipping illustrates what such a "positive" embrace of climate change might look like. Up to now, the Arctic and the Arctic Ocean have been a space that was difficult to penetrate and was not relevant in terms of transportation. To navigate it, that is, to cross it to the East or West, was the subject of much imaginative speculation, but actually realizing this was an almost hopeless undertaking (Müller 2022). Today this is no longer true in the same way. Man has achieved his goal, however, not by the optimization of technologies necessary for it, but because he has behaved in such a way that the materiality of the earth itself has changed.

Due to climate change, the Arctic Ocean is becoming increasingly relevant in terms of geopolitics, military strategy, as well as economic viability. This is due to the decline in sea ice, which is changing the navigability of this region of the world (Østreng et al. 2013; Farré et al. 2014; Aksenov et al. 2017; Lasserre and Faury 2019; Paul 2022).[10] Sea ice, that is, frozen seawater, is very significant for the Earth's climate balance because it reflects sunlight more strongly than dark seawater and therefore protects the oceans from warming; if the amount of sea ice decreases, the oceans become warmer, which leads to a further melting of sea ice. In 1996, the eight Arctic littoral states joined together to form the Arctic Council, namely Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden, and the United States. The Artic Council is a high-level inter-governmental forum that exercises sovereignty over the lands within the Arctic Circle. Significantly, the said eight countries considered themselves "members," while the six Indigenous communities – the Aleut International Association, the Arctic Athabaskan Council, the Gwich'in Council International, the Inuit Circumpolar Council, the Russian Association of Indigenous Peoples of the North, and the Saami Council – were only admitted under the status of "permanent participants."[11] The climate-driven development described above involves very different interests, ranging from access to resources to issues of

10 For further information, see the *Arctic Marine Shipping Assessment 2009 Report*, which was developed under the direction of the Protection of the Artic Marine Environment (PAME) Working Group, one of the six working groups of the Arctic Council (Arctic Council 2009).

11 See also the website of the Artic Council, https://arctic-council.org/ (accessed August 25, 2022).

great power status (the USA, Russia, and China), tourism destinations (Greenland) to the establishment of previously unused sea routes (Paul 2020, 5). What is at stake here is nothing less than the renegotiation of the routes of world trade and thus a global restructuring of the transport network and the associated relations of proximity and distance.

Already the construction of canals like Suez or Panama, which have organized the connection of Atlantic and Indo-Pacific spaces for more than 100 years (Paul 2020, 5), had drastically relativized the proximity and distance of places. In 1886, Ferdinand de Lesseps, designer of the Suez Canal and initially involved in the construction of the Panama Canal, too, stated that both canals were "two great highways of commerce and civilization" (De Lesseps 1886, 519), which made it possible to transport goods more quickly by connecting the different world regions. While the Suez Canal was said to be the "open door" between Europe or North Africa and South Asia, the Panama Canal opened the connection from Europe and America to China, Japan, and Australia (De Lesseps 1886, 519). Accordingly, de Lesseps already had a tabular listing of the shortened routes due to the Panama Canal. The trip from New York to Vancouver, for example, was reduced to a quarter of the previous distance (→6).

Even though the completion of the Panama Canal was delayed for almost twenty years due to planning errors and a financing debacle of the construction company under de Lesseps's leadership (it opened only in 1914), this does not change the visions that accompany such infrastructure projects. History, however, also makes clear "the great lines of tension in world politics that a new high-performance transport route is capable of triggering" (Voigt 1965, 195, my translation). For canals refigure in a fundamental way the geography within a local environment as well as the network of world traffic as a whole (Krajewski 2015, 15).

But what has climate change brought about for the Artic Ocean? The so-called Northeast Passage (the section along the coasts of Siberia is also referred to as the Northern Sea Route) is today already navigable, which is to say, ice-free, for four to five months a year (July to November) on various routes (Paul 2020, 13) (→7).

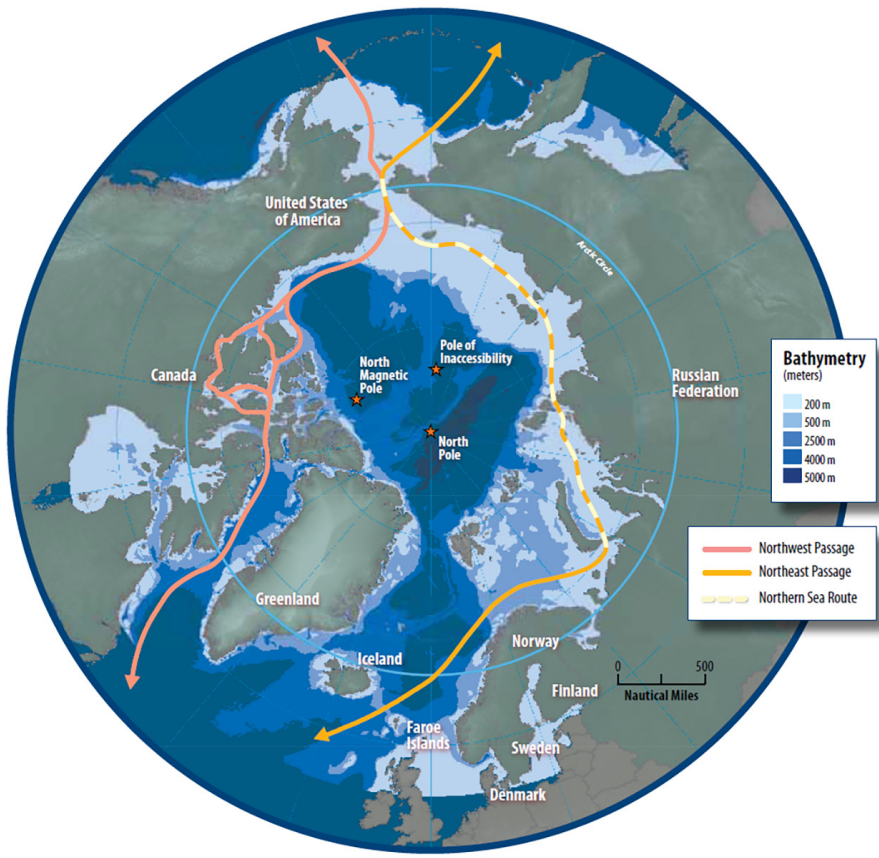
However, the infrastructure necessary for frequent use has not yet been developed, although Russia has high expectations for it (Liu et al. 2021; Paul and Swistek 2022).[12] This is why China – itself not a littoral state of the Artic – supports Russian projects in Siberia in the sense of an "Artic Silk Road"

12 It is also emphasized that the melting sea ice is not seen by Russia solely as an advantage (resource extraction, shipping routes), but also as a "loss of security" (Paul and Swistek 2022, 6), which in turn could promote Kremlin military aggression and thus destabilize the region overall. The new naval doctrine of July 2022 can be seen in this context, which both underlines Russia's claim to be a great maritime power and its ambitions with respect to the Arctic Ocean, is causing concern among the other seven Arctic states, together with China's research activities (Reuters 2022; Spiegel 2022).

6 Distance in miles saved between various ports when using the Panama Canal (Source: De Lesseps 1886, 519)

Names of ports.	Distance by Cape Horn.	Distance by Panama canal.	Distance saved.
London or Liverpool to San Francisco	16,900	8,200	8,700
Havre to San Francisco	16,100	7,900	8,200
London to Sydney	16,400	10,900	5,500
Havre to Sydney	16,100	10,600	5,500
Bordeaux or Havre to Valparaiso	10,900	7,450	3,450
London to Sandwich Islands	14,900	7,900	7,000
New York to Valparaiso	10,600	3,900	6,700
New York to Callao	11,200	3,000	8,200
New York to Guayaquil	12.000	2,400	9,600
New York to San Diego	15,400	3,700	11,700
New York to San Francisco	15,900	4,200	11,700
New York to Vancouver	16,600	4,600	12,000

7 Arctic Shipping Routes: Northwest Passage (red) and Northeast Passage (yellow) (Source: Artic Council 2009, 17)



(Lim 2018), but is equally interested in the Northwest Passage, which in turn interferes with Canadian interests that understand it as an internal water route (Lackenbauer et al. 2018). The Northwest Passage is still covered by ice all year round, but it is expected that it will be navigable on up to 130 days a year during the course of the 2030s. At the same time, and in contrast to the Northern Sea Route, there are very branched, different shipping routes through the Canadian archipelago, which comprises 36,000 small and tiny islands whose position respectively could change drastically in geopolitical terms as stations of a navigable Northwest Passage (Paul 2020, 18). The same applies to the Transpolar Sea Route that passes close to the North Pole, which is currently only navigable with heavy icebreakers, but would have the advantage of crossing the high seas and thus international waters, thereby avoiding territorial conflicts. It is expected that this route will be ice-free and thus navigable in the 2040s (Paul 2020, 18). Besides access to resources (coal, oil, gas) or tourist destinations (such as Greenland), it is also about a drastic shortening of transport routes, which would further shrink the world in David Harvey's sense (Harvey 1990, 241). For while a container from Murmansk to Shanghai currently takes 37 days to cover a distance of 12,500 kilometers by sea through the Suez Canal, this would be halved to 18 days and 6,500 kilometers on the Northern Sea Route.[13]

13 However, connections via the Arctic Sea would not always be more cost-effective than the routes via Suez or Panama, as a shorter route might only be navigable more slowly due to ice conditions (Paul 2020, 19).

In the case of Arctic shipping, then, climate change is not only leading to a rethinking and a modification of existing infrastructures, as is happening, for example, regarding renewable energy or other forms of urban mobility, but here it is, quite materially, giving rise to entirely new ways of infrastructuring the planet that would not have been possible "without" climate change.

Conclusion

Infrastructures are "in time" in various ways. This concerns their everyday forms of fragility and the activities of care and maintenance directed at them. We have come to know this as the processuality of infrastructures, which can be understood as the work permanently invested in maintaining infrastructures (Schabacher 2022). The background here was the fundamental connection between infrastructures and breakdown, which is not an exception but always affects normal operations and makes infrastructures epistemically understandable in the first place. We have further addressed the aging of infrastructures, seeing how different layers of lifetimes overlap and interfere with each other in complex large-scale technical systems and organizations. Then again, infrastructures that are no longer in use do not simply disappear, but remain in a specific

way, which has effects on the lifeworlds of those who have to deal with them. This is particularly evident for imperial infrastructures, but also warlike conflicts and ecological catastrophes produce such "ruins." They figure as "material witnesses" (Schuppli), which through their "duress" (Stoler) refer to the historical contexts that produced them. Looking at anthropogenic climate change and how infrastructures are related to it, I have distinguished three types of temporal relations. First, infrastructures are significant contributors to climate change, for instance through the extraction of fossil energy resources, and are thus its primary *causes*. Second, infrastructures *respond* to climate change, for example, by developing alternative energies and forms of mobility. Here, then, they help transform and modify the consequences of climate change, with a focus on reducing its impacts. Finally, with Arctic shipping, we have learned about an example where climate change actually becomes a producer of new infrastructures (transport routes, tourism destinations). Here, in a cynical and short-term manner, there is speculation on how best to *profit from* the changes associated with climate change. To conclude, infrastructures are closely related to anthropogenic climate change: they produce it, they deal with it, and they systematically exploit it. Thus, infrastructures are fundamental mediators of climate change. In their precarious temporality, they are themselves material witnesses to the ecological disasters of this planet.

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