The Persistence of Technology:

From Maintenance and Repair to Reuse and Disposal

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Today, the act of repair has developed into a kind of social movement. The repairers who meet in repair cafés and other such venues, assisted by various organisations, forums and online platforms, are driven by the political idea that by fixing objects, they can fix the world and its predominantly capitalist economic model.[1] In their view, repairing is associated with sustainability goals; it is seen as an act of environmentalism.[2]

Yet at its core, repairing is, and will remain, a user operation on objects and goods; it is a fundamental interaction between humans and technology. According to Stephen Graham and Nigel Thrift, repair and maintenance constitute "the engine room of modern economies and societies".[3] Henke and Sims see repair at work in any process which restores social or material order, but they particularly emphasise the role of infrastructure repair in today's interconnected, standardised world – interventions that encompass local fixes as much as systemic approaches or efforts to "reflexively" repair the unintended environmental consequences of modern infrastructures.[4] This omnipresence makes it somewhat

1 See https://repaircafe.org/en/foundation, ifixit.com or www.reparatur-initiativen.de (all accessed 04.11.2019).

2 See Baier, Andrea et al. (eds.): Die Welt reparieren: Open Source und Selbermachen als postkapitalistische Praxis, Bielefeld: transcript 2016.

3 Graham, Stephen/Thrift, Nigel: "Out of Order: Understanding Repair and Maintenance", in: Theory, Culture & Society 24, 3 (2007), p. 1–25, here p. 19.

4 Henke, Christopher R./Sims, Benjamin: Repairing Infrastructures: The Maintenance of Materiality and Power, Cambridge, MA: MIT Press 2020.

surprising that repair has emerged only recently as a major field of research for historians of technology and scholars of science and technology studies. One reason why maintenance and repair have been overlooked can be found in the traditional innovation-centric research agenda of the history of technology. This is why the current "maintainers network" argues for an emphasis on maintenance instead of the traditional focus on invention and innovation in the field.[5]

In the research literature on repair that has become available, it is possible to identify four clusters, each of which maps out a distinct way of looking at repair: first, "broken world thinking"; second, repair as invisible work; third, repair as *bricolage*; and last, repair as an innovative act.

The first cluster presents a call to consider any technological act from the starting point of brokenness. Steve Jackson recently argued for "broken world thinking": historians of technology should take "erosion, breakdown, and decay, rather than novelty, growth, and progress, as ... starting points" for their research and narratives.[6] Obviously, repair then takes centre stage as it serves to remediate decay and breakdown.

In the second cluster, repair is described as a "hidden field" or as "invisible work". In this view, repair is conducted behind the scenes – in an unseen backroom, for example, in the case of consumer goods or, in the case of infrastructure, at night, when it causes the minimum possible disruption. In addition, repairs are often carried out in informal markets, a phenomenon that has best been described in the context of the Global South. It is also becoming clear that the low social status frequently assigned to repairers contributes to their apparent invisibility.[7]

The third cluster examines the particular characteristics of repair know-how. This know-how is conceptualised as experiential, situational and embodied knowledge. Improvisation and *bricolage* are emphasised.[8] This literature also

5 See themaintainers.org (accessed 04.11.2019), see also Russell, Andrew L./Vinsel, Lee: "After Innovation, Turn to Maintenance", in: Technology and Culture 59, 1 (2018), p. 1–25.

6 Jackson, Steven J.: "Rethinking Repair", in: Gillespie, Tarleton/Boczkowski, Pablo J./Foot, Kirsten A. (eds.): Media Technologies: Essays on Communication, Materiality, and Society, Cambridge, MA: MIT Press, 2014, p. 221–239, here p. 221.

7 See e.g. Henke, Christopher: "The Mechanics of Workplace Order: Toward a Sociology of Repair", in: Berkeley Journal of Sociology 44 (1999/2000), p. 55–81.

8 See e.g. Orr, Julian: Talking about Machines. An Ethnography of a Modern Job, Ithaca, NY/London: Cornell University Press 1996; Strebel, Ignaz/Bovet, Alain/Sormani, Philippe (eds.): Repair Work Ethnographies, Singapore: Palgrave Macmillan 2019.

provides some insight into the difficulties involved in any attempt to standardise and automate maintenance and repair work.

The fourth cluster stresses the innovative nature of repair, despite the fact that it is essentially about conserving existing things or infrastructures. Repairers often alter the original structure of things, textiles or other objects; such repairs are described in this literature as incremental innovations.[9] Another aspect is the blending of old and new, of "Western" and "non-Western" technology as a result of repairs – what David Edgerton, for example, has termed "creole technologies".[10]

Adding to this literature, we argue in this volume that repair should be discussed from a temporal perspective – one which reaches beyond the timescale of the repair process itself.[11] This includes the historicity of repair, i. e. that repair practices and cultures have changed over time and should be investigated in their respective historical contexts. But it reaches beyond historicity and refers to the manifold temporalities included in processes, infrastructures and acts of repair. Maintenance and repair react to the wear and tear that happens over time and they represent interventions with the temporal aim of prolonging the time an object can stay in use. Moreover, when studying repair we also need to raise the question of what comes after repair (or non-repair): removing or hoarding for future reuse or care? Reuse, e.g. through second-hand resale or dismantling into reusable parts? Sorting for final disposal? And what happens thereafter?

Our claims are thus twofold: firstly, repair practices should be viewed from a historical perspective. Our selection of case studies in this volume focuses on seminal 20th-century technologies, from infrastructure to production plants to the motor car. It is often assumed that practices of repair and reuse have gradually declined along with the rise of 20th-century mass production, mass consumption and throwaway societies.[12] History shows, however, that repair has always gone hand in hand with any human-object interaction, from mediaeval bridges to

9 See e.g. Graham/Thrift, "Out of Order", p. 5.

10 Edgerton, David: "Creole Technologies and Global Histories: Rethinking how Things Travel in Space and Time", in: Journal of History of Science and Technology 1, 1 (2007), p. 75–112.

11 On different timescales of repair (e.g. repair as routine activity, the before and after of repair, preventive maintenance, etc.), see Henke/Sims: Repairing Infrastructures, p. 25–26.

12 For a more detailed account, see Krebs, Stefan/Weber, Heike: "Rethinking the History of Repair: Repair Cultures and the 'Lifespan' of Things" (this volume).

today's mobile phones.[13] Technological infrastructures and technology are all about serviceability and usability – which, of course, implies maintenance and, if there are faults, repair. This is why we argue that the declensionist narrative does not reflect the historical development of repair. A closer historical look at 20th-century infrastructures and consumer cultures demonstrates that maintenance and repair have not become obsolete in modern consumer societies; rather, their modes, their appearance and the sites and actors of repair have changed substantially.[14] However, we still know surprisingly little about these historical changes and even less about what happens after repair. In his plea for a history of "technology-in-use", David Edgerton summarised: "Unfortunately we are not in a position to give an overview of the main trends in the history of maintenance and repair. Has maintenance as a proportion of output gone up or down? Where there has been a trade-off between initial cost and maintenance, what have producers and consumers gone for?".[15] This finding has changed little in the past ten years. More recent historical studies, including this volume, suggest that repair practices have followed different trajectories and trade cycles.[16] Krebs and Hoppenheit have for example shown that employment in the repair sector continued to increase in the 1970s and 1980s.[17] The overall importance of repair might have declined for some (consumer) technologies, but emerging technologies have also led to the establishment of new fields of maintenance and repair. The widespread adoption of cars, radios and washing machines, for instance, was based on customer services and repair facilities and on second-hand markets. Furthermore, repair knowledge, tools and motives have also changed over time.

Second, we argue that practices of maintenance and repair are not only linked to the innovation, use and consumption of technology but that they are part and parcel of technology's different temporalities. When technical artefacts become old and worn out, their users or owners have to decide whether it is necessary, worthwhile or possible to maintain and repair them and thus extend their

13 On smartphone repair stores in Switzerland, see Nova, Nicolas/Bloch, Anaïs: Dr. Smartphone: An Ethnography of Mobile Phone Repair Shops, Lausanne: IDPURE 2020.

14 See Krebs, Stefan/Hoppenheit, Thomas: "Questioning the Decline of Repair in the Late 20th Century: the Case of Luxembourg, 1945-1990", in: Hilaire-Pérez, Liliane et al. (eds.): Technical Cultures of Repair from Prehistory to the Present Day, Turnhout: Brepols Publishers 2021 (forthcoming).

15 Edgerton, David: The Shock of the Old, London: Profile Books 2006, here p. 81.

16 For a more detailed account, see Krebs/Weber, "Rethinking the History of Repair".

17 Krebs/Hoppenheit: "Questioning the Decline of Repair".

present use; to reuse, hoard or dismantle them for different purposes; or finally to get rid of them. So we need to tackle the question of what becomes of "old" technologies: whether they are repaired or not is closely related to questions of reuse and removal, dismantling and disposal – the complex decision between "mending and ending" (see also Weber, this volume) depends on many factors including the availability of second-hand markets, repair infrastructures and dismantling or disposal facilities.

Accordingly, in this volume, we intend to go a step beyond "broken-world thinking". For us repair is one of the many aspects of the temporalities of technology, and in particular of its intractable persistence, which rarely ends with the end-of-use of a technological artefact. The questions of how long and in what shape technology remains in use, how and why it is taken out of use and what happens afterwards are related to the contexts and conditions of maintenance, repair, reuse and disposal infrastructures, to their availability or absence, and to the related economies of waste, recycling and reuse.

In the first part of this introduction, we want to elaborate on what we mean by temporalities of technology, including the "persistence of technology" which gave the book its title. The second part provides an overview of the contributions in the volume, all of which stress questions of repair, reuse and disposal in situations of technology-in-use, technology-in-the-making or technology-in-the-unmaking. The chapters focus on technologies which have shaped the 20th century such as the power grid, ocean-going vessels, telephones and cars. Geographically, we cover various Eastern and Western European countries, North America, China, India and the former Soviet Union.

TECHNOLOGY'S PERSISTENCE: A TEMPORAL PERSPECTIVE ON TECHNOLOGY AND ITS REPAIR, REUSE AND DISPOSAL

In the field of history, considerable thought, and some rethinking, is currently being devoted to the subject of time and temporality.[18] By bringing such thoughts into the history of technology, we argue that technology harbours manifold temporal dimensions, including the fact that it is relatively persistent.

18 See e.g. the "Viewpoints" section in Past & Present 243, 1 (2019); Champion, Matthew: "The History of Temporalities: An Introduction", in: Past & Present 243, 1 (2019), p. 247–257; Tanaka, Stefan: "History without Chronology", in: Public Culture 28, 1 (2015), p. 161–186.

From such a temporal perspective, repair becomes an intervention that is intended to prolong the time that a certain technology can stay in use; dismantling and disposal, by contrast, are interventions that bring an end to the use phase. In most cases, these interventions disaggregate and transform infrastructures, buildings or things into reusable parts, recyclable materials and "stuff" to be discarded, and they often come with an "afterlife", as demonstrated by the issues of waste legacies or industrial ruins.

As contemporaries of the COVID-19 crisis, we have all been eyewitnesses to diverse temporalities of technology: some infrastructures were brought to a standstill, others were accelerated. Hospitals were erected in just a few weeks, while the grounding of around 20,000 planes entailed complex caretaking activities to stockpile them for future use. Intercontinental container shipping schedules were disrupted, resulting in blank sailings (cancellations) and prompting the growing practice of "schedule sliding" (adding buffer time to sailing schedules to allow for delays). Reflections on technology and its development in respect to temporalities – which go far beyond temporal issues such as the chronologies and innovation timelines of technologies or the technical measurement of time – are beginning to emerge in science and technology studies and the history of technology. Heike Weber, for instance, has appropriated Reinhart Koselleck's metaphor of "Zeitschichten" (sediments or layers of time) to map out the timescapes of technology, and Jens Ivo Engels has interpreted technical infrastructures as products as well as producers of time.[19] From a media studies perspective, Gabriele Schabacher has argued that any infrastructure is formed by layers of different ages and follows temporally different patterns of (non-)care such as repair, abandonment or repurposing, while Gabriele Balbi and Roberto Leggero underline that focusing on maintenance can help us to understand communication infrastructures in their *longue durée* existence.[20] Similarly, anthropologists have conceptualised infrastructure as a process over time, from

19 Weber, Heike: "Zeitschichten des Technischen: Zum Momentum, 'Alter(n)' und Verschwinden von Technik", in: Heßler, Martina/Weber, Heike (eds.): Provokationen der Technikgeschichte. Zum Reflexionsdruck historischer Forschung, Paderborn: Schöningh 2019, p. 107–150; Engels, Jens Ivo: "Infrastrukturen als Produkte und Produzenten von Zeit", in: NTM. Zeitschrift für Geschichte der Wissenschaften, Technik und Medizin 28, 1 (2020), p. 69–90.

20 Balbi, Gabriele/Leggero, Roberto: "Communication *is* maintenance: turning the agenda of media and communication studies upside down", in: H-ermes. Journal of Communication 17 (2020), p.7–26.

design to construction then maintenance or abandonment, breakdown, demolition or ruin.[21]

In this collection, we want to highlight three temporal dimensions:[22] first, the polychronic structure of our mechanised world, i. e. that any given society has used or uses technologies from diverse past times and from the present; second, each technology goes along with certain temporalities ascribed to or inscribed in it, e.g. expectations on how long it should be in operation; third, these temporalities include the so-called "afterlife" of technology as one of the most problematic examples of its potential persistence. These are temporal dimensions for which historians of technology have yet to develop a keen awareness – an awareness that extends beyond industrial archaeology or the conservation and restoration of historical objects which up to now have constituted the main fields for history's reasoning on "aged" technology. They ultimately concern hitherto overlooked questions, namely how societies value and treat a technology in respect to time and how societies not only "make" and "use" technology but also "unmake" it.

By referring to the "polychronic" nature of technology, we want to underline that in no society has the latest technology been used to the exclusion of older technologies; on the contrary, the technology of any given historical period has always been a patchwork of old and new. Most technologies persist long after the emergence of technically superior alternatives or are put to other uses elsewhere. David Edgerton in particular has underlined this point recently with his technology-in-use perspective: the objects, infrastructures and practices in use originate in different historical times, yet they coexist simultaneously and in parallel in our present. Svante Lindqvist made a similar point in the mid-1990s. The world of technology, he said, was almost entirely driven by "old-age" technologies that had already reached maturity or were in decline. "For any given technology and at any time we will find that the prevailing technological volume is a mixture of several and at least the following three components: an older technology in decline (A), a second at its peak (B), and a third one emerging (C)."[23] The

21 Schabacher, Gabriele: "Time and Technology: The Temporalities of Care", in: Volmar, Axel/Stine, Kyle (eds.): Hardwired Temporalities. Media, Infrastructures, and the Patterning of Time, Amsterdam: Amsterdam University Press (forthcoming); Anand, Nikhil/Gupta, Akhil/Appel, Hannah (eds.): The Promise of Infrastructure, Durham/London: Duke University Press 2018.

22 The following paragraphs draw on Weber, "Zeitschichten des Technischen".

23 Lindqvist, Svante: "Changes in the Technological Landscape. The Temporal Dimension in the Growth and Decline of Large Technological Systems", in: Granstrand, Ove

illustrative examples he cites include the last charcoal-fired blast furnace in Sweden, which was not closed down until 1966, and the use of horses in Germany, which, because of their enduring importance in agriculture, did not peak until the 1920s, in other words when motor vehicles were already on the rise. In his book *The Shock of the Old*, David Edgerton identifies a multitude of other examples, including "shocking" cases such as asbestos, which is still a common construction material in many parts of the world (see also Dhawan, this volume). This polychronicity is in evidence even in the context of one single technological system in a given region. Today's automobility, for instance, comprises a constantly evolving diverse vehicle pool and myriads of infrastructural elements that require constant maintenance and renewal. Likewise, the "digital revolution" of our day would have been impossible without the copper-core cables of the telephone era; the late 20th-century German telecommunication system, for instance, identified copper cables rather than optical cables as the basis for future digitisation.[24] In view of this polychronicity of the technical world, it would be wise to shed the dualistic conception of "old" and "new" technologies altogether,[25] because this terminology suggests a linear sequence or even replacement – often associated with linear progress – , whereas an additive overlap and a polychronic hybridity actually prevail. The manifestations of this technological polychronicity vary between regions and historical eras and they essentially depend on the respective cultures of maintenance, repair, reuse and disposal.

The second aspect concerns temporal dimensions ascribed to or inscribed in technology itself, e.g. innovation cycles or questions of durability, degeneration and obsolescence or the persistence of technology. A current pertinent example is "Moore's law", which has dictated the short innovation cycles of digital equipment in recent decades.[26] We often apply anthropomorphic metaphors such

(ed.): Economics of Technology, Amsterdam: Elsevier 1994, p. 271–288, here p. 276 and 284.

24 Henrich-Franke, Christian: "'Alter Draht' – 'neue Kommunikation': Die Umnutzung des doppeldrahtigen Kupferkabels in der Entwicklung der digitalen Telekommunikation", in: Habscheid, Stephan et al. (eds.): Umnutzung: Alte Sachen, neue Zwecke, Göttingen: V&R unipress 2014, p. 97–112.

25 For a more detailed treatment, see Weber, "Zeitschichten des Technischen"; see also: Tanaka, History without Chronology.

26 While Ceruzzi framed Moore's Law as technological determinism, Mody hinted at the social construction of this "law", e.g. through mass sales of laptops and cell phones. See Ceruzzi, Paul E.: "Moore's Law and Technological Determinism: Reflections on the History of Technology", in: Technology and Culture, 46, 3 (2005), p. 584–593;

as "age", "lifespan", "technological generations" or "death" to refer to some of these temporal dimensions of technology, as if the "biography of things" resembled a human biography. While Arjun Appadurai's idea of an "anthropology of things" was once helpful in understanding changing social and cultural meanings of objects,[27] in the light of recent challenges such as fast fashion, increasing quantities of waste and the toxicity of e-waste, it seems inadequate to parallelise the temporalities of the material word with the traditional and centuries-old idea of human life stages. Yet in the absence of more appropriate terms, our book also sometimes applies terms such as "old" technology or the "afterlife" of technology.

It is therefore all the more important to emphasise that technological objects rarely follow the plain "bio-narrative" of an arrow-like path from cradle to coffin. Large-scale infrastructure systems such as telephone networks or electricity grids (see the contributions by Tan, Lean and Hadlaw in this volume), for instance, are highly polychronic entities, which are never switched off unless a fault or blackout so dictates. Servicing, overhaul, refurbishment, repair and constant updating or replacement of outdated parts are indispensable for these systems to deliver the desired continuous operability, and these processes serve to counteract the infrastructure's inevitable degeneration and wear and tear. The case of airports and planes during the coronavirus crisis has demonstrated that infrastructures cannot simply be put on hold; grounding aircraft requires time-sensitive activities such as preparing engines and tanks so that they can be put into storage. By contrast, other technologies or infrastructures are simply left to decay and turn to ruin, or are dismantled or demolished. Some technological artefacts remain operational through diverse cascades of reuse; others are salvaged for various reasons or conserved as cultural treasures in museums, by private collectors or hobbyists. Certain old car models, for instance, have become objects of such intentional preservation by hobbyists that they serve as a kind of "time capsule" (see Lucsko in this volume).

When it comes to the "lifespans" of technical artefacts, material wear and tear and especially – at least in mass consumer societies – cultural obsolescence and society's expectations on technical progress and newness define whether, when and why artefacts are to be considered as "aged" and "obsolete". The example of houses illustrates the strong influence that regional cultures have on

Mody, Cyrus: The Long Arm of Moore's Law. Microelectronics and American Science, Cambridge, MA: MIT Press 2017.

27 Appadurai, Arjun (ed.): The Social Life of Things. Commodities in Cultural Perspective, Cambridge et al.: Cornell University Press 1986.

construction: an average house in Japan, for instance, stands for 30 years before it is demolished; in the United States, this average lifespan amounts to 55 years and, in Britain, no less than 77 years. Needless to say, with these diverse lifespans come differing practices, intensities and costs of maintenance and repair,[28] as demonstrated by the case of Samarkand houses and their cross-generational persistence based on tacit construction knowledge and continuous repair and restoration (see van der Straeten/Petrova in this volume).

The idea of quantifiable "service lives" of technology emerged along with the development of mass production and mass consumption, and it is a notion that forms the backbone of any planning and engineering of investment and consumer goods.[29] Twentieth-century bridges, for instance, were designed to last for several decades, whereas the product lifespan of cars, based on average use frequency and driving habits, was conceptualised within a range of 10 to 12 years. Currently, a mobile phone is considered outdated after less than two years, and Snapchat is programmed to obliterate messages after 24 hours. As these examples show, by the late 20th century time and technology had intersected in novel forms that were not designed to coordinate the rhythms of work, workers and machines as in the 19th century, but to shape institutional, organisational and social time constructs for innovation and allow "adequate" time for substitution and the decline of "mature" technology.[30]

Many technological objects that are discarded in wealthy societies as "obsolete", however, find their way, after repair or dismantling and resale, into second-hand markets. In contrast to pre-modern markets, these modern second-hand markets and their scope and meaning for mass consumption are as yet underexplored,[31] but it is clear that they have played a key role, for example in the dissemination of consumer technologies to less affluent consumer classes. In the course of the 20th century, trade routes lengthened from local to global, with the

28 Cairns, Stephen/Jacobs, Jane M.: Buildings must die: a perverse view of architecture, Cambridge, MA et al.: MIT Press 2014, p. 127.

29 See Weber, Heike: "Made to Break? – Lebensdauer, Reparierbarkeit und Obsoleszenz in der Geschichte des Massenkonsums von Technik", in: Krebs/Schabacher/Weber (eds.), Kulturen des Reparierens: Dinge – Wissen – Praktiken, Bielefeld: transcript 2018, p. 49–83; Slade, Giles: Made to Break: Technology and Obsolescence in America, Cambridge, MA: Harvard University Press 2006.

30 Helga Nowotny has spoken of a "chrono-technology" for these processes, see Nowotny, Helga: Eigenzeit. Entstehung und Strukturierung eines Zeitgefühls, Frankfurt a. M.: Suhrkamp 1989, p. 64–66 and 73.

31 Fontaine, Laurence (ed.): Alternative Exchanges. Second-Hand Circulations from the Sixteenth Century to the Present, Oxford/New York: Berghahn Books 2008.

result that used technology is now primarily exported from Western places of first use to poorer regions of the Global South, and often through informal channels and markets.

While historical research on the polychronic structure of technology, on user cascades, second-hand markets or obsolescence is relatively rare, virtually no historical studies have thus far considered the "unmaking" of technology. Researchers in the fields of social science and the history of technology have filled libraries with concepts on innovation and the "making" of technology, and they have developed notions such as appropriation, domestication, normalisation or creolisation to describe the use phase. By contrast, there is a conceptual absence when it comes to the removal, dismantling, decline and decay of technology. Only some initial articles have explored what the vast field of "unmaking" of technology could mean for the history of technology.[32] Technology does not simply disappear; every removal from the place of service or use requires an active intervention, once the decision for "divestment"[33] has been taken.

Studies within the field of consumption history on throwaway practices might generate valuable input. For example, in her seminal book *Waste and Want*, Susan Strasser explained how in American households the once common "stewardship of objects" was gradually replaced by a throwaway culture, once mass consumption and municipal disposal infrastructures were taken for granted.[34] Technologies of removal, however, include more than waste disposal services. Indeed, alongside the repair sector, there exist dismantling and scrapping businesses – a vastly underexplored and often informal, even illegal field of economic activity which has been analysed for the metal scrap business and car recycling.[35] More attention has been paid to cities and their inherently polychronic

32 Rare examples are Weber, Heike: "'Entschaffen': Reste und das Ausrangieren, Zerlegen und Beseitigen des Gemachten (Einleitung)", in: Technikgeschichte 81, 1 (2014), p. 1–32; Salehabadi, Djahane: "The Scramble for Digital Waste in Berlin", in: Trischler, Helmuth/Oldenziel, Ruth (eds.): Cycling and Recycling. Histories of Sustainable Practices, Oxford/New York: Berghahn Books 2016, p. 202–212; Zimring, Carl A.: "The Complex Environmental Legacy of the Automobile Shredder", in: Technology and Culture 52, 3 (2011), p. 523–547.

33 Gregson, Nicky/Metcalfe, Alan/Crewe, Louise: "Moving things along: the conduits and practices of household divestment", in: Transactions of the Institute of British Geographers, 32, 2 (2007), p. 187–200.

34 Strasser, Susan: Waste and Want. A Social History of Trash, New York: Metropolitan Books 1999.

35 Zimring, The Complex Environmental Legacy; id.: Cash for your Trash. Scrap Recycling in America, New Brunswick/London: Rutgers University Press 2005; Denton,

architecture: demolition, obduracy and rebuilding have shaped modern cities and are part of urban planning.[36]

The challenge of "unmaking" technology is encapsulated in the numerous 21st-century photographs of plastic or e-waste piles and industrial ruins of our age, such as Edward Burtynsky's "technofossils" series.[37] These images also remind us of the third point, the "afterlife" of technology. Historians have yet to begin to examine the diverse legacies of "unmaking" technology – after-effects that extend into an unknown future in which the technology itself might no longer exist in its present form. While the long-term effects of technology are nothing new, by the late 20th century they had assumed unprecedented geographical and temporal dimensions – dimensions currently explored in the ongoing Anthropocene debate.[38] The 21st-century global world is increasingly lacking so-called sinks in which to dispose of all the extracted resources and manufactured products, while toxic waste legacies – such as microplastics in the sea or in our blood or the growing levels of carbon dioxide in the earth's atmosphere – have rebutted the idea of an "ultimate sink" with which we could forever unmake the made.[39] Besides, many engineering activities are intended to "repair" technological paths taken by former generations: examples range from the insulation of buildings to reduce heating energy to the latest order on phosphate recovery from sewage sludge – measures that are intended to lighten the ecological footprint of the given infrastructure; likewise, electric cars are meant to remedy the damage caused by emissions from combustion engines (see Marhold in this volume). Moreover, remediation and so called "after-care" have become genuine fields of interaction between humans and technology with the aim of "repairing" the after-effects of certain technologies. In coal areas, for instance, water regula-

Chad/Weber, Heike: "Rethinking Waste within Business History: A Transnational Perspective on Waste Recycling in World War II.", in: Business History, DOI: 10.1080/00076791.2021.1919092.

36 Hommels, Anique: Unbuilding Cities. Obduracy in Urban Sociotechnical Change, Cambridge, MA/London: MIT Press, 2008; Ryan, Brent D.: Design after Decline. How America Rebuilds Shrinking Cities, Philadelphia: University of Pennsylvania Press 2012.

37 Burtynsky, Edward/Baichwal, Jennifer/de Pencier, Nicholas: Anthropocene, Göttingen: Steidl 2018.

38 See e.g. Bonneuil, Christophe/Fressoz, Jean-Baptiste: L'Evénement Anthropocène. La Terre, l'histoire et nous, Paris: Édition du Seuil 2013.

39 Tarr, Joel A.: The Search for the Ultimate Sink. Urban Pollution in Historical Perspective, Akron: University of Akron Press 1996.

tion and evacuation work are in place and remain so even after the mining activity itself has been abandoned.

With this volume, we want to demonstrate that a temporal perspective on technology and its persistence has an important role to play in the history of technology. In our view, the "Shock of the Old" (D. Edgerton) is not only about the long and diverse technology-in-use phase; it is also about the fact that technologies remain efficacious even beyond that phase. The notion includes situations of repair and reuse as much as technology's abandonment, decay or removal and diverse forms of its "afterlife". It is only by taking this persistence of technology seriously that we can appreciate how closely the practices, structures and economies of repair, reuse and removal are interwoven and understand how they have changed over time.

FROM MAINTENANCE AND REPAIR TO REUSE AND DISPOSAL: THE SECTIONS OF THE BOOK

Repair has always been a dominant field of interaction between humans and their technologies. Production and infrastructure facilities are in constant need of maintenance to keep them running. And even the spread of new consumer technologies such as automobiles, television sets and household appliances has greatly depended on maintenance and repair services as well as second-hand markets and refurbishment shops. In our introductory essay "Rethinking the History of Repair" (Krebs/Weber, this volume) we question the common narrative of a linear decline of repair during the 20th century. Instead we argue that the long history of repairing things saw multiple ups and downs, with changing cultures of repair and DIY repair and a varying set of actors involved. Moreover, changing disposal infrastructures and changing practices of reuse and disposal have shaped the forms and intensities of repair.

As already mentioned, infrastructure such as roads and electricity grids requires constant maintenance and repair. The first section of the book, "Maintaining Infrastructures", brings together three chapters that feature different times and geographical regions. In the first chapter, Ying Jia Tan investigates the repair of China's power grid between the Anti-Japanese Resistance and the early years of the People's Republic. During this time of what he calls "perpetual warfare" a significant shift in repair culture occurred. The system builders of the Chinese electrical network were initially preoccupied with the replacement of worn-out and defective machinery. Cut off from foreign supplies, Chinese engineers had to turn to repair to make war-damaged turbines run again. During the

early years of the People's Republic two different repair cultures competed with each other: a more systematic top-down engineering approach, and more bottom-up repair practices of ordinary workers and technicians. The latter fitted well with the Party's ideology of mass mobilisation, highlighting the political significance of maintenance and repair.

The next chapter deals with another political decision that significantly changed repair cultures. In "Changing Perceptions of Repair and Maintenance", Thomas Lean describes how repair practices and perceptions of them changed after the privatisation of the British electricity supply industries. During the state monopoly period, maintenance and repair were given high priority. Drawing on oral history interviews Lean shows that engineers identified with high maintenance standards because they were delivering a public service aimed at "keeping the lights on" in the country. After privatisation a more flexible and supposedly also more efficient maintenance regime was introduced to ensure the financial profitability of the now private electricity suppliers. Although the lights stayed on, engineers struggled with the new repair practices, which were inconsistent with their identity of delivering public service.

Under the title "Business as Usual", Jan Hadlaw investigates in the third chapter maintenance and repair at Bell Telephone Company of Canada. Between the 1880s and the 1930s, the North American telephone market was divided between several companies. For these monopolistic providers the "telephone plant" encompassed everything from local loops, trunks, switches and cables to telephones in the homes and offices of their customers. Because they owned the telephone sets and private branch exchanges, maintenance and repair of the equipment was an integral part of the companies' operations. In the mid-1920s, when the first American manufacturers turned towards planned obsolescence, Bell Canada decided to expand and rationalise its repair activities. However, for Bell it was an economic rather than an environmental concern to keep its telephones in service for as long as possible.

The chapters by Lean and Hadlaw highlight how business cultures of state utilities and private companies had a decisive influence on maintenance and repair practices. They also reveal that repair regimes shaped the perceptions and identities of technicians and engineers, and that changes in repair standards challenged the self-perception of the workforce. Furthermore, Tan and Lean show the interconnectedness of political ideologies and repair: while Maoist communism enforced bottom-up repair practices, the neo-liberal privatisation of the British electricity network favoured a new short-term maintenance regime. However, the "Maintaining Infrastructures" section also reminds us that the history of technology is in need of more systematic and comparative studies on how

the maintenance, replacement and disposal of technologies in large technical systems developed over time.

The second section focuses on "Users and Repair" – house owners, car owners and professional car and bus drivers and their activities of repairing, reworking or improving technology. In "Building, Maintaining and Improving One's Own House in Soviet Samarkand", Jonas van der Straeten and Mariya Petrova explore the case of self-making and analyse building, maintenance and repair strategies for adobe courtyard houses in Samarkand. During the Soviet period and its manifold modernisation efforts, this house type, associated with private house ownership, was dominant, along with the respective traditional practices and knowledge of constructing and repairing it; prefabricated concrete apartment blocks made their appearance only at the urban margins. While the construction of adobe courtyard houses required high levels of labour and the finished houses were in need of constant care and rebuilding – not least each year after winter –, they suited local needs, mentalities and customs. In the regional tradition of collective self-help and labour mobilisation (*hashar*), male relatives or neighbours participated in the (re)building processes, while females took over caring activities such as preparing meals for everyone. By preserving their traditional material environment through constant building and repairing, the residents of Samarkand also maintained their pre-Soviet cultural identity in Soviet times.

In his chapter "Maintaining the Mobility of Motor Cars: the Case of (West) Germany, 1918-1980", Stefan Krebs investigates maintenance and repair as a central part of automobility. Mobility has always been (and still is) at the heart of car consumption. A motor car would lose its use value as a consumer item, at least temporarily, in the event of a breakdown, and the exchange value of a broken car would be lower if it were sold. So maintenance and repair to prevent or remedy malfunctions were necessary and recurrent moments in the consumption of an automobile. However, car repair also became a leisure activity in the interwar years and especially in the post-war period, when members of the working classes started to own automobiles. Self-repair was cheaper than taking a car to a professional garage. Furthermore, self-repair also served as means to shape and foster male identities as skilled and knowledgeable amateur mechanics.

As Karsten Marhold demonstrates in his article "Of Buses, Batteries and Breakdowns: The Quest to Build a Reliable Electric Vehicle in the 1970s", engineers from a German and a French electrical utility company saw battery maintenance as a major challenge in constructing an electrical car for daily use. For them, reliability ranked higher than performance, and batteries were the key issue here since charging and changing batteries required regular inspections and knowledgeable care. However, drivers tended to charge and discharge the batter-

ies of their electric car in sub-optimal ways, a fact which further complicated the battery maintenance issue. While questions of maintenance thus shaped innovation processes, engineers did not take into account the battery's afterlife and disposal, even if contemporary batteries had relatively short life cycles. Dismantling and disposal were and still are barely taken into account in innovation and production.

The third section of the book, "Reuse and Conservation", looks at two examples of the persistence of apparently obsolete technology. In "A Bargain or a 'Mousetrap'? A reused Penicillin Plant and the Yugoslavians' Quest for a Healthier Life in the Early Post-war Era", Sławomir Łotysz investigates the transfer of a Canadian Merck penicillin plant to Yugoslavia – a plant that was actually worn out and had an obsolete design. Łotysz scrutinises the different arguments of the Yugoslavian officials and engineers who insisted on acquiring a second-hand plant instead of accepting an offer from UNRRA for new equipment. This historical case also highlights the long "lifespan" and persistence of technology in basic and heavy industries.

David Lucsko studies a completely different case: that of old cars. In the chapter "'Proof of Life': Restoration and Old-Car Patina", he traces the history of a new trend in old car restoration. For many years old car enthusiasts tried to refurbish their cars to factory-new conditions, but since the early 2000s some of them have started to proudly display the faded paint, patches of rust and worn and stained upholstery of their restored cars. In this example the persistence of old technology is, of course, driven by very different motives as these cars became fashionable and precious collectibles long after they had become obsolete and were put out of use. The paradox identified by Lucsko is that the "patina" cars are carefully repaired "time capsules" that are perceived by their owners as being more original than their "factory-new"-restored counterparts, despite the fact that they were obviously not worn out when they were new.

Both chapters highlight that the persistence of technologies and their potential cascades of use depend not only on economic and technical factors but also on cultural and ideological circumstances. The history of obsolete technologies that are still used and valued by some actors can help improve our understanding of the different temporalities of technological objects.

The final section, "Obsolescence and Disposal", sheds in its two chapters light on the close interrelatedness of production, repair, reuse, recycling and removal. It tackles the question of what comes after repair and why the option of repair is sometimes rejected when decisions for final removal are taken. Moreover, the section underlines that the temporalities of technology do not end with removal and that technology's "unmaking" might have an "afterlife".

In her article "Mending or Ending? Consumer Durables, Obsolescence and Practices of Reuse, Repair and Disposal in West Germany (1960s–1980s)", Heike Weber tackles changing practices of "mending" and "ending" in West Germany through the lens of contemporary bulk waste collections, repair services and popular repair booklets, and the planned obsolescence debate that erupted in the early 1970s. By the 1960s, the FRG had turned into a mass consumer society. In the ensuing years, the American model of a "throwaway society" was widely criticised, and in the 1970s an environmental awareness took hold, at a time when the public discourse also included major criticism of the "planned obsolescence" idea. Nevertheless, it was during this critical period that West German consumers considerably changed their practices of care and divestment with respect to consumer durables. Repair and reuse did not disappear, but the majority of consumer durables were eventually sorted and discarded via bulk waste collections – thereby redefining the "durability" implicit in the term "consumer durables" as merely a modest number of years.

Diverse cascades of use, even forms of reuse at the stage of dismantling and disposal, are highlighted in the contribution by Ayushi Dhawan, who also reflects on issues of interregional transfer and the afterlife of technology. In her article "The Persistence of *SS France*: Her Unmaking at the Alang Shipbreaking Yard in India", she takes a close look at the widely discussed topic of ship dismantling which for nearly all the world's ships happens on a few stretches of the Indian and Bangladeshi coastlines. Ships often have a very long lifespan and Ayushi Dhawan follows the example of the *SS France* through her many stages of life, starting with her initial use as a famous French ocean liner and her reuse as a Caribbean cruise ship (as the *SS Norway*) and ending with her scrapping as the *SS Blue Lady* in the Alang Shipbreaking Yard. Her story contains many sad ironies. The ship was – illegally – sent to be scrapped after a boiler accident, a consequence of both material fatigue and poor, even careless maintenance and inspection. While her legal decontamination and disposal in accordance with the European Waste Shipment Regulations would have incurred high costs, Indian court authorities decided that her unmaking at the Alang Yard would provide both jobs and reusable asbestos for local building purposes. So although the life of the ship thus came to an end, parts of the *SS France* still persisted – whether in the form of reused steel, cutlery, clocks or fire extinguishers sold at the local second-hand markets or waste dumped at the local landfill. Dhawan sums up that the arduous unmaking represented a process that was "toxic and life-giving at the same time".