
Transformations of Infrastructure Systems

Report of the second International Conference of the Research Training Group KRITIS at the Technical University Darmstadt, Germany



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Abstract

On the 4th and 5th of November 2021, more than 50 scholars from different disciplines and countries came together in an online conference to discuss the multiple aspects of **Transformations of Infrastructure Systems** at the second international conference organized by the **Research Training Group KRITIS** at the Technical University of Darmstadt, Germany. The focus of this conference was on the dynamic and changing nature of infrastructure systems and describing, understanding, and explaining transformation processes of infrastructures. Within the four multidisciplinary panels (Safety, Cultures, Governance, and both Temporality and Spatiality) the participants shared their research and knowledge on various aspects of transformation of infrastructure Systems. The conference gave an insight into the triggers of transformations and highlighted the conditions under which they take place and the consequences. The keynote lectures by Prof. Dr. Timothy Moss (Humboldt University of Berlin), Dr. Anique Hommels (Maastricht University), and Niklas Vespermann (Federal Network Agency, Germany) further highlighted and deepened the aspects relevant to this context.

Keynote Lecture by Timothy Moss: “Navigating Messy Histories of Urban Technology: Berlin, 1920-2020”

In his talk, Prof. Dr. Timothy Moss provided an insight into his most recent book “Remaking Berlin”: A History of the City through Infrastructure”. The book explains the infrastructural change in Berlin from 1920 to 2020 grounded on two well-known concepts: Large Technological Systems or LTS (Hughes, 1983) and socio-technical transitions (Geel / Schot, 2000), and at the same time develops a concept which allows to grasp the ambiguousness of urban infrastructural development. After all, in Berlin’s 100 years of infrastructural history, Moss argues, one can find features of both path dependency and sociotechnical change, as well as features and examples that fit neither picture. Moss conceptualized those “misfits” that don’t fit into one or the other concept as “historical assemblages.

Moss began his keynote by presenting the two dominant concepts in the context of the notion of technological change. In Berlin, when looking at infrastructure, one can find both: **Aspects that fit the LTS perspective as well as aspects that fit the perspective of sociotechnical transition. At the same time, there are aspects that fit neither categories.** For example, the material persistence of the city’s physical networks like sewers, water mains, etc. fits the LTS perspective very well. Another example for persistence would be the lasting appeal of the build-and-supply management logic of

infrastructures that lasted across all of Berlin's political division. Another persistent tradition according to Moss is the obduracy of fossil fuels in the city's energy mix.

Nevertheless, the LTS-perspective has strongly emphasized path dependencies (self-reinforcing mechanisms of system components sustaining infrastructures against radical change) and "lock-in", and not so much on processes of change. Changes in technologies and technological systems can be better explained by the model of socio-technical transitions, a concept developed by Jan Geel und Johan Schot (2010) to theorize the emergence and manifestation of technological innovations by taking a **Multi-Level-Perspective (MLP)**. **Empirical findings that fit the sociotechnical transitions narrative can be found in Berlin's infrastructural history, too. There are various changes that happened during its 100 years of integrated infrastructure in *Groß-Berlin*:** Moss names the shift from coal to oil and gas as the main energy sources and certain narratives in the context of infrastructural services.

Moreover, in Berlin, one can find quite a few examples of changed infrastructures and changed practices of use that cannot be categorized in either one or the other theoretical explanatory pattern – those "misfits" that Moss named "Historical Assemblages". This comprises for example "Elektrissima", an instalment payment system for electricity bills and household appliances by the local energy supplier BEWAG. It was enrolled in different kind of assemblages and served different purposes in different times of Berlin's energy history: It was used for promoting electrification and household appliances during the mid 1920s, for directing consumption away from peak times in the late 1920s, offsetting the dramatic drop in industrial power use during the early 1930s, serving the war effort in the late 1930s and showcasing consumers in West Berlin (mid-1950s). Another example would be the idea of an underground gas storage system below Grunewald, that survived, although slightly adapted to the circumstances of the time, the various regimes since the time of the cold war. Moss' third example was the practice of pumping water out of the surrounding lakes to maintain groundwater levels in Berlin stable in reaction to changing demand by households and the industry by. According to Moss, this is practiced since the 1880s and it is actually quite contested.

To fully understand the dynamics of urban infrastructures, it is important to also look at those "misfits", that don't quite fit into the dominant narratives. It is about disassembling and reassembling the objects of interest, broadening the look and taking into account all kinds of aspects of infrastructure. Moss concluded his talk by suggesting this could be done by moving away from the dominant systems or also considering the urban hinterland.

Panel "Safe Transformation"

The first Panel of the Conference, moderated by Prof. Dr. Florian Steinke (Technical University Darmstadt), dealt with the aspect of Safe Transformation. Given the dynamic nature of infrastructures, change can occur as rapid and comprehensive changes in one or more interconnected systems. But compared to incremental changes that represent the "day-to-day" business of adaptation and repair, profound changes seem riskier for an infrastructure system because they change the fundamental parameters of its operation.

Therefore, one might assume that transformation increases the risk of instabilities, failures, or breakdowns and that the safe operation and continuous functioning of a given system are of fundamental importance for transformation processes. With regard to the potential threats posed by transformation, it should be noted that concepts and strategies for infrastructure security and protection must be as dynamic and adaptive as the infrastructures themselves. In this context, this panel explores the question of whether infrastructure systems become more vulnerable as a result of transformations, or whether and under what circumstances transformation can lead to more resilient infrastructure systems.

In her presentation "**How to Govern the Transformation to Resilient Digitized Energy Systems**," Sanja Stark (University of Oldenburg) discussed the benefits and vulnerabilities associated with the integration of ICT technologies into the existing energy system and what (policy) measures need to be taken to make digitized energy systems more resilient. She emphasized the increasing complexity of managing energy systems due to the integration of decentralized renewable energy sources, changing consumption patterns, and the ongoing digitization of the overall system. This requires a paradigm shift from focusing on resilience instead of mere robustness, where the goal is to avoid known risks that can lead to power outages. In contrast to robustness, the goal of resilience is to be prepared for unknown incidents and to promote rapid recovery, especially in the event of cascading outages, which are more likely as the power system becomes increasingly interconnected. Stark, therefore, proposes several measures: The interactions between ICT and the power system must be understood and managed through continuous analysis and the establishment of communication rules. In addition, cybersecurity must be systematically introduced, and standardization will help improve grid stability as more (small) devices are integrated. Finally, long-term risks need to be institutionalized and the level of resilience assessed on a regular basis.

Alexandros Gazos (Karlsruhe Institute of Technology) applied a socio-technical perspective to critical infrastructures in times of crisis, as indicated in the title "**Resilient Transformations of Critical Infrastructures in Crisis**". Similar to the previous presentation, Gazos acknowledges the increasing complexity of systems, but conceives the concept of resilience as a "refuge of operators and regulators". Inspired by the literature on "transformative autogenesis", he emphasizes that resilience should be understood as "a continuous operation of transformative processes" and thus constitutes both persistence and transformative capacities. The presenter points out that social actors and technology maintain the continuity of operations in critical infrastructures by transforming them in response to critical events (crisis). How this transformation affected the core of critical infrastructure can only be assessed after the transformation happened ("after the fact"). The occurrence of a crisis therefore shapes the fabric of critical infrastructures and what constitutes resilience in a distinctive way. In conclusion, Gazos emphasizes the benefits of crisis assessment, which can help approximate the emergent quality of an event. The crisis serves as a point of reference to better understand complex interconnections, and its assessment provides a basis for defining resilient transformations.

Following these theoretical contributions to the panel, the practitioners Jan Hoff (E. ON Digital Technology GmbH) and Paul Weissmann (Insignals GmbH, openkritis.de) presented their concept of an infinite loop of oscillation between resilience and fragility of critical infrastructures in the energy sector. In their talk "**An Infinite Loop - How Transformation and Digitalization Create New Fragilities in Critical Infrastructures**", using a review of technological innovation in the energy sector over the past 30 years, they identified four drivers of infrastructure fragility - government regulation; the influence of the corporate sector and society; emerging technologies; and their convergence (e.g., the switching from separate data and telephone lines to a shared line). They conceptualize the interconnectedness of transformation, the emergence of (new) vulnerabilities followed by a new state of resilience until, eventually, new changes lead to new vulnerabilities again, as a "loop". The vulnerabilities created by such changes facilitate new actions taken to bring systems back to an acceptable level of resilience - until, at some point, new changes lead to a new iteration in this cycle. As changes accelerate, so does the speed of these loops. In their view, changes are accelerating and thus increasing the speed of these cycles.

Consequently, they pose the question of how to break this cycle. The speakers call for improving anticipation and adaptation to future change - rather than dwelling on the status quo or the past, as most current policies do. They see two measures as critical to increasing resilience in the future - continuity management and safety by design. As the ensuing discussion made clear, it is particularly difficult to find good (government) incentives for the latter.

Concluding the Safe Transformation panel, Dr. Brian Nussbaum (University at Albany) presented in his talk **“Learning about the Transformation and Digitalization of Infrastructure from a Cybersecurity Pioneer”** a case study of cybersecurity pioneer Dan Geer on infrastructure transformation and digitalization of infrastructure. Dan Geer has collected a magnitude of knowledge and experience in IT security throughout his career, which began in the 1970s, and has been involved in several large-scale IT projects, management, and consulting. He points out that security (of critical infrastructure) is not about preventing, but being able to manage any unexpected scenario in the future. Especially in the era of interconnected systems, the transitivity of dependency on IT infrastructure is amplified (e.g., if a cyberattack blocks a fuel pipeline, resulting in a collapse of fuel supply and affecting everyone who relies on fuel, regardless of one’s attitude toward IT systems).

Nussbaum emphasizes that in Geers’ view, increasing interdependence introduces a level of complexity that makes it impossible to measure the associated risks and ultimately leads to their underestimation. In particular, a longer latency period between critical events leads to an increased feeling of safety, thereby reinforcing a positive feedback loop. To counter this, current incentives in economics must be aligned to improve security and resilience.

Panel “Cultures of Transformation”

The panel “Cultures of Transformation” was moderated by Prof. Dr. Martina Heßler, TU Darmstadt (Germany), and focused on the questions **if cultural drivers can lead to transformations of critical infrastructures** and **whether there are cultural factors that impel transformation**. The contributions in this panel explored the interactions between social/cultural transformation and the transformation of infrastructures.

While some panelists focused on the transformation of infrastructures as a consequence of cultural changes in society, other speakers mainly analyzed the impact of infrastructures on socio-cultural change.

In the first presentation of the panel, **„The Role of Wayfinding Systems for Pedestrians in the Functional Transformation of Urban Mobility Infrastructure”**, the Urban Planner Anna Yukelson focused on the development of pedestrian infrastructure. The presenter introduced the case of the wayfinding system for London, the Legible London Pedestrian Wayfinding System, which was operated by Transport for London since 2007. With the motivation to facilitate the mobility until the Olympics in 2012, the city council of London implemented a new wayfinding system for pedestrians to promote walking as a mode of mobility in the inner city. First, with a prototype in Bond Street, the plan was to introduce maps on the walkways; including information on predicting journey time and navigational information, Yukelson interpreted the “Legible London” project, which was implemented to facilitate public transport, as a trigger for a deeper, structural change in the way people, tourists and citizens, move around the city. In her presentation, she showed how wayfinding signs were used as a tool to encourage pedestrian traffic. Through measures like introducing maps on pavements that also included information on distance and walking times, signs (the so-called “monoliths”, “megaliths” and “miniliths”) that indicated routes and helped pedestrians orientate themselves, and the use of common route colors to make signs recognizable, a transformation of mobility practices and the transport infrastructure could be initiated. The placement of this artefact not only facilitates the movement within the mobility infrastructure but becomes part of the infrastructure itself.

Another example of how transformation of infrastructure “from above” can be used to change socio-cultural practices was given by Chaitali Dighe (TU Darmstadt). In her talk on **„Smart City**

Strategies as Transformation Campaigns: Cases of Singapore and India”, the presenter explored how smart city strategies are used as transformation campaigns in India and Singapore. Both governments aim to improve their urban infrastructure by introducing digitization to accelerate a socio-technical transformation. Dighe showed how the smart city strategy does not consider socio-cultural aspects of infrastructural transformation. The case study in India displays a problem in the governance structures in urban local authorities. Due to a model of institutional coordination and the lack of participation and representation of cultural groups and practices, development did not consider and reflect the socio-cultural reality of users. This is contrasted with understanding the smart city strategy as part of a broader transformation of society towards a digital society as it was done in Singapore. There, the government's initiative focused on empowering society to “become digital”, for example by promoting digital literacy among the elderly and children. But there, strategies to include the cultural reality of users failed again, because some major groups of users, such as migrant workers, were left out. In conclusion, Dighe argues that infrastructures can influence the socio-cultural structure of a society, but equally, culture influences the development and change of infrastructures. In saying so, it is obvious that cultures are not static constructs, with no influences or interconnections outside their frame.

The role migrants play in transforming infrastructure was also the topic of the presentation by Youcao Ren from the School of Environment, Education, and Development at the University of Manchester. In her talk **“No more night pots: Migrants’ perception of appropriate sanitation and the changing public toilets in central Shanghai”**, Ren focused on migrants' perceptions of adequate sanitation and access to public toilets in central Shanghai. The city’s rapid demographic and infrastructural growth, can be seen by the modernization of new buildings and flats. The new residences are equipped with individual toilets, what can be seen as a novelty, since private access to sanitation is not common in old buildings. In the old part of the city, sanitation infrastructure mainly consists of public toilets. Since 1950, infrastructural connectivity has remained the same, making the use of night pots and waste collection stations an everyday norm even if the cultural perception of the use of night pots might differ according to the user group. Old-established residents see this practice as traditional, while new residents see it as unhygienic and try to limit toilet use to the opening hours of public facilities. In 2015, there was a government approach to improve access to public toilets, part of an initiative to boost tourism, but with no intention to change everyday practices. Ren closes her presentation with a remark about the role of gender for the research: “there is a gender inequality, cleaning and emptying the night pot is a female task, there is a superstition, that it brings bad luck if men touch the night pot – woman have much voice in this topic and are the driving force in changing the connectivity”

The panel closes with the Jan Hansen’s (Humboldt University of Berlin (Germany) presentation **“Open Ditches, closed pipes, and the making social order in L.A. 1860-1900”**. Hansen examined the changing of user’s practices and accessibility to water infrastructures in Los Angeles. Hansen was able to show how infrastructures became spatialized, perpetuating segregation and marginalizing user groups that relied on traditional water infrastructures. The example of the ditches, called “zanjas” allows us to see the attribution of infrastructures and how they changed from being important for cultural life to a marginalized infrastructure that also segregated its users when other, more elaborate, and above all, private infrastructure systems emerged. The ditches changed from something that was seen as necessary for water supply and cultural life to an inferior infrastructure that contributed to the marginalization of certain social groups that had no other access to water. As a result, those who were excluded from the new water supply system were seen as unhygienic and became even more discriminated against. With this example, Hansen showed how infrastructures can be used as a power tool to exclude and discriminate by aspects of race and class.

Keynote Lecture by Anique Hommels, Maastricht University: „Infrastructural Responses to Crisis: The role of temporary Infrastructure in the attempts at permanent urban transformation“

In her presentation, Dr. Anique Hommels, Associate Professor at the Faculty of Arts and Social Sciences at Maastricht University, talked about **how infrastructures respond to a breakdown in society**. Her example of that is the so-called “Pop Up Bike Lanes”, the temporary cycle infrastructures that emerged at the beginning of the Corona crisis in many cities – from Bogota to Berlin and even small and middle-sized cities.

During the corona pandemic in 2020 and 2021, many cities were in lockdown for at least a number of months. Due to high population densities, cities are often considered as hotspots of COVID-19 infections, and mobility of people, in particular, is seen as a major factor contributing to the spread of the virus. As crises have often had a major influence on choices made in infrastructure governance (see Högselius, Hommels, Kaijser, and van der Vleuten, 2013), this lecture discussed how (infrastructural) transformations and adaptations emerged in cities in response to the COVID crisis. Building on Science and Technology Studies, social practice theory (Shove, Pantzar & Watson, 2012), and infrastructure research, Anique Hommels analyzed how the values, policy ideals, materialities, and competencies embedded in urban infrastructure before the COVID crisis, became re-negotiated, challenged and (provisionally) changed during the crisis. With that, she aimed to make a critical contribution to the often-made claim that “the COVID crisis entails an excellent opportunity for planners and policymakers to take transformative actions towards designing cities that are more just, resilient, and sustainable.” (Sharifi & Khavarian-Garmsir, 2020). What is the role of temporary infrastructure in attempts at permanent urban transformation?

There are many examples of pop-up bike lanes from different European cities. The arguments from officials to imply those temporary protected bike lanes were often similar: they would remove existing bottlenecks, lead to an increase in bike use, and are a way to achieve a “healthy city”.

These pop-up bike lanes are temporal interventions, implied under very special circumstances. This idea of temporal interventions is often referred to as “Hacking the city” (de Lange & de Waal, 2019) or “Tactical Urbanism” (Lydon & Garcia 2015) – small temporary intervention to achieve urban change. But the problem with these temporary interventions is, that they often get removed when a crisis is over, plus: after a crisis, there’s a tendency to go back to “normal” and give up the temporary spaces created during the crisis (Deas, Martin & Hincks 2020; Colomb 2012). They are often taken over by commercial interests, too. So how can they transform into obdurate urban elements that can be permanently integrated into the urban fabric? Following Elizabeth Shove’s practice theory, Hommels argues that temporary cycling infrastructure has a chance to become permanent if meanings, materiality, and competences are successfully aligned. For a better understanding of obduracy – as an enabling as well as constraining aspect of innovation – promises to be relevant for resurrecting dormant but yet not dead remnants within as part of more sustainable systems of the future. We have to understand urban/societal “pockets of persistence” (Schipper 2020). User routines or materiality are often such persistent elements, that are quite obdurate.

How can pop-up bike lanes become a stable social practice? How can they become more persistent than the “pockets” of motor-vehicle mobility? Pockets of automobility are more likely to persist, argues Hommels – unless pop-up cycling lanes can enhance and retain their material obduracy, can be better embedded in the overall urban infrastructure, get better aligned with cycling competencies, are supported by shared urban imaginaries and meanings and become part of collective memories and experiences that can be revived.

Keynote Lecture by Niklas Vespermann: “Assessing Critical Infrastructure: A Regulatory Perspective on the Power and Gas Sector”

The second day opened with the keynote by Niklas Vespermann from the German Federal Network Agency (“Bundesnetzagentur”) who presented a national regulator's perspective on the status, challenges, and further development of the regulatory framework for safe operations of critical infrastructures, drawing on the example of the power sector. Vespermann highlighted the kind of challenges actors are confronted with when managing transformation processes *and* keeping the system in working order at the same time. Following this, the presentation revolved around the question **“How to ensure the secure operation of the power and gas sector, while changing the system at heart?”**

Vespermann began his presentation with a brief overview of the history of the power sector. He points out that it is an infrastructure system that has undergone many profound changes since Thomas Edison built his first complete power system in 1882 and, again today, it is experiencing a major shift, namely from fossil to renewable energies. At the very beginning, it was the case that single companies served the whole supply chain. This status remained more or less unchanged until the 1990s when more competition was desired.

In general, power systems are confronted with different challenges in cases of interruptions or breakdowns: “storing” of electric power is not feasible yet, which means that supply must always meet demand in the power grid; breakdowns can lead to cascading effects that threaten power infrastructures. Vespermann further stressed that the decarbonization and decentralization will lead to a profound change of the whole system.

The National Network Agency has various ways of securing stability: One is a model-based assessment which basically means setting up scenarios and determining their impact on supply, and the second, is the regulatory security of supply that addresses critical infrastructure and uses the measures of resilience regulation and cyber security.

Resilience regulation describes the process of defining the critical elements of a system and continuously reassessing their regulation and keeping the criteria for criticality updated. That also means including new elements or adjusting the threshold of those criteria. Vespermann pointed out that resilience strategy is yet to be finalized.

Cyber Security, however, consists of three dimensions: *Prevention*, *observation*, and *reaction*. For the Federal Network Agency, *prevention* is the most important part of securing a stable system, whereas *reaction*, for example, falls more within the remit of the Federal Cyber Security Authority. *Prevention*, in this case, means defining cyber security standards and to cooperate with the federal cyber security authority to obtain customized system security. *Observation* consists of continuously analyzing current vulnerabilities as well as communicating on the cyber security status to raise situational awareness. The dimension of *reaction* contains measures like analyzing security incidents in cyberspace and reporting on security issues to classify cyber security incidents.

Despite those security measures, there are still open questions when it comes to securing power supply systems, says Vespermann. These relate to the question, of whether it is possible to incentivize resilience and cyber security in a market-based manner and to which extent decentralization can serve as a resilient mechanism as well as the question of future vulnerabilities that come along with the energy system transformation due to the decarbonization.

Panel "Governance of Transformation"

The following panel "Governance of Transformation" was moderated by Prof. Dr. Michèle Knodt (Technical University of Darmstadt). This panel addressed the question: How are transformation processes governed and how do different (groups of) actors influence these transformation processes? The assumption here is, that transformation involves different (groups of) actors and that such groups affect different levels and elements of infrastructure systems themselves. Therefore, in this panel are included empirical and theoretical contributions that address different modes of governance for infrastructure transformation.

In the first panel presentation, "**Repoliticizing Infrastructure? Intermediary Power and Everyday Governance Practices in Neighborhood Water Supply Transformation: The Case of a Small Town in India**", Suchismita Chatterjee, a Ph.D. candidate at the Tata Institute of Social Sciences (Mumbai, India), discussed the role of intermediary and non-state actors in transforming water infrastructures in Baruipur, India. In doing so, the presenter highlighted the link between everyday governance and the framework of political urban ecology to understand the idea of "governance of transformation" through water infrastructures. Chatterjee examined the neighborhood ("Para" in Bengali) level to explore how power operates on the ground with the following objectives: to understand 1) water infrastructure as a socio-technical configuration, 2) the neighborhood as a socio-spatial construct, and 3) local councilors as "rule makers" in contrast to "club boys" as a social construct. Her findings suggest that local councilors are the "decision-makers" who play an intermediary role between the city government and citizens (Kadfak 2019; Roy 2002). They are locally elected representatives who are the critical decision-makers in municipal water supply concerning the 'where, when, to whom, and how' of the city. They often have political interests, and accordingly, their (political) strategy is the visibility of infrastructure along with the assessment of public opinion, established habits, and customs in the neighborhood. However, the real influencers are the neighborhood "youth clubs," led by the "boys" of the club and the "dadas" (big men) of the party, who act as intermediaries between the local political leaders and the residents. They often have their delineated areas of power in the neighborhoods of the city. Local councils are often at the mercy of these clubs when it comes to carrying out installation or relocation work. In summary, power does not necessarily reside with the state, but also with individuals, local youth clubs, party members, etc., and the question can be asked whether infrastructure is being depoliticized by locally based power brokers.

Following the different levels of transformation through governmental structures, Eline Punt, a Ph.D. student at the KRITIS Graduate College of TU Darmstadt (Germany), presented "**Digital Transformation: Rethinking the Governance of Cyber Risks at the Port of Rotterdam**", based on identifying the key governance challenges in building cyber resilience at the Port of Rotterdam, in the Netherlands. The presenter first defined digital transformation (of seaports) as a process that aims to improve an entity through significant changes in the communication technologies of its property - e.g., from pioneer to container ports, and then to fully automated ports as well as smart ports. Rotterdam was selected as a case-study because of a cyber resilience program, that was already launched there in 2016, and the Netherlands has also established a National Cyber Security Center (NCSC) that provides cyber threat information to critical infrastructure providers. The main challenges identified in the Port of Rotterdam's digital transformation were 1) lack of awareness of cyber resilience due to lack of skilled staff and focus on physical security, 2) diversity of stakeholders leading to intra- and inter-organizational coordination, 3) communication gap between the digital world and business operations, 4) desire to maintain a balance between efficiency and cybersecurity measures which is particularly the case for critical infrastructure because of the importance of continuity of services and lastly 5) legislation not being able to keep up with digital transformation meaning lack of regulatory requirements for the entire maritime sector, as the legal framework, only applies to a selection of companies in the port area. Punt concluded that the implementation of new governance structures varies greatly depending on the local institutional

landscape (Ng & Pallis, 2010) and that the way forward after identifying these challenges is now to determine what role institutions can play in addressing these governance challenges.

The third presentation, "**Communing Infrastructures: Governing the Maintenance of Civic Roads in Sweden**," by Alexander Paulsson, Ph.D., and Jens Alm, Ph.D. of Lund University (Sweden), was based on a larger MISTA-funded research project: smart technologies and how they can be used in infrastructure. The presenter began by introducing roads as "common property," highlighting the importance of these networks in daily life and the importance of maintaining them for modern societies. Initial research revealed that Sweden has a vast municipal road network (accounting for about half of Sweden's total road network) that is managed by countless small associations. This led the researchers to examine how road associations in Sweden manage the maintenance of civic roads in the context of climate change, urban sprawl, broadband infrastructures, and (new) knowledge about road maintenance itself. Conceptualizing roads as common property and road associations as self-governing bodies provided a theoretical basis for empirical studies and data collection. The municipality of Vellinge, located south of Malmö was selected for empirical data collection. The results of the study show that road associations receive their money from membership fees to finance maintenance, which is often insufficient; moreover, they cannot borrow because they do not function as a legal entity. The conclusions - 1) Roads as common property: the infrastructure belongs to the members of the road associations and is maintained by them, but the use is allowed to all. 2) Road infrastructure maintenance is enmeshed in local politics: The road associations want the community to take over the roads as roads are multi-layered infrastructures where too many things happen on, under and along them for the road associations to keep up with.

Finalizing the panel, the presentation "**Polyphony without Power: The Case Study of the Committee of the River das Velhas**" by Ana Claudia Teixeira, Ph.D., University of São Carlos (São Paulo, Brazil) explored the role of participatory governance institutions in the transformation of infrastructure systems using the example of watershed committees in Brazil. The study area is the intersection of the Belo Horizonte metropolitan region and the watershed of the river Rio das Velhas. Preliminary findings show how the Brazilian legal framework includes several participatory institutions, namely the River Committees, which were created to address sanitation and electricity issues. However, the capacity of these committees to play a transformative role is quite low. An empirical study of the Rio das Velhas River Committee found that government and social technicians such as the Engineers Association and the Water Company dominate the committee, while the participation of residents' organizations is low. In the first 10 years, the committee focuses on self-regulation, self-governance, and administrative management. The committee's management and work show that, contrary to bibliographic claims that these spaces are "domesticated" and offer little room for real social conflict, there is indeed room for conflict over concessions, risks of dam breaches, mining, and more. The committees have conducted several campaigns to raise awareness and mobilize society. The presenter concluded with questions for future research: Why does Brazil have so many participatory laws but problems with implementation? How can participatory processes be made less missionary and less top-down? Finally, consideration should be given to how not only the absence of infrastructures but also their presence can create inequalities (Iossofova, 2021).

Panel “Temporality and Spatiality of Transformation”

The last Panel of the Conference moderated by Prof. Dr. Jochen Monstadt (Utrecht University, Netherlands) addresses the view, that changing infrastructures does not only involve transformations of the spatial relations within an infrastructure network, namely the spatiality of infrastructures but also stipulates much broader and extensive spatial transformations. Additionally, infrastructures do not only mediate space but they also have varied temporalities and mediate *time*. This panel spans over various aspects of temporality and spatiality of transformation by asking questions like “*How and in which contexts is temporality relevant for transformation?*”, “*How can we understand temporalities of continuity and change in infrastructural transformations?*”, “*What is the relationship between transformation and durability?*”

The first contribution by Dr. Bregje van Veelen and Dr. Magdalena Kuchler (both University of Uppsala) focused on the ‘unmaking’ of high-carbon materialities and various heterogeneous temporalities underpinning processes of unmaking. In their presentation “**Anticipating disappearance? Towards a Heterotemporal Understanding of ‘Unmaking’ High-Carbon Infrastructures**” they put forward a **conceptual understanding** of “phasing out” high-carbon infrastructures by their newly introduced concept of *heterotemporalities*, which draws on Foucault’s notion of *heterotopias*. The concept of heterotemporalities enables us to reconsider the process of infrastructural unmaking. The core question “How can foregrounding “multiple temporalities” open up new ways of understanding the process of phase-out or ‘unmaking’?” was shed light on through three dimensions that bring the material and the temporal together – **Ruination, deferral and suspension, and lingering and obduracy**. The anthropological literature shows us, that ruination can be understood, not as an externally triggered event, but as the idea that something which is already embedded in infrastructure – that infrastructures are always and already on the way to becoming a ruin. The dimension of deferral and suspension challenges the idea that infrastructures have plot lines or a time scale that can be neatly measured. Instead one can find a lot of openness in infrastructure. The last dimension of lingering and obduracy questions the idea that the phase-out of infrastructures has an endpoint which marks its completion. Instead, they argue, infrastructures always have a material or social afterlife. The lens of lingering and obduracy sees the future neither as a utopia nor a dystopia but rather emphasizes the *ongoingness* of the present and how the present and future are connected.

Laura Höss, Ph.D. candidate at KRITIS Graduate College, TU Darmstadt (Germany) gave an insight into her ongoing PhD-project and presented empirical findings about the transformation of energy and mobility infrastructures in the region of Leipzig in East Germany from 1980-2000. In her presentation, “**Changing the System, Changing the City? Infrastructural Transformation in Leipzig and its Spatial Implications after the ‘Wende’**” she spoke about the transformations that local energy infrastructures went through and the spatial restructuring of the city that came with it as well as the temporal dimensions that characterized those processes of transformation. Höss presented spatial aspects of the transformation processes that happened in the south of Leipzig due to lignite mines growing close to the city. However, the Wende of 1989 and the shutting down of open-cast lignite mines and power plants ultimately also led to a reorganization of space as well as a change in the spatial hierarchy in the Leipzig urban area. Concerning the temporal aspects, Höss pointed out that those transformation processes were supposed to happen much earlier because the majority of the inner-city power plants dated from the beginning of the 20th century and had long since passed their life cycle in the 1980s. It was due to political decisions of the SED leadership at the end of the 1970s and beginning of the 1980s that favored lignite as a domestic raw material. It thus initiated a “turning away from the turning away” from brown coal as originally planned and cemented the development path of the GDR energy supply and its infrastructures for the next decades. She further stressed that the velocity of those transformation processes changed over time. As the life cycle of power plants and lignite, in general, had been

excessively stretched during the socialist rule, the transformation accelerated after the end of the regime. Thus, the social and political framework conditions must permit *transformation*.

Höss draws several conclusions from her findings: it becomes clear how political power is expressed in the production of temporality. Life cycles of technologies can be artificially extended if politically desired. Further, besides spatial aspects of infrastructure transformation, looking at temporality can help to gain a more profound understanding of the mechanisms at work during infrastructure transformations. Finally, this case example shows, that *incremental changes do not necessarily add up to one fundamental transformation*. On the contrary, it seems that incremental changes rather had a stabilizing effect on the energy system.

Dr. Delljana Iossifova's (*University of Manchester*) talk "**The Agency of Infrastructural Formations in the Transformation of Spatial Patterns and Rhythms of Everyday Life**" looked at infrastructures from the perspective of the home. Sometimes, activities associated *with* the home actually take place outside the home as is the case in her case study about Shanghai's sanitation infrastructures. To begin with, Iossifova pointed out that it is necessary to add to the socio-technical definition of infrastructures the notion of the 'ecological': Infrastructures are *socio-eco-technical* as they also tie humans and nature into a global capitalist transaction. In the case of Shanghai, the non-availability of functioning (sanitation) infrastructure *inside* the dwelling contributes to how residents use infrastructures *outside* of the dwelling (emptying pots of fecal waste at waste collection stations): There is a creation of social connectedness and socializing, that extends the "home" beyond the four walls of the dwelling. As opposed to this, Iossifova mentions, that modern building complexes are serviced by very different infrastructure systems, which points out that infrastructure may reinstitute social injustices over time. Also, the expansion of sanitation networks and infrastructure to provide universal coverage and modernization of technological infrastructure is often associated with increased extraction of resources – in this case energy, and water. Talking about transformations not being linear, Iossifova stresses that they overlap, happen incrementally, and we see the contiguity of different stages of infrastructural development. Moreover, older types of infrastructures continue to co-exist alongside new infrastructures. This coexistence of infrastructure produces an infrastructural *space-time entanglement* that could not otherwise exist without infrastructure agency, production, and reproduction. China's high-speed urban transition from the old night pot and waste collection system to a convenient, potentially wasteful system entails the contraction of the home to the boundaries of the dwelling due to the new infrastructures being located and accessible *within* the home. They free up time for other activities but they *also* contribute to the *compression of entire lifeworlds*, as she noted in the conclusion.

In his presentation **Infrastructure's Temporal Modalities: A(nother) framework for analysis**, Jean-Paul Addie from Georgia State University made an appeal to position time and infrastructure time as a boundary concept that is able to bring together technical, political, economic, and effective approaches to urban infrastructure. Drawing on Lefebvrian thinking by reinserting temporality into Lefebvre's spatial triad (perceived time, representations of time, representational time) as well as inspired by David Harvey, Addie presented a multi-dimensional understanding of infrastructural space-time based on three temporal abstractions (repetition, cycle, period) that Lefebvre sketches out in his work "Rhythm Analysis" (1992). There are three different but related forms of approaching time and temporality through an abstraction grounded in Lefebvre's discussion of rhythm. The three frames serve as a conceptual starting point of inquiry into how urban and regional spaces and infrastructural lives are thought about, and also give a practical challenge for those making decisions about how infrastructures are regulated, maintained, governed, brought into being, and rendered obsolete. But, in order to pose these questions, one needs to pay particular attention to different modes of abstraction and the types of concepts in use to understand and articulate infrastructures' *temporality*. All of this gives "time" to think about identifying sites of innovations and collective re-appropriation that can exist within and beyond the networked metropolis. Playing with time and thinking through time create fusions, and cracks, that

enable us to play with mutation, political resistance, subterfuge, and these types of things. Infrastructural time is both rhythmic and a-rhythmic, has poly-rhythm, it is harmonious and discordant. Because of these tensions, it is something that is inherently political. A multitude of times permeates urban infrastructures.

About the Research Training Group KRITIS

KRITIS is an interdisciplinary research training group funded by Deutsche Forschungsgemeinschaft (DFG) since October 2016 dedicated to the study of critical infrastructures in cities. As part of the research training group, young researchers analyse the practices of constructing critical infrastructures, avoiding functional interruptions, and preparing for crises. The focus is on the technical as well as the political, social, and cultural aspects of urban security. The doctoral students of the program come from the humanities, social sciences, and engineering and work under the supervision of ten professors on network-related technical infrastructures in cities. The goal is to advance the still incomplete basic research on critical infrastructures. For more information, please visit www.kritis.tu-darmstadt.de.