Research Training Group KRITIS (editor)

Concepts of Infrastructure

Whitepaper of an internal workshop

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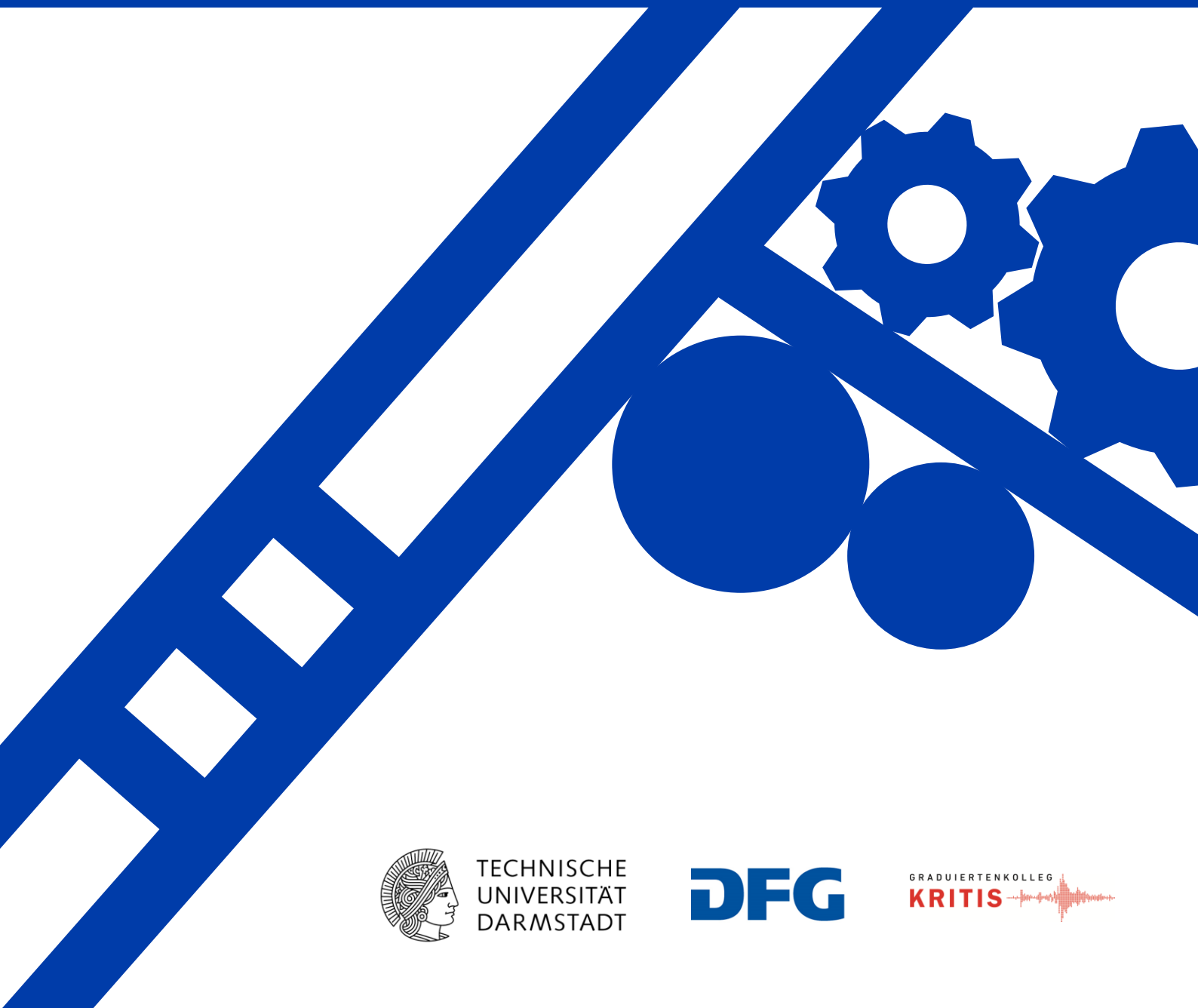

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Locating the RTG KRITIS within infrastructure discourses: an introduction

Andrea Protschky[1] and Raphael Longoni[2]

Over the last year, political and public discourse have increasingly pointed to the *systemic relevance* of Critical Infrastructures – socio-technical arrangements that are substantial for social life, for instance by providing water, energy, mobility or communication (Hübscher 2020). The Covid-19 pandemic is connected to infrastructures in various respects: On the one hand, the propagation of the virus and the measures taken to contain it are conditioned by networked infrastructures, such as flight or shipping connections that enable global trade and business or by the lack of sanitation to maintain hygiene especially for many poor and marginalized groups (Connolly et al. 2020). On the other hand, the current situation also affects the operation and use of infrastructures, for example by the reduction and selectivity of cross-border mobility (WTO 2020; Pro Asyl 2020). This recent debate occupies public and scientific attention and sometimes supersedes other critical and partly connected issues in which infrastructures appear central: They are affected by climate change and can contribute to its mitigation (Jaag, Schnyder 2019); they mirror and shape social inequalities by unequal access and possibilities to use them (Graham, Marvin 2008; Truelove 2019); they form the base for economic activities and are contested as a domain between private investment and public good (Harvey 1978; Becker et al. 2017).

As a basis for our research in this field, this whitepaper aims to document and further the interdisciplinary discussions on infrastructure concepts within and beyond our Research Training Group (RTG) KRITIS at the Technical University of Darmstadt, featuring researchers from history, sociology, political sciences, philosophy, urban planning, computer science and civil engineering. The RTG investigates the construction, functional crises and protection of Critical Infrastructures, which have become a research object within a growing transdisciplinary field closely connected to disaster and security studies and civil protection (e.g. Little 2002; Coaffee 2008; BMI 2009; Högselius et al. 2013). The focus of our group is set on "networked technical infrastructure[s]" (Engels 2018a: 5). These comprise and are embedded in social settings and therefore we understand them as socio-technical systems or arrangements. We deal with infrastructure systems in urban areas that enable the circulation of people, goods, information and energy, and which harbor substantial problems in the case of impairment. With regard to the relevance of disaster and crisis for infrastructure research, our colleagues from the first cohort of the RTG have described and evaluated four boundary concepts as tools to facilitate interdisciplinary communication in the field: *criticality*, *vulnerability*, *resilience* and *preparedness & prevention* (Engels 2018b). However, applying these concepts reasonably requires a theoretical understanding of infrastructures. Hence, we, the second cohort of the RTG, held a workshop where different concepts of infrastructures were presented, explored and debated. This whitepaper offers summaries of the workshop contributions, largely focusing on social components of infrastructure, the relationship between institutions and infrastructures as well as their different spatial dimensions.

Infrastructures are widely debated: Whereas infrastructure scholarship for a long time primarily focused on technical infrastructure *networks*, more recent contributions have been contesting this emphasis, since it does not mirror the full scope of service provision and is in some cases also rejected as a viable ideal (Coutard, Rutherford 2016). Other accounts have been questioning if infrastructures predominantly rely on technical installations or may also consist of social practices and networks (e.g. Simone 2004). More broadly, the term *infrastructure* is applied to a wide array of social and technical configurations, designed as substructure that renders substantial services for their participants (Laak 2018). This comprises installations of a preponderantly technical nature, e.g. for stabilizing the natural environment, spatial surveillance or territorial boundary consolidation (Wilkinson 2019), as well as institutions mainly relying on

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social interaction, e.g. of public welfare (Hurrelmann et al. 2010), medical provision (Hanseth et al. 2019), banking and financing (MFAN 2016) and organizational fields more in general (Hinings et al. 2017: 172–176).

A nuanced understanding of Critical Infrastructures needs to reflect such different notions. As RTG, we are working with a perspective that focuses on infrastructures as socio-technical arrangements on the basis of technical networks. Insights from various fields of infrastructure research may prove relevant within this focus and help evaluate, enrich and advance our conception of these arrangements. Questioning and debating these ideas in an interdisciplinary context contribute to developing our own position and link notions in the humanities and social sciences to rather technology-oriented concepts from engineering and vice-versa.

This whitepaper contains eight contributions by KRITIS doctoral researchers and a concluding comment. In a preliminary thought, Felipe Beuttenmüller Lopes Silva discusses the necessity of a fundamental understanding of infrastructure for the analysis of its criticality. Eva Platzer reflects on the idea of networked space, which is often implicitly presupposed in infrastructure scholarship, and shows how an understanding of different spatial dimensions may benefit infrastructure research. Tilman Beck traces the conceptual development of information infrastructure, highlighting the tensions within the discourse. Three contributions circle around the idea that infrastructures might sometimes not primarily consist in technical networks, but that people, their relations and practices adopt the most central functions: Andrea Protschky shows how AbdouMaliq Simone's (2004) metaphorical use of *people as infrastructure* might be translated to infrastructure research, while Luisa Kuhn and Chaitali Dighe indicate potential benefits of such a perspective by giving examples of civil defense practice and neighborhood *sousveillance*. In the final two contributions, Eline Punt and Raphael Longoni demonstrate similarities, links and overlaps of infrastructures and institutions and show how institutional theory may be integrated into infrastructure research. Together with all participants of the workshop, we finally wrap up some of our debates and identify desiderata of our interdisciplinary work.

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„Ist das eine (Kritische) Infrastruktur?“: Infrastrukturkonzepte als Grundlage für einen Kritikalitätsdiskurs

Felipe Beuttenmüller Lopes Silva[1]

Prämisse

Das Graduiertenkolleg KRITIS setzt sich mit Definitionen und Konzepten netzgebundener Kritischer Infrastrukturen auseinander. Ziel ist unter anderem zu verstehen, wieso und welchen Infrastrukturen Kritikalität zugeschrieben wird. Dafür wurden im Kolleg Konzepte erarbeitet, die eine interdisziplinäre Sprechfähigkeit ermöglichen (Engels 2018). Mit Konzepten von *Kritikalität* (Lukitsch et al. 2018), *Vulnerabilität* (Eifert et al. 2018), *Resilienz* (Elsner et al. 2018) und *Preparedness & Prevention* (Crespo et. al. 2018) wird eine Grundlage für die Kommunikation zwischen den Disziplinen gelegt. Doch ist innerhalb interdisziplinärer Diskussionen über die Kritikalität von Infrastruktur immer noch Dissens festzustellen.

Eine der ersten Fragen bei fachlichen Diskussionen über Kritische Infrastrukturen ist beispielsweise: „Was macht aus der untersuchten Infrastruktur eine Kritische Infrastruktur?“ Im Laufe dieser Debatten zeigt sich häufig, dass die eigentliche Frage eine andere ist. Wenn nicht „typische“ bzw. „konventionelle“ Kritische Infrastrukturen wie Transport, Strom- und Wasserversorgung untersucht werden oder wenn diese Leistungen nicht mithilfe technischer Netzwerke erbracht werden, muss zunächst geklärt werden, was eine Infrastruktur ausmacht, bevor überhaupt über die Kritikalität der untersuchten Infrastruktur diskutiert werden kann.

Infrastrukturkonzepte

Der Begriff der Infrastruktur ist je nach Disziplin und Forschungsbereich unterschiedlich bestimmt. So gesehen ist es nachvollziehbar, dass Ingenieur*innen Infrastruktur anders verstehen als Historiker*innen oder Soziolog*innen. Dies kann beispielsweise innerhalb interdisziplinärer Forschungsgruppen, wie dem Graduiertenkolleg KRITIS, beobachtet werden. Die dort untersuchten Infrastrukturkonzepte sind teilweise sehr fachspezifisch und äußern sich in unterschiedlichen Ansätzen. Wenn es beispielweise darum geht, Personen als Infrastruktur zu verstehen (Dighe, Kuhn und Protschky in diesem Whitepaper), die Relation zwischen Kritischen Infrastrukturen und Kritischer Informationsinfrastruktur aufzuzeigen (Beck in diesem Whitepaper), oder die den Infrastrukturkonzepten zugrunde liegenden sozialräumlichen Beziehungen zu betrachten (Platzer in diesem Whitepaper), scheinen sich diese Ansätze – zumindest auf den ersten Blick – in dem Verständnis von dem, was Infrastruktur ist, zu unterscheiden.

Solche fachspezifischen Ansätze verlangen deshalb ein Verständnis und eine Diskussion der zugrunde liegenden Definition von Infrastruktur, ohne die ein Konsens über den Begriff von Kritikalität erschwert würde.

Um einen Eindruck der Vielfalt der Ansätze und Definitionen von Infrastrukturkonzepten zu bekommen, sollen hier zwei Beispiele angeführt werden. Auf der einen Seite wird das Infrastrukturkonzept stark auf dessen Begriffsentwicklung zurückgeführt, bei der technische Elemente grundlegend sind (Schienen, Straßen etc.) (Laak 1999). Auf der anderen Seite stehen Erweiterungen oder neue Interpretationen des Infrastrukturbegriffs, welche ihren Hauptfokus von technischen Elementen wegbewegen (Simone 2004).

In seinem Text „People as Infrastructure: Intersecting Fragments in Johannesburg“ (ibid.) postuliert der Urbanist AbdouMaliq Simone, dass der Infrastrukturbegriff nicht auf technische Elemente restringiert werden solle. Er unterstreicht wie wichtig es sei, andere Komponenten, wie beispielsweise Menschen und ihre Praktiken, als Infrastruktur zu betrachten und zu untersuchen. Der Historiker Dirk van Laak anderseits kritisiert die Ausweitung des Infrastrukturbegriffs, weil dadurch dessen analytische Funktion abnehme (Laak 2019).

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Bei den obigen Beispielen zeigt sich, dass es durch den Rückgriff auf unterschiedliche Infrastrukturkonzepte zu Dissens innerhalb des interdisziplinären Austauschs und der Forschung über Kritische Infrastrukturen kommen kann. In Anbetracht dieser konzeptionellen Unterschiede muss, bevor der Fokus auf eine gemeinsame Definition von Kritikalität gelegt wird, ein gemeinsames Verständnis von Infrastrukturen bestehen. Eine interdisziplinäre Sprechfähigkeit kann sich somit erst voll entfalten, wenn diesem Umstand Rechnung getragen wird.

Fazit

In den zahlreichen Beiträgen dieses Workshops wurden verschiedene Infrastrukturkonzepte präsentiert und diskutiert. Als Folge der Auseinandersetzung mit dem Thema Infrastruktur kann festgehalten werden, dass zuerst die Infrastrukturkonzepte, mit denen gerade gearbeitet wird, allen Gesprächspartner*innen bekannt sein bzw. diese festgelegt werden müssen, bevor der Frage nach der Kritikalität einer Infrastruktur überhaupt nachgegangen werden kann. Diese müssen als Prämisse für die Diskussion über Kritikalität gesehen werden. Nur dann ist es möglich, eine möglichst klare Diskussion über die Zuschreibung von Kritikalität bzw. die Klassifizierung von Infrastrukturen als kritisch zu führen.

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Taking space into account: ideas for a space-related conception of infrastructures

Eva K. Platzer[1]

General discussion

One concept of critical infrastructures, as suggested and used by the RTG KRITIS, considers space as a registration plate for these infrastructures. The grids infrastructures rely on bind them to physical space. Therefore, they become an influencing factor on the design of space itself. This means infrastructures structure space and material traces of infrastructural processes are manifested in physical space. Hence, in this case space is mainly understood as a category external to infrastructure. The other infrastructure concept of the RTG KRITIS concentrates on the spatial structure of the grid. They are understood as network. The infrastructures are made up of nodes and edges and the concept emphasizes their connectivity and interdependencies within (Belina 2013: 121ff.; Jessop et al. 2008: 390).

The following discussion aims to diversify how the relationship between space and infrastructures can be conceived and acknowledges the production of space within an infrastructure. It thereby emphasizes the concept of socio-spatial relations and its impacts on infrastructure handling by introducing the role of airports when handling a pandemic.

Research example: spatial conceptions of airports in times of a pandemic

Airports can be conceived in two different ways. First, they are called nodes in the network of global aviation infrastructure (Mayr 2003: 172; Nuhn, Hesse 2006: 144). Secondly, from the perspective of border studies, airports represent the outer rim of national territory and and enable permeability as well as impermeability (Cresswell 2006; Muller 2008; Salter 2008; Adey 2009). They stand for governmental control over entering the state territory ("ports of entry", Salter 2008: ix), global interconnectivity and freedom of movement. These two socio-spatial conceptions of infrastructure are key arguments when controlling the occurrence of infections like Covid-19 in 2020.

As shown by Füller and Everts (2011, 2014), when looking at the political strategies for coping with non-spatially fixed threats like infectious diseases, three major types of measures are central to national disease control. One measure to control the spread of an infectious disease is to reterritorialize the threat. The threat (in case of SARS-CoV-2, the virus) is located and in this sense fixed within a distinct space. The space is thereby characterized as homogeneously infectious and dangerous, even if the spread patterns are frayed and backtracing to the spatial origin is delicate. This political practice is evident in responses of the WHO, US or Germany facing the 2014 Ebola outbreak (describing West Africa as dangerous), the SARS-epidemic in 2003 (characterizing parts of China and Hong Kong as homogeneously dangerous) or in our example the Covid-19 pandemic (characterizing first the Chinese province of Wuhan in Jan. 2020 and later different hot spots like Italy in Feb. 2020 as dangerous) (BMG 2020). These measures stigmatize habitants as possibly infectious. When reterritorializing the threat, a second strategy is to take additional security measures. These are aimed to keep the threat outside the protected territory and are usually implemented at "ports of entry" (Salter 2008: ix) to the territory which is meant to be protected. Looking at the timeline of the Covid-19 control strategies, the importance of airports for this step can be retraced. In Germany, for example, in the beginning of February air travels were informed about the symptoms and questions on contacts to (possibly) infected persons. By February 27, travelers had to fill out so-called *Aussteigekarten*, documenting details about their travel and origin, while, starting a day before, pilots where bound to inform the tower on the health state of passengers from China (BMG 2020). The threat strategy describing the production of new borders (between sick and healthy) are fundamental for the strategies of disease control. In these strategies, airports become especially important as transitory spaces where the inside and outside meet and sick and healthy attributed individuals might mix. Therefore, the impact of the three core strategies is projected onto the infrastructure airport, due to its role as node in the global transport infrastructure aviation and its part in the national

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territory. Looking back at the start of the Covid-19 pandemic, this strategy can easily be shown. The spatial construction of airports as part of the network lead to them being especially important for the strategies of disease control, since they transport the disease. At the same time, airports are ports of entry to the territory that is aimed to be protected. Hinchcliffe et al. (2013: 532) identify the "four t's" (travel, trade, tourism, transportation) as reasons why infectious disease spread easily. Airports are places where all four t's are important for its relevance. Therefore, one strategy in containing Covid-19 was to reterritorialize the threat to a region in China, where it first occurred. The region was therefore marked as an infectious territory and the four t's were restricted. In reality it is highly possible that Covid-19 had spread beyond this territory by then. Therefore, designated security measures in form of special practices at the airports were taken. With the worldwide travel warning the four t's were finally reduced to a minimum and the ports of entry started to lose their importance for the occurrence of infections.

As seen in this case, the role of airports during the 2020 Covid-19-pandemic can best be discussed from a social science perspective if we move beyond the one-dimensional spatial notion of infrastructures as networks and focus more on their socio-spatial construction. In this case it is clear that airports have more than one spatial reality, since they can be nodes in a network, a national territory and even a borderline at the same time, all of which reflect on the governmental security measures to contain an infectious disease.

Taking space into account

To take space into account means to consider space as a variable that can help to understand the researched phenomena. Therefore, when wondering if and how space ought to be taken into account in one's own research, the leading question could be: Does space (in any form) matter in this context? In this sense it is important to get an insight if and how socio-spatial relations, perceptions or discourses might affect the research questions and the object of study. The second step here could be to identify which spatial concepts could be a valuable explanatory factor. Here one can draw on numerous publications from the research field of human geography. These can range from concepts like Jessop et al. (2008), focusing on the relations between spatial dimensions, to the idea of spatial flows by Castells (2004), who includes time as a valuable dimension in addition to space, or to Belina (2013), in case a more general introduction into the conception of space is needed.

Space, as emphasised in Sojas (2003) *thirdspace* concept, is an important pillar of society. As shown in the example above, space is not an objective category but rather a set of ideas and social constructions projected onto the concept of an infrastructure. Thus, they shape social interaction as well as political decision-making. Where different spatial dimensions meet, as shown above, actions are justified by them. In the context of infectious disease control, from a critical perspective, security measures based on spatial conceptions have been used to exclude and stigmatize individuals. Therefore, spatial dimensions have the potential to clash when different actors have conflicting conceptions of space and therefore set different priorities for action. At this point, researchers should learn to consider the implications of contradictory socio-spatial constructions of actors who operate, use, manage and regulate infrastructures. As a result, conflicts or, in the case of political interference, overregulation can occur. Therefore, it might be helpful to consider the different perspectives on infrastructures and their spatial reality, especially when dealing with phenomena such as conflicts, power struggles or social practices that affect and shape an infrastructure.

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Information infrastructure

Tilman Beck[1]

A source of confusion

Several research areas (e.g. public policy discourse, Science and Technology Studies or information systems research) have both used and shaped the concept of *information infrastructure (II)* within the last decades such that it is not possible to point at a single-fit definition across literature. In social studies of computing, the earliest attempts to analyze infrastructures in a computing-related discourse were made by Rob Kling, Walt Scacchi and Tom Jewett (Kling, Scacchi 1982; Kling 1987; Jewett, Kling 1991) in criticism that in research at that time "the social context in which the technology is developed and used, and the history of participating organizations, are ignored" (Kling, Scacchi 1982: 2). Thus, Jewett and Kling (1991) bridged this gap by introducing the concept of *infrastructure* to put focus on the supporting factor of computing devices in work environments.

The term *II* itself was mainly popularized in the wake of the National Information Infrastructure initiative by the Clinton Administration in the mid-1990s in the USA. This was due to the establishment of many essential telecommunication protocols and a more wide-spread implementation of the necessary underlying infrastructure, e.g. passing of the High Performance Computing Act of 1991 by the initiative of Senator Al Gore (U.S. Congress 1991). Hence, such services were called infrastructures and the term *II* was frequently used among scholars and government officials around that time.

In their highly-cited works, Susan Leigh Star, Karen Ruhleder and Geoffrey C. Bowker (Star, Ruhleder 1994; Star, Bowker 1995; Star, Ruhleder 1996) suggested to extend the conception of *II* by incorporating classification schemes and standards which are used in networked computing facilities. Thus, Star and Ruhleder extended the *infrastructural inversion* (Bowker 1994) with respect to the term *infrastructure* in general and state that "infrastructure is something that emerges for people in practice, connected to activities and structures" (Star, Ruhleder 1996: 112). More generally, they say that "an infrastructure occurs when local practices are afforded by a larger-scale technology, which can then be used in a natural, ready-to-hand fashion" (ibid.: 114). This conceptualization was later criticized by Lee and Schmidt (2018: 191–192) who, while acknowledging that "a technical installation is only an infrastructure to the extent that it has been incorporated into organized practices", state that "as a result of the 'inversion', the term 'infrastructure' can be used to mean just anything". Especially with regards to computing technology, they claim that "we need to be able to distinguish [...] the computational representation of objects, procedures, protocols, notations, classifications, etc. from the objects, procedures, protocols, notations, classifications, etc. of the practices in which the computational representations are applied" (ibid.: 195) and that this is not possible when using the term *infrastructure* for both aspects.

Tensions within Information Infrastructure

In the last two decades, a network of researchers (Hanseth et al. 1996; Hanseth, Monteiro 1997, 1998; Ellingsen, Monteiro 2006; Ellingsen, Røed 2010; Monteiro, Rolland 2012; Monteiro et al. 2013) has tried to merge and combine the definitions existing in various research directions. To account for the fundamental differences in the development of *IIs* compared to other technical systems, in their book Hanseth and Monteiro (1998) identify the following key aspects of *IIs*:

1. *Enabling*. "Infrastructures have a supporting or enabling function" (ibid.:41).
2. *Shared*. "An infrastructure is shared by a larger community (or collection of users and user groups)" (ibid.:41).
3. *Open*. "Infrastructures are open" (ibid.:42).

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4. *Socio-technical networks*. “IIs are more than ‘pure’ technology, they are rather socio-technical networks” (ibid.:43).
5. *Ecologies of networks*. “Infrastructures are connected and interrelated, constituting ecologies of networks” (ibid.:44).
6. *Installed base*. “Infrastructures develop through extending and improving the installed base” (ibid.:47).

These aspects reflect several issues which are inherent in *IIs*. First, the *enabling* and *shared* characteristic of *IIs* directs at the tension between standardization and flexibility (Hanseth et al. 1996) where protocols are standardized in order to enable communication between technical components but at the same time must be flexible enough to allow for dynamic changes to support new or updated components. Second, the tension between local and global is reflected in its *openness* meaning that there are no limits with regards to the number of users, stakeholders, network nodes or other technological components. Hanseth and Monteiro (1998: 42) illustrate this using an example from health care where a hospital and its employees (e.g. doctors) exchange information both locally (patients, surgeons, human resources) and globally with other medical institutions and public sector institutions, even across countries. Finally, there is the tension between the inertia of the *installed base* and the dynamically changing technologies and practices that depend on it. Thus, one cannot speak of designing a *new* information infrastructure, but rather the integration into or replacement of another one. This is further reinforced through their connections and interrelations (*ecologies of networks*) in the sense that *IIs* are layered and link related networks.

Conclusion

The impressively fast evolution of computing infrastructure around the world has sparked large interest in various research disciplines and lead to a clouded meaning of the term *information infrastructure*. This ambiguity is not limited to *II* but can be observed in general in other literature about infrastructure research. Therefore, I argue in line with Lee and Schmidt (2018) that research projects studying (information) infrastructure do need to define the conceptualization which their work is based on and thus enable fellow scholars to study it in context. Further, I highlighted the conceptual tensions within *II* research which I also mainly attribute to its rapid development. Thus, with *IIs* experiencing rapid transformations in a relatively short time, I view *II* as a prime example to study the temporal and spatial dynamics of technical networks for (information) circulation which is one of the primary goals of our research training group.

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People as infrastructure: translating a metaphor for infrastructure research

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The Research Training Group KRITIS relies on a conception of infrastructure that has become classical in infrastructure research in the Global North over the last decades: It "is devoted to networked technical infrastructure" (Engels 2018: 6), while emphasizing the socio-technical nature of these networks. Urbanistic and infrastructure research especially in the Global South however indicate that this notion of infrastructure, strongly tied to technical components (Simone 2004) and universally networked systems (Coutard, Rutherford 2016), may not be adequate to grasp the full reality of service provision in the case of fragmented or network-independent infrastructure. In this contribution, I present AbdouMaliq Simone's (2004) seminal text "People as Infrastructure: Intersecting Fragments in Johannesburg", which he has complemented in a recent essay (Simone 2021), and indicate how it may still serve as an inspiration for research on basic infrastructures today. Coming from an urbanistic perspective, Simone mostly uses the term *infrastructure* metaphorically to describe "intersections" (Simone 2004: 407) and "networks" (ibid.: 426) among people, the things they use and the spaces in which they interact, which form the basis for urban life. Nevertheless, these configurations also form basic infrastructures like transport systems and water supply. In this text, I will show the continued relevance of Simone's argument on the one hand, and on the other hand argue that due to Simone's inattention to other aspects of infrastructure, like the role of technology (which he partly addresses in his 2021 article), *people as infrastructure* needs to be translated to present infrastructure discourses to become applicable for research in the field.

In his paper, Simone aims to extend the "common" (ibid.: 407) understanding, which grasps infrastructure "in physical terms, as reticulated systems of highways, pipes, wires, or cables" (ibid.) by the "incessantly flexible, mobile, and provisional intersections of residents that operate without clearly delineated notions of how the city is to be inhabited and used" (ibid.). These intersections, which he calls "people as infrastructure" (ibid.) depend on the "ability of residents to engage complex combinations of objects, spaces, persons, and practices" (ibid.: 407f.) in order to "derive maximal outcomes from a minimal set of elements" (ibid.: 410f.). The author argues that these conjunctions of people play a central role in African cities, where state administrations and civil institutions often do not have the power or ability to clearly delineate and control the spatial and social organization of cities (ibid.: 409) – which also includes the lack of a wide and constant coverage with networked basic infrastructures. Simone emphasizes that the configurations of people and things are pursued not in "contrast to non-African urban priorities […] but as specific routes to a kind of stability and regularity that non-African cities have historically attempted to realize" (ibid.: 409f.).

The author illustrates this argument with various examples. Drawing on the case of the transport depot in Abidjan, he describes how people run a stable transport system with limited formal regulation by taking differentiated, flexible roles and by shifting connections and collaborations between each other (ibid.: 410). The example illustrates how, alongside other functions like informal trade or credit systems, people and their networks, utilizing various things and urban spaces, form basic infrastructures that provide water, energy, mobility and communication.

What Simone describes as a *common understanding* of infrastructure as technical systems does not mirror the perspective of contemporary infrastructure research. From the 1980s onwards, scholars have emphasized the mutual shaping of infrastructures and their social environment as well as their socio-technical nature (e.g. Star 1999; Hughes 2012). From a more recent perspective of Science and Technology Studies, Olivier Coutard and Jonathan Rutherford (2016) define infrastructures as "'seamless' […] relational system or arrangement of technology, actors, skills, knowledges, practices, cultural meanings and values, resources, money and politics" (ibid.: 8). In this conception, technical and human components

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cannot be separated. Simone does not take up such discourses and therefore misses the chance to connect to arguments regarding the relation of technical and social infrastructure components that had already been made. Nevertheless, I contend that Simone's text proved visionary at the time of writing and may still benefit infrastructure research in at least four ways:

Firstly, Simone points out the centrality of people's practices for the functioning of cities at a time when they were much less in the focus of infrastructure research. His conception therefore influenced much urban research in the Global South (e.g. Anand 2017) and has also been taken up in the Global North, especially in contexts of inequality and limited regulation, like the precarious infrastructure use or replacement by persons without permanent shelter (Marquardt 2017). The role specific technologies play in infrastructure practices however remains unexplored in Simone's original (2004) account – whereas he acknowledges their significance for urban processes in his recent essay (Simone 2021: 6). To investigate these practices in more detail, we however need to draw on contributions focusing on the way artifacts prescribe certain (politically intended) actions (e.g. Schnitzler 2008) and on infrastructure and practice theoretical scholarship that may help understand socially differentiated practices (ibid.; Bourdieu 2007; Truelove 2019). Looking at infrastructure practices from such a nuanced perspective delivers insights on technical connectivity as well as on social accessibility and differentiated possibilities to use or replace infrastructure. In addition, it puts a focus on the constant co-creation of infrastructure, which requires regular action to run machines, sell tickets, turn on taps or collect deposit bottles to be able to afford the public toilet. In Europe, the need to understand practices of interaction with infrastructure has been emphasized throughout the last decades (e.g. Coutard, Shove 2019). While this research delivers detailed analyses of prevalent infrastructure practices, it may still be complemented by more investigations on practices in the face of technical limitations and social inequality.

Secondly, Simone's observations show that people in many contexts do not and cannot rely on technical networks, whereas they do use various forms of artifacts. This is in tune with more recent contributions in infrastructure research, questioning the almost exclusive focus of earlier scholarship in the field on technical infrastructure *networks*, which often do not constitute the reality of service provision, especially in the Global South (e.g. Kooy, Bakker 2008; Coutard, Rutherford 2016). Based on Simone's notion of *people as infrastructure*, we could also argue that infrastructure is often networked, but that these networks are not always technical – rather it may be human connections and conjunctions that keep up circulation and that make use of non-networked or decentralized technology.

Thirdly, and connecting to this point, Simone demonstrates people's role not only in running a technical system, but providing a *social system* with technical components. Parallel to the perspective on practices as integral parts of infrastructure (e.g. Anand 2017), the role of *social networks* as coproducing infrastructure together with technical networks or elements is increasingly addressed (ibid.; Truelove 2011). In his more recent contribution, Simone (2021) outlines how the flexible social networks described in his 2004 paper are in danger of collapsing under the pressures of modern capitalism – especially among marginalized groups, for instance by their displacement from the inner city (ibid.: 4f.). The outcomes of this shifting sociality together with more and more complex and pervasive technology constitute a pressing topic for infrastructure research.

Fourthly, based on Simone's idea that flexibility and improvisation in the face of limited technology and unregulated urbanity may create some degree of stability, we may grasp people's role as balancing and stabilizing urban functions. Relatedly, Paul Edwards (2019) outlines how the relationships between components of infrastructure – technological artifacts, social arrangements, people – shift and take over different and more or less central roles (ibid.: 355). According to the author, human action changes in conjunction with the kind of technology in place – like the task of water distribution when it is either fetched from central standpipes or accessed via individual taps. In comparison to this concept of a socio-technical equilibrium, Simone's idea highlights the stabilizing role of humans that react flexibly to given conditions. This function can so far hardly be taken up by technology, for instance in the face of uncertain incidents and sudden impacts on infrastructure.

In summary, *people as infrastructure* emphasizes people's role in providing and contributing to flexible arrangements that form a basis for social and economic life. In infrastructure research, it helps grasp the

centrality of practices for the functioning and understanding of cities and infrastructures. It highlights the limitations of researching technical networks, especially in contexts where such networks are fragmented and dysfunctional – while it in turn originally disregards the still pivotal role of technology. It helps us understand how people take up functions like circulation and connection that have often been attributed to technology. And finally, it demonstrates how people may achieve a certain degree of stability by flexibility, which suggests a balancing role of people in infrastructure arrangements. Embedding the urbanistic idea of *people as infrastructure* in a contemporary socio-technically oriented infrastructure discourse may therefore still deliver inspirations for our understanding of these arrangements.

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Einsatzkräfte des Katastrophenschutzes als *People As Infrastructure*

Luisa Kuhn[1]

Das Bundesministerium des Innern definiert in der „Nationalen Strategie zum Schutz Kritischer Infrastrukturen“ (BMI 2009) und dem Dokument „Schutz Kritischer Infrastrukturen – Risiko- und Krisenmanagement. Leitfaden für Unternehmen und Behörden“ (BMI 2011) die Kritischen Infrastrukturen für Deutschland aus Sicht der Bundesregierung und unterteilt diese in neun Sektoren und dazugehörige Branchen. Außerdem erfolgt eine einfache Einteilung in „Technische Basisinfrastrukturen“ und „Sozioökonomische Dienstleistungsinfrastruktur“ (BMI 2009: 5). Diese Einteilung erhält mit dem Dokument „10 Jahre KRITIS-Strategie“ (BBK 2020) zwar eine Überarbeitung hinsichtlich der Aufteilung in Sektoren, Branchen und einer weiteren Subkategorie „Kritische Dienstleistungen“ (ebd.: 24), bleibt aber dahingehend gleich, dass keine Differenzierung in der Bewertung der Kritikalität von technischen und sozioökonomischen Infrastrukturen und auch sonst keine differenzierte Auseinandersetzung mit diesen außerordentlich unterschiedlichen Konzepten erfolgt. Dabei ist offensichtlich, dass Infrastrukturen, die größtenteils oder ausschließlich durch die Arbeit und Leistung von Menschen konstruiert werden, sich bedeutend von ihren überwiegend technischen sozio-technischen Verwandten unterscheiden. Folgend soll der Katastrophenschutz mit seinen Organisationen und Einsatzkräften als eine solche, von menschlicher Leistung getragene, Infrastruktur untersucht und die Übertragbarkeit des Konzeptes *People As Infrastructure* von AbdouMaliq Simone (2004) auf diesen geprüft werden.

Werden Organisationen und Einsatzkräfte des Katastrophenschutzes als Infrastruktur betrachtet, gibt es zunächst drei verschiedene Möglichkeiten, wie diese mit vorwiegend technischer Infrastruktur in Kontakt kommen, wie sie mit ihr interagieren und somit als Komponenten netzgebundener Infrastruktur betrachtet oder sogar als eigene selbständige Infrastruktur gesehen werden können.

Die erste Kontaktnotwendigkeit ist es, Schäden und Störungen von Infrastrukturen oder Infrastruktursystemen zu reparieren und zu beheben oder Schadstellen zugänglich zu machen. Die Organisationen des Katastrophenschutzes und deren Helfer*innen können somit als eine Art Werkzeug zum Reparieren und Instandsetzen betrachtet werden, das aufgrund von Ausnahmezuständen, Krisen und Katastrophen zum Einsatz kommt. Diese Aufgabe erledigen die Helfenden in der Regel unter Einsatz technischer Vorrichtungen und Hilfsmittel – auch der Katastrophenschutz ist somit ein soziotechnisches System. Die Einsatzkräfte fungieren in dieser Sichtweise nicht als die betrachtete Infrastruktur selbst, sondern sind ein Bestandteil des erweiterten Begriffs des Infrastruktursystems der betrachteten Infrastruktur. Beispielhaft lassen sich hier als solche Reparatur- und Instandsetzungsmaßnahmen das Beheben von Sturmschäden, Pump- und Förderarbeiten, Sichern von Gebäuden und Bauwerken durch Abstützmaßnahmen, Instandsetzung von Leitungssystemen und Anlagen sowie das Freiräumen von Verkehrswegen anführen (THW 2014).

Die zweite Idee besteht darin, die Organisationen des Katastrophenschutzes als temporäres Ersatzteil aufzufassen, das die Funktion der beschädigten (Teil-)Infrastruktur so lange übernimmt, bis diese ihre ursprüngliche Aufgabe selbst wieder vollständig ausführen kann. Die Katastrophenschutzorganisationen mit ihren Helfer*innen, Gerätschaften und ihrer Technik werden in diesem Fall zu einem Bestandteil der beschädigten oder zusammengebrochenen Infrastruktur, um deren Funktion weiterhin sicherzustellen. Selbstverständlich kann bei einem totalen Zusammenbruch einer Infrastruktur diese auch zeitweise komplett ersetzt werden. Dazu werden eigene Gerätschaften und Technik verwendet, um Wasser und Energie sowie auch Lebensmittel bereitzustellen. In dieser Betrachtungsweise liegt der Fokus auf den technischen Komponenten des Katastrophenschutzes. Technische Infrastrukturen werden – unter Zuhilfenahme menschlicher Arbeit und Leistung – mit technischen Ersatzteilen temporär wieder funktionsfähig gemacht und zu einer Infrastruktur zusammengefügt. Konkrete Beispiele dafür sind der Bau von tempo-

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rären Wegen (z. B. Stegen, Straßen- und Eisenbahnbrücken), Einrichten von Trinkwasseraufbereitungsanlangen, Einrichten von Stromerzeugung und -versorgung, Einrichten von Heizanlagen, Damm- und Deichsicherungsarbeiten (THW 2014).

Die dritte Sichtweise fasst die Organisationen des Katastrophenschutzes bzw. übergreifender gesehen die der humanitären Hilfe als menschliche Infrastruktur in sich auf, sodass die Einsatzkräfte mit ihrem Wissen und Fähigkeiten die eigentliche Infrastruktur bilden. Denn es gibt keine eigenständige Technik – wie in anderen Bereichen, in denen der Mensch nur für die Steuerung oder Bedienung der Infrastruktur zu ständig ist – die die Aufgaben der humanitären Hilfe übernehmen kann. Die Arbeit wird in diesem Bereich hauptsächlich durch Menschen geleistet und idealerweise ggf. durch den Einsatz von Technik unterstützt. Dabei handelt es sich vor allem um Ortungs-, Rettungs- und Bergungsmaßnahmen, sanitäre Hilfeleistung und ärztliche Soforthilfemaßnahmen, Betreuung und Verpflegung Betroffener, um nur ein paar Beispiele zu nennen (THW 2014; DLRG 2015; HMdIS 2019a, 2019b).

In dieser dritten Perspektive der Funktionsweise lassen sich die Einsatzkräfte als *People As Infrastructure* im Sinne von Simones Konzept fassen. Nachdem die Einordnung in das Konzept geklärt ist, muss weitergehend die Frage gestellt werden, ob für eine Einordnung und Bewertung dieser menschlichen Infrastruktur als Kritische Infrastruktur Brückenkonzepte wie *Criticality*, *Vulnerability*, *Resilience* sowie *Preparedness & Prevention* genutzt werden können, diese sinnvoll erweitert werden oder sogar neue Konzepte definiert werden müssen. Die Darlegung dieser Betrachtung ist leider aufgrund der Kürze des Beitrags selbst und der des Whitepapers an dieser Stelle nicht möglich.

Bevor allerdings überhaupt ein Blick auf die Brückenkonzepte Kritischer Infrastruktur gerichtet werden kann, muss dieser zunächst auf ein relativ neues Forschungsfeld fokussieren, das sich mit dem menschlichen Faktor in technischen Systemen beschäftigt und bereits auch das Thema Einsatzkräfte miteinbezieht – die Human-Factors-Forschung:

> „Human Factors ist eine interdisziplinäre Forschungsrichtung, die zum einen Grundlagenforschung realisiert mit dem Ziel des Erkenntnisgewinns über Menschen als Ressource und begrenzendem Faktor im System Mensch und Technik. Zum anderen ist Human Factors eine angewandte Wissenschaft, die Anwendungswissen für Problemlösungen in der Praxis bereitstellt. Die vorrangige Zielstellung besteht darin, negative Folgen der Interaktion von Mensch und Technik zu vermeiden bzw. zu vermindern und so das Wohlbefinden der Handelnden zu gewährleisten und die Sicherheit sowie Funktionsfähigkeit des Systems zu verbessern“ (Badke-Schaub et al. 2012: 7).

Wie auch im Feld der technischen Infrastruktursysteme geht es hier um das Stärken des Systems, indem soziale und fachliche Kompetenzen gestärkt und geschult werden, um den Anforderungen von komplexen sozio-technischen System gewachsen zu sein, während Schwächen und Fehler vermieden bzw. insbesondere als Chance gesehen werden sollen, um daraus lernen zu können. Gerade im Bereich der Stabsarbeit und auf Führungsebene etabliert sich dieses Forschungsfeld immer mehr. Der Schwerpunkt liegt auf der Schulung und dem Training von Individual- und Gruppenkompetenzen wie Kommunikationsfähigkeit, Situationsbewusstsein, Kooperationsfähigkeit, Führen in stressigen Situationen, Problemlösungskompetenzen, Selbsteinschätzung und Etablierung einer ausgewogenen Fehlerkultur und vieles mehr (Badke-Schaub et al. 2012). Zur Vermittlung solcher Kompetenzen wird in der ebenfalls recht jungen Bevölkerungsschutzpädagogik auf kompetenzorientierten Lernkonzepten aufgebaut. Es sollen nicht nur Einsatzkräften, sondern auch der Bevölkerung wichtige Handlungskompetenzen – bestehend aus Fach-, Human- und Sozialkompetenz – vermittelt werden (Karutz, Mitschke 2018a, 2018b). Dies zeigt, dass die Fokussierung auf hauptsächlich technisches Wissen und technische Fähigkeiten nicht genug ist und die Forschung im Bereich des Bevölkerungsschutzes die ersten Schritte in die Richtung, den Menschen mit dessen Stärken und Schwächen als wichtigen Bestandteil einer Infrastruktur bzw. als Infrastruktur zu sehen, bereits getan hat, aber eben erst am Anfang steht.

Dieser Text zeigt, dass sich mit Ansätzen zur Rolle menschlichen Handelns und menschlicher Netzwerke neue Fragen und Ansätze für die Infrastrukturforschung aufgetan haben, die innerhalb des politischen und wissenschaftlichen Diskurses zu KRITIS noch wenig aufgenommen werden. Sie sind es wert, im Rahmen der KRITIS-Forschung weiterverfolgt und genauer beleuchtet zu werden.

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Eyes on the street for *people as infrastructure*

Chaitali Dighe[1]

In this contribution, I outline how we can understand *eyes on the street* as *people as infrastructure,* which AbdouMaliq Simone has conceptualized in a 2004 article, extending the notion of infrastructure directly to people's activities in the city. I illustrate this with examples of contemporary initiatives that propagate the *eyes on the street* concept to create more safety in cities. Finally, I include a critical reflection on the approach to demonstrate its misuse.

The term "eyes on the street" was coined by Jane Jacobs (1961: 54), an American-Canadian activist in her most famous book "The Death and Life of Great American Cities". With this slogan she describes "the creation of positive social control through extensive use of public space" (Midlaszewski 2020, own translation). Jacobs shows how, before the use of CCTV (closed-circuit television) cameras as surveillance infrastructure for crime prevention or detection, people acted as live cameras to serve the purpose. In the chapter "The use of sidewalks – safety" (Jacobs 1961: 29) she narrates "stories of direct connection between city surveillance and city safety" (Center for the Living City n.d.). She also refers to it as "Do-it-yourself surveillance" (Jacobs 1961: 39) which, according to Jacobs, is based on people's enjoyment of watching activity and other people on the streets. These "built-in-eyes" (ibid.: 40) belong to what she addresses as "natural proprietors of the street" (ibid.: 35). Jacobs further strengthens her argument by stating that "horrifying public crimes can, and do, occur in well-lighted subway stations when no effective eyes are present. They virtually never occur in darkened theatres where many people and eyes are present" (ibid.: 42).

Natural surveillance

Several other concepts and initiatives stemmed from Jane Jacobs' *eyes on the street* slogan. One such concept is *natural surveillance* – a term used in *crime prevention through environmental design* (*CPTED*) models for crime prevention that were initially devised by criminologist C. Ray Jeffery in 1971. Tandon Gaurav (2018) outlines the claim of *CPTED* that "the community, homeowners, planners, developers and architects can play a greater role in protecting the community and themselves from crime by integrating *CPTED* principles" (ibid.: 6). DIY surveillance or the placing of legitimate eyes on the street increases the perceived risk to offenders. *Natural surveillance* is one of four principles of *CPTED*. Another theory evolved from *CPTED* is called *defensible space – crime prevention through urban design*. This theory by architect and city planner Oscar Newman (1972) encompasses ideas about crime prevention and neighbourhood safety. Newman argues that architectural and environmental design plays a crucial part in increasing or reducing criminality (Newman 1972). These principles are still followed all over the world under the same or different names either individually as *natural surveillance* or in combination with technology. The Office of Crime Prevention, Western Australia developed a crime prevention initiative under the same name *eyes on the street* that "enables agencies such as the City of Swan (Western Australia), through its employees, to identify possible criminal activities and suspicious behaviour and report it to the Police" (Crime Stoppers Western Australia 2017).

Internet eyes

With the onset of modern technology, CCTVs became the eyes on the street for crime detection and prevention and this augmented the dependency on technology. However, soon it was realized that merely having technology is ineffective if there are no *real* eyes to monitor it (BBC 2009). This brought back the original *eyes on the street* concept, but with an intention to be implemented in combination with technology. In October 2009 in the UK, an Internet Eyes website was announced which would pay members of the public to view CCTV camera images from their homes and report any crimes they witnessed. In spite of UK being the "world capital of CCTV" (BBC 2009) – with an estimated one camera per 14

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people, London Metropolitan Police estimated that in the year 2008 just one crime per 1.000 CCTVs was solved in the capital (BBC 2009). The website aimed to add "more eyes" to cameras which might be insufficiently monitored (ibid.).

Crime and control in the digital era

Today in the digital age, everyone can carry a CCTV in their pockets in the form of a smart phone or other advanced media like a body-worn camera. In addition to *eyes on the street*, whether it is via natural surveillance or CCTVs, today there are "a number of other senses like touch and sound that can be captured by photo, live streaming and text – fast disseminated via social media – through the use of personal smart phones, app etc." (Ceccato 2019a: 5). Complementing surveillance (CCTV) and natural surveillance (people), Mann (2004: 620) coined the term *sousveillance* that refers "both to hierarchical sousveillance, for example, citizens photographing police, shoppers photographing shopkeepers, as well as personal sousveillance, bringing devices down to eye level, for human-centered recording of personal experience" (ibid.). Hence the concept today has been expanded to "Eyes and apps on the streets" (Ceccato 2019b) that depict a high use of sousveillance in the digital era.

Critical reflection on *eyes on the street*

Alongside the possible benefits of *eyes on the street* schemes, the misuse of this concept is also on the rise. There are many neighbourhood watch groups that have misused their authority to become "would-be police officers" (Pridmore et al. 2019: 100) and in turn try to take law in their hands. While reporting suspicious behaviour, its interpretation can differ from person to person as it is based on subjective feelings and beliefs. As opposed to using technology to detect crime, people as this crime detection infrastructure may easily affect harmful stereotyping and racist behaviour. Such incidences demonstrate the thin line between citizens taking appropriate action versus them acting as illegitimate law-enforcers. In this era of sousveillance just as technology makes it easy for citizens to join such platforms, the ease of sending a message on such a neighbourhood watch Watsapp group, for example, can lead to negative consequences and at the same time can spread at lightning speed (Pridmore et al. 2019). Hence, even though *eyes on the street* has been promoted as a positive concept, it has its negative implications based on whose eyes are actually on the street.

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Critical Infrastructure systems and institutional arrangements

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This contribution looks at the definitions and meanings of institutions and infrastructures and how these terms are interrelated. I highlight that institutions interact with material components of infrastructures in socio-technical systems and should therefore also be studied in interaction. Socio-technical systems consist of both technological components as well as economic, social and political elements (Engels 2018). Hereby, institutions interact with technology and evolve over time. This text is structured as follows: First, I define institutions and provide some theoretical background on how institutions have been studied in the past. Then I introduce the concept of *institutional arrangements* and provide some discussion points in how institutions and infrastructures interact as part of socio-technical systems.

Theoretical background

A well-known definition of *institutions* frames them as: "humanly devised constraints and instruments that shape human (political, economic and social) interactions" (North 1990). Institutions guide actors (and organizations) in their behavior and actions and thus shape societal processes. North (1990) also compares them to the *rules of the game*. The consequent governance of these societal processes is then referred to as the *play of the game* (North 1990). Ostrom (1992) distinguishes between two types of institutions: formal and informal. *Formal institutions* are rules and procedures that are created, communicated and enforced through channels widely accepted as official. *Informal institutions* are socially shared rules, usually unwritten, that are created, communicated and enforced outside of officially sanctioned channels. Contrary to everyday use of language, organizations and institutions are not synonymous.

Two theorical approaches for studying institutions are discussed here: *neoinstitutionalism* and *new institutional economics*. The first theoretical approach is *neoinstitutionalism*. This approach is often applied when studying institutions as part of a broader system or context. It views institutions not as independent (objective) entities, but as entities that are embedded in and influenced by their cultural and historical environment. Institutions are seen as building blocks of organizational action that are constituted as social entities by an evolving set of rationalized patterns, models and cultural schemes (Meyer, Rowan 1977). *Neoinstitutionalism* can be seen as a sociological approach to studying institutions opposed to technical, psychological and economic approaches that are based on more objective, technical and quantitative definitions of institutions rather than a critical perspective on the role, function and definition of institutions (Lim 2011). *Neoinstitutionalism* explains how and why organizational arrangements continue to persist over time even when there are compelling rational or functional reasons for their modification or demise. The common (critical) questions asked here are: "How and why do specific formal and informal mechanisms emerge and become appropriate over time?" and "why are these mechanisms and actors privileged?" (Lim 2011: 15). These questions are questions of legitimacy, which can be defined as "a generalized perception or assumption that the actions of an entity are desirable, proper or appropriate within a socially constructed system of norms, values, beliefs and definitions" (Suchman 1995: 574). *Legitimacy* is a concept that is socially constructed, meaning that legitimacy is achieved through interaction with others and is socially situated. When viewing institutions through this lens, critical questions can be asked regarding their position, role and function in society.

The second approach I address is *new institutional economics*. This approach is mostly concerned with how institutions emerge, transform and persist and how they influence economic organization and reality (North 1990; Williamson 1998). In their paper van der Horst et al. (2019) present a framework originating from *new institutional economics* and *transaction cost theory* (fig. 1) to show that institutions do not develop randomly but evolve within a certain time period. At the top level we find informal

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institutions. These *informal institutions* are broad beliefs, values and norms which are deeply rooted in society and thus only change over a long period of time, namely between 100 and 1.000 years. Below informal institutions are formal institutions that refer to formal or legal embeddedness. Here, according to Williamson (1998), the laws regarding property rights – their definition and enforcement – are prominently featured. Moreover, it includes the area of formal governmental policy, property and decision rights. Periods of change at this level take between 10 and 100 years. The third level concerns market organization and institutional arrangements. The relevant theoretical lens here is *transaction cost economics*. Periods of change are quite short, namely between 1 and 10 years. Resource allocation, behavior and performance by the market actors that change continuously are described at the fourth level (van der Horst et al. 2019).

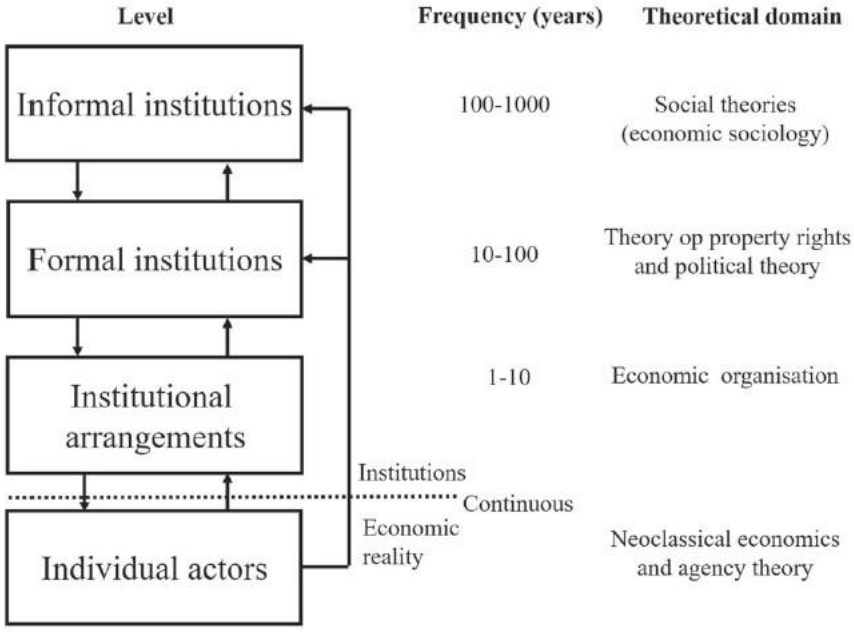

Figure 1: New institutional economics framework (van der Horst et al. 2019), CC BY-NC-ND 4.0

Zooming in: institutional arrangements

To discuss how infrastructures and institutions are both part of socio-technical systems, I want to highlight the interaction of institutions and organizations in *institutional arrangements* (fig. 1) and show how these arrangements interact with the material components of infrastructures. Institutional arrangements can be defined as systems of rights, values, rules and decision-making procedures that enable or constrain the action and interaction of different actors. They can be summarized as the social and economic rules that shape the organization of socio-technical systems. The connection between social or economic aspects of socio-technical systems and technological aspects becomes particularly visible in Critical Infrastructures. Critical Infrastructures are essential for the functioning of a society and economy, as they provide public services, enhance quality of life, sustain private profits and spur economic growth (van Asselt et al. 2015). Critical Infrastructures are complex collections of interacting components in which change often occurs as a result of learning processes (Rinaldi et al. 2001). Critical Infrastructure systems are thus interdependent on and interconnected with each other. On the other hand, institutional arrangements have become fragmented due to restructuring processes, such as privatization, liberalization and deregulation in recent decades (De Bruijne, Van Eeten 2007). Due to this institutional fragmentation, responsibility and accountability is spread across different actors with their own systems of rules. Furthermore, there is a divide between public and private sectors. This shows a disconnection between institutions and infrastructures, where institutions have become increasingly fragmented, but material infrastructural components have become increasingly connected. Institutional fragmentation can negatively impact the ability of organizations that manage Critical Infrastructures to provide reliable services (De Bruijne, Van Eeten 2007). This shows that institutional arrangements and infrastructures should be

studied in interaction to improve the reliability and functioning of Critical Infrastructures. However, in academic literature little attention has been payed to the interaction of these components. Instead the primary focus has been on the technical aspects of infrastructure systems. This thus suggests that Critical Infrastructure research would benefit from an improved understanding of the interaction of institutional arrangements with material components of Critical Infrastructures. A *system of systems* approach that views Critical Infrastructures as "multiple, heterogeneous, distributed socio-technical systems embedded in networks at multiple levels, which evolve over time" (Eusgeld et al 2011: 681) and in which Critical Infrastructure systems and institutional arrangements are considered as interacting entities could contribute towards that.

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Institutions and infrastructures: common concepts and interactions

Raphael Longoni[1]

As historian Dirk van Laak (1999: 280–290) describes, the term *infrastructure* originated in french railway engineering in the 19th century and spread to other domains concerned with mobility and transport, to socio-political structures mediating and governing economy as well as to the institutions of the welfare state. The only common traits among the different interpretations of the term is the idea of structures providing basic or intermediary functions that enable a wide array of further activities or processes, often related to basic needs of society (Laak 2008: 107–108). While the word *infra-* indicates a carrying or connecting capacity, *-structure* denotes a makeup of several meaningfully connected parts, sometimes forming networks. These characteristics allow the semantic application of the term *infrastructure* for systems of both technical provision and social organization, such as institutions. Despite different purposes, they are each socio-technically complex – i.e. they are built and used according to ideological principles, they concretize materially in physical space, their management is socially organized and they connect actors and systems at different levels (Schenk, Eifert 2018: 49–54).

Hence, this contribution attempts to explore how institutions and infrastructures are related to one another in terms of systemic conception and functional interaction. Common traits are highlighted by firstly tracing developments in institutional theory and secondly drawing on the debate on large technical systems. Thirdly, they are synthesized in a conclusion.

Old institutionalism: institutional vs. classical economics

In his "Theory of the Leisure Class" from 1899 Thorstein Veblen laid out an innovative idea of socio-economic development. Arguing against classical economic thought, Veblen (2007) imagined social institutions as informal patterns of thought, social customs, rules and behavior which determine one's choice of action to a bigger extent than the drive to maximize individual utility. In his view, slowly changing cultural modes of emulation within society ultimately bring about its stratification into classes of exploited workers and exploiting proprietors (ibid.: 7–27). The members of society are intrinsically driven to the accumulation of wealth with the goal to improve their social status – manifesting itself in *conspicuous consumption* of goods, time (*leisure*), labor force and money by the upper classes (ibid.: 28–110).

Unlike Karl Marx, whose theories rely on quantifiable means of production and financial capital, Veblen's emphasis is on what Pierre Bourdieu (1983) has coined *social* and *cultural capital*, which follow the imperatives of regionally specific informal institutions rather than a universal logic of profit (Hodgson 1998: 167–170). These institutions, according to Veblen (2007: 125–139), cannot be changed immediately and at will by individuals or groups, but do so slowly, over several generations, in an evolutionary manner.

New institutionalism: integrating collective rules and individual choice

One of the most prominent developers of recent institutional theory was political economist Elinor Ostrom. In her seminal comparative study "Governing the Commons" (1990: 58–181) she investigates small-scale systems of self-governed collective land use on three different continents that have persisted for decades up to several centuries. About one third of them are centered around irrigation infrastructure. Trying to find reasons for success and failure, she starts developing a concept of bounded rationality by according the users' free choice of action within a given framework of moral values, legal rules and regulations (ibid.: 29–57). Ostrom explains them by arguing that in uncertain, complex environments the rational choice for a land user is choosing contingent strategies with others, which requires institutional measures for coordination and regulation in order to be effective (ibid.: 185–187). According to this model, institutions shape incentive structures, e.g. by lowering the transaction costs for individual

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gain and sanctioning selfish behavior by exclusion from the user group (ibid.: 94–100; Thelen, Steinmo 2010: 9–10).

This demonstrates that the lines between actors and the institutions they represent become blurry – as do the lines between institutions and infrastructures, especially where infrastructures play a central role and to some extent become a physical manifestation of the former.

Large technical systems: integration of the socio-technical

Since the 1980s, scholars of sociology and history of technology maintain that large technological networks had quite transformative effects on society. Thomas P. Hughes' conception of Western electrification opened the predominant engineering focus from technological artifacts to their networked nature as large regionalized systems embedded in culturally specific arrangements of technical interaction and social organization (Zumbrägel 2015: 94–95). Renate Mayntz (1993: 100–102) regards infrastructures as integrated functional systems of society serving basic needs of supply, traffic and communication that enable a wide range of economic, political and social activities. According to her, large technical systems, such as electric grids or the railway, form their basic technological component. Their innovation and development exert a decisive effect on the process of social differentiation into functional sub-systems, and state authority over their organization results in the symbiotic co-evolution of governance institutions and infrastructures (ibid.: 103–107).

Another important feature of the development of large technical systems is their connectivity. Ingo Braun (1994: 455–465) has demonstrated different modes of socio-technical coupling by using among others the example of organ transplant provision in Central Europe. The initiative started in 1967 and until the 1990s included sub-systems of procurement, surgical transplantation and quality control of organs. While finding donors and receivers resulted in the setup of communication systems exclusively for this cause, transport was largely based on existing infrastructures. The processes are coordinated by hospitals, laboratories and other organizations, whose operations provide the input necessary to get the traffic of organs flowing.

Conclusion

We have seen that contemporary theories of both institutions and infrastructures by now embrace the whole socio-technical complex and thus share systemic similarities. They are both made up of technical, organizational and ideological components, and many systems in fact simultaneously incorporate infrastructures and institutions.

The *system of systems* idea applies to both institutions and infrastructures, even though with different properties. They both structure processes at the concrete operational level, turning them into habits, and reach abstract dimensions, some ingraining themselves in the subconscious of society over time (Welzer 2011). At all these scales, networks are often an important feature. This goes for circulatory infrastructure as well as organizational institutions, since they basically always contain essential communication networks.

Both infrastructures and institutions are said to be very slowly changing, robust, not fully controllable and not necessarily touched by historical events affecting society (Laak 2008: 109–110). While neo-institutionalist theory has been addressing change (Thelen, Steinmo 2010: 13–26), theories of infrastructure have mostly stressed continuities by focusing on path dependency (e.g. Ambrosius, Franke 2015). Institutionalist approaches to address systemic dynamism (e.g. Krasner 1984: 240–244) could be tested for the investigation of infrastructures as well.

Identifying these commonalities between institutions and infrastructures informs their conceptualization. But for a more thorough comprehension, working out important differences is still a desideratum.

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Conclusion

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Critical Infrastructures, defined as socio-technical networks of circulation, are set as the main focus of the interdisciplinary Research Training Group (RTG) KRITIS. The workshop aimed at widening the picture by drawing on complementary conceptions of infrastructure in order to locate the definition used by the RTG within the general discourse. This should foster our basic understanding of technical infrastructures as a prerequisite for assessing issues such as their *criticality*, *vulnerability*, *resilience* and *preparedness & prevention*. As researchers within the field of Critical Infrastructure we have to be aware of prevalent conceptions of the corresponding disciplines in order to create a mutual understanding and find transdisciplinary application opportunities.

Most of the contributions presented here are strongly inspired by approaches from the social sciences. Infrastructure theory emanating from engineering scholars has been considered through the reception in publications by their colleagues from social sciences. Unfortunately, no attention could be paid to infrastructure research from economics who have a great deal to say about infrastructures of logistics, trade and financing as well as from natural sciences occupied with environmental resources and their exploitation via infrastructures. Many accounts in this whitepaper focus on people's role within and in connection to infrastructure as well as the spatial dimension of infrastructure systems. Social science perspectives on space and technology have gained momentum with epistemological shifts like the *spatial turn*, the *infrastructural inversion* (Bowker 1994; Harvey et al. 2017: 3–5) and the establishment of Science and Technology Studies already since the 1980s, but the collaboration between more technologically oriented and socially scientific scholarship remains limited to certain fields.

Spatial dimensions

Physical topographies have long been considered in research on technical infrastructures, e.g. railway networks or electricity grids, since they constitute determining properties for engineering. Although space plays a decisive role for the way in which infrastructures function, there is often no engagement with spatial theory or a notion of networked space is implicitly presupposed. Based on geographical conceptions, technical infrastructures and their components can be perceived as a place, a territory or a node depending on the spatial focus and the issue at stake (Platzer in this whitepaper). The case of Covid-19 underscores the relative importance of all these dimensions: Airports simultaneously represent a place where infectives and susceptibles might mix, the boundary of a territory the state seeks to protect as well as a node in the global network potentially diffusing the disease. The relativity of spatial relations also becomes evident in information infrastructure (Beck in this whitepaper). Topologies are most relevant for their architecture and are becoming highly dynamic according to the endusers' increasing mobility and ever-changing connectivity to the internet. As these examples indicate, properties of flows as different as trajectories of disease or streams of digital information seem to be determined by parameters of multiple dimensions of space.

Socio-technical dimensions

The majority of the contributions in this whitepaper have come to stress the social component within the socio-technical complex that infrastructures constitute – although on different takes. Human action must be organized by distributing competence and coordinating procedures among people with respect to technical and environmental conditions. When such actions are collectivized and stabilized they take the form of social practices and institutions. The role practices and social networks play when using and ensuring basic services is so crucial in cases such as fragmented basic provision, neighborhood security, emergency response against disaster and information infrastructure that technical artifacts without the human component would hardly qualify as *infrastructure* (Protschky, Dighe, Kuhn and Beck in this whitepaper). Institutionalist research shows how corporate actors create informal routines and conventions as well as formal regulations within and among each other on different societal and territorial levels of

governance (Punt and Longoni in this whitepaper). As these perspectives emphasize, technical and social entities are co-creative, co-dependent and co-evolving due to their close entanglement with one another. The question under which circumstances and to what extent they stabilize each other, inhibit change or incite transformation is still under investigation. A debate between practice theoretical approaches, that emphasize both reproduction and change, and institutionalism with its strong focus on inertia, could be envisaged for this type of inquiry.

Critical dimensions

With respect to the key concepts for Critical Infrastructure research, the workshop may deliver some interesting inspirations. In the case of *vulnerability* for instance, infrastructure research focusing on people's practices and networks can draw on disaster studies dedicated to the significance of racialization, class and gender alongside the more technical fragilities of infrastructure systems (Wisner et al. 2004; Bolin, Kurtz 2018). With respect to critical events, many discussions focus on the *resilience* of communities and persons. In such cases however, we have to be careful not to use social concepts of *resilience* to legitimize inaction in the domains of social inequality and *preparedness & prevention* (Kaika 2017). A nuanced perspective on different spatial dimensions in turn might help to see spatial logics beyond network effects like cascading failures (Hernandez-Fajardo, Dueñas-Osorio 2013) and consider impacts on local infrastructure users and communities or processes of territorial opening and closure. All of these perspectives continuously inform our understanding of *criticality* as a construct that strongly depends on social power relations and the respective focus of analysis.

Dynamic dimensions: an outlook

For the next years, the RTG KRITIS has set forth to conceptualize dynamic aspects of infrastructure, i.e. *transformation* of and *circulation* within these socio-technical arrangements, taking the perspective of an analytical *system of systems* approach. Hence, in addition to space, time needs to be considered as a dimension of context and systemic relations. The insights gained from our workshop may provide some starting points for such a theorization. As indicated above, the focus on practices and social aspects of infrastructure emphasizes the constant re- and co-creation of infrastructures. Alternating with phases of stability, infrastructures and participating institutions may undergo transformation processes due to internal and external influences, e.g. induced abruptly by critical events or incrementally due to change in social, spatial or temporal relations. But infrastructural *transformation* can also trigger social change. For instance, the reduction of the time to reach destinations by transport or to communicate with others has enabled new ways of work and social life – a process that has been going on at least since the 19th century (Schivelbusch 2011), but has been significantly accelerated by flight connections and the development of the internet. Radical change of characteristics might also occur through an increase of connectivities, binding formerly rather isolated infrastructures into a large *system of systems*, as exemplified by the development of global advertising based on information infrastructure. Questions of transformative and circulatory dynamics arise especially where intersystemic socio-technical coupling requires mutual adaptation and coordination between networks and actors on different levels of functional, spatial or temporal order. Generating, upholding and conditioning *circulation* of goods, matter, people, energy and information, i.e. their multidirectional movement within networks, requires synchronization of different flow rhythms and routines (Engels 2020: 80–85) in order to avoid overload, breakdown and crisis. Although all these terms are being widely used in public discourse, they still lack theoretical grounding. Due to their mediating character relating people, technologies and environments at different spatial and temporal scale, Critical Infrastructures seem especially well suited as a research object for the multidisciplinary investigation of such dynamics.

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