# Urban Infrastructures: Criticality, Vulnerability and Protection

## Report of the International Conference of the Research Training Group KRITIS at Technische Universität Darmstadt, Germany

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***Abstract***

*From the 7th to the 8th of February 2019, more than 70 scientists from different disciplines and countries came together for the international Conference "Urban Infrastructure: Criticality, Vulnerability and Protection" which was organised by the Research Training Group KRITIS at Technische Universität Darmstadt. The focus of the conference was on networked critical infrastructures (CI) in cities as socio-technical systems that require special protection strategies due to their vulnerabilities. Five multidisciplinary panels on Governance, Spatiality, Temporality, Safety and Security, and ICT Solutions elucidated urban CI protection. The keynote lectures by Per Högselius (KTH Royal Institute of Technology, Stockholm), Jon Coaffee (University of Warwick; New York University) and Christoph Lamers (State Fire Service Institute North Rhine Westfalia) highlighted and deepened the aspects relevant to this context. Despite all the diversity of the contributions from many different disciplines, one aspect has always been prominent: the enormous complexity of urban CI. Regardless of the task at hand - governing and planning cities, creating security concepts and making cities more resilient - the complexity of the CI systems must always be considered. On the conference, civil engineers, computer scientists, urban and spatial planners, architects, sociologists, political scientists, historians and philosophers as well as practitioners from public administration, and operators of critical infrastructures made interesting suggestions on how to deal with the uncertainties involved. It also became clear that current challenges require approaches that cannot be found in a single discipline alone.*

Cities are the major sites and physical nodes in the infrastructurally mediated flows of water, energy, waste, communication, people, goods and services. Networked infrastructures have become increasingly critical for urban life. Their smooth operation is a prerequisite for social well-being, economic prosperity and political stability in our cities. However, their smooth functioning is not a given. Due to their complexity, interconnectedness and strong interdependency, these systems are highly vulnerable. The failure of a subsystem or system components can cause serious cascading malfunctions within and across the system boundaries. Obviously, there is a need for protecting critical infrastructures, considering their specific characteristics as socio-technical systems and their embeddedness in urban space. Besides engineering, the social sciences and the humanities provide important perspectives in assessing the challenges and requirements of critical infrastructure protection. Such protection strategies have to take into account the criticality, vulnerability, and resilience of critical infrastructures in their interrelatedness with, and embeddedness in urban space. Above all, the high complexity of urban critical infrastructures must be taken into account.

## Keynote Lecture by Per Högselius: "The Dialectics of Complexification"

In his keynote lecture, *Per Högselius* (KTH Royal Institute of Technology, Stockholm), one of the leading researchers of the past "Tensions of Europe" international research project on the history of technical infrastructures on the European continent, introduced the fundamental category of 'complexity'. He pointed out that complexity represents a challenge to both, infrastructure providers and social and historical scientists researching infrastructures. At the same time, he insisted, it is an opportunity for fruitful research. Although starting from an urban setting, Högselius underlined the need to analyse urban infrastructures always as being connected to a wider geographical context, taking into account the relations both between different cities and between cities and non-urban areas. He mentioned several examples of water infrastructure in 19$^{th}$ century England, present-day China and Chicago, adding examples of international energy infrastructures, thus not only showing growing interconnectedness but also increasing complexity.

Growing complexity seems to be an inescapable feature of infrastructure. It is, Högselius stated, closely related to the concepts of risk and vulnerability, in a double way: while complexity has often been the outcome of efforts to manage vulnerability in infrastructures, it has historically also given rise to new infrastructural risks and threats. Citing civil protection brochures from different countries, Högselius reminded the audience of the ever-growing social desire for security.

It was shown that growing complexity in infrastructures often motivates attempts to get them under control, which again ends up in complexification so that critical infrastructures cannot really be controlled. In the end, Högselius showed some recent attempts to get along with complexity in a smart way – for example sharing of streets (vehicles, bicycles and pedestrians) or developing de-centralised energy production and grids – all of them based upon accepting complexity.

## Panel "Governance": Resilience, Renewal, and Integrated Risk Management

People's longing for security and the difficulty of ensuring it in the case of complex urban infrastructures also played a role in panel Governance. Faced by various external threats as well as the risk of multi-infrastructural collapse, urban infrastructures have become a key priority in the academic and policy debates on critical infrastructure protection. However, preventing various infrastructural failures from happening, and preparing for the case of a failure, entails unusual governance complexities. Often, the urban governance of CIs overarches different, often fragmented, policy domains and territories, as well as institutionally unbundled utility (sub-)domains. Preventing infrastructural breakdowns and preparing for them is not usually based on experience from past events, but on destructive scenarios of cascading failures, and involves considerable uncertainty and contestations among local decision-makers. In many cases, generally accepted institutions, procedural norms, and organisational capacities that could guide urban policy-making, the practices of utility companies and local crisis management are still missing. This panel included theoretical and empirical contributions that address the "wicked" governance challenges involved in protecting urban infrastructures and in making them more resilient.

In his presentation on "Governing urban infrastructure resilience: institutional barriers and opportunities", *Andreas Huck* (Technische Universität Darmstadt) from the Research Training Group KRITIS, critically assessed recent calls for cross-boundary stakeholder collaboration and flexible and adaptive forms of governance as generally accepted principles for urban resilience governance and risk management. Drawing on urban case studies in the Netherlands and New Zealand, Huck pointed to the complex governance challenges in coordinating various policy fields, infrastructure domains,

governance levels, and private and public actors. Crisis management authorities that are faced with such complex tasks, he argued, need to more critically assess and prioritise which types of institutional connectivity and collaboration are actually needed for enhancing specific urban and infrastructure resilience capacities. This might ultimately reduce some of the governance complexities and provide decision makers with a much clearer vision of how to enhance the resilience of cities and infrastructures.

*Mark de Bruijne's* (Delft University of Technology) presentation on "Dutch challenges in urban infrastructure renewal: How to design to manage infrastructure interdependencies?" focussed on the massive challenges of Dutch infrastructure managers in urban infrastructure renewal. Especially in urban environments, they face challenges by having to innovate and replace their ageing assets. As Mark de Bruijne pointed out, infrastructure providers have to facilitate new societal and environmental requirements and changing use(r)s while, at the same time, taking into account cross-infrastructural requirements for design as well as efficient operations and maintenance. Based on selected examples focusing on the cross-infrastructural requirements and interoperability of infrastructure domains, the presentation outlined infrastructure design practices and approaches to anticipate such challenges.

*Eva Stock* (Federal Office of Civil Protection and Disaster Assistance (BBK), Bonn) talked about "Critical infrastructure protection: Integrated risk management as an approach to address governance complexities and cooperation in civil protection in Germany". She addressed the local governance challenge to integrate the risk management of critical infrastructure operators and emergency management organisations despite their different institutional interests, expertise and practices. In this context, Stock presented a novel Integrated Risk Management (IRM) tool that aims at combining perspectives of local emergency and infrastructure managers. More particularly, it addresses what kind of information should be exchanged between infrastructure and emergency managers and how the communication and cooperation among those actors could be facilitated as an essential requirement for the smooth and successful implementation of risk management. Her presentation demonstrated how integrated risk management could address the governance complexities and the cooperation in critical infrastructure protection in order to enhance urban and infrastructural resilience.

*Panel Chair: Jochen Monstadt (Utrecht University)*

## Keynote Lecture by Jon Coaffee: "Futureproofing City Infrastructures"

In his keynote lecture on "Futureproofing city infrastructures: Transitioning from risk towards resilience", *Jon Coaffee* (University of Warwick, Coventry; New York University) focused on the shift from protective-based risk management towards adaptive-based resilience and its relevance for critical infrastructures. The aim of this new thinking is to advance risk management through new mechanisms of coping with, and adapting to multiple risks, which are only partially known. Thus, risk mitigation and preparedness increasingly cannot rely on experience-based knowledge. Significantly implicated in this endeavour have been critical infrastructures. The frequency and severity of recent crises (e.g. 9/11, the North American blackout of 2003, recent hurricanes in the USA or Storm Frank in late 2015 in the UK) have channelled attention to vulnerable physical assets whose failure or interruption of normal service has significantly affected public safety, security, economic activity, social functioning, and environmental quality of major cities.

While critical infrastructure protection was initially prioritised and conventional risk management principles were adopted, the frequency of complex and interdependent infrastructure failures has proliferated resilience thinking. Despite the clear parallels between critical infrastructure protection and resilience as mainstream policy concerns, there has been little interconnection between theory and

practice despite a greater appreciation of the interconnectivity and interdependence of critical infrastructure networks. Within this context, and drawing on the results from a number of EU-wide projects focused on operationalising infrastructure resilience, Jon Coaffee provided a critical assessment of how resilience shapes the ways infrastructure providers' deal with complex risk and the tensions elicited in the paradigm shift/transition from risk management towards resilience. He also highlighted the implications for organisational governance in seeking more integrated ways of assessing risk across multiple systems, networks and scales in order to futureproof our cities.

## Panel „Spatiality": Perception of Space, Street Design, and Sociotechnical Networks

For an understanding of the socio-technical significance of critical infrastructures, it is inevitable to look at their spatial and temporal effects. The following panel explained, why it is important to take spatial effects into account and how the "technical side" of a city shapes our perception of space. Without doubt, the conceptualisation and material design of urban infrastructures may tell us a lot about how space was conceived at the period of their construction, as well as in times of their adaptation to sociotechnical or political change. It is important to note though that infrastructures are also constituents of space, as they shape our notions of spatial distance and thus our social relations, for example. Correspondingly, the speakers of the "Spatiality" panel addressed questions of how tacit or explicit conceptions of space have impacted on the spatial layout of urban infrastructures, how the spatiality of infrastructures (de-)limited sociotechnical and political change, and how infrastructures may become flexible and adaptable to different spatial layers, demands and concepts.

In their joint presentation on "The Impact of Infrastructure Disruptions on Our Everyday Perception of Space", the two PhD researchers from KRITIS, energy science engineer *Ivonne Elsner* (Technische Universität Darmstadt), and philosopher *Marcel Müller* (Technische Universität Darmstadt), discussed how disruptions of critical infrastructures illustrate the decisive role these networked systems play in our perception of space. They argued that while the reliable provision of infrastructure services, habituation, and embeddedness in our daily activities obscure the spatial characteristics of these socio-technical systems, disruptions may unveil the immense impact large technological structures have on our perceptions of territorial cohesion, physical distance, and socio-technical interconnection. Elsner und Müller showed that infrastructure disruptions such as flight cancellations after the Eyjafjallajökull volcano eruption in Iceland (2010) brought geographical distances, and thus the notion of absolute space, to mind that we otherwise overcome every day – either physically via traffic or virtually via information and communication technologies. In comparison, they pointed to the Northeast Blackout in the US and Canada to illustrate a relational conception of space consisting of a complex network with nodes and interconnections. This conception turned a local blackout into a collapse of the entire electric system in 2003. The speakers concluded that infrastructure systems shape our spatial relations in manifold ways, and that failures of critical infrastructure systems allow us to question our normalised spatial conditions.

In the following, the Senior Programme Manager *Pranjali Deshpande-Agashe*, (Urban Works Institute/ Institute for Transportation and Development Policy, Pune), presented her paper "Towards a Sustainable City: Pune". Deshpande-Agashe introduced Pune as an Indian city that seeks to implement India's National Urban Transport Policy to achieve its sustainable transport goal of reducing dependency on private motorised vehicles from fifty to ten percent by 2031. Once a 'bicycle city', Pune became a 'two- wheeler city' in the 20th century which disturbed the social fabric of the city consisting of many walkable streets and public spaces. Today, the city invests approximately 50 percent of its transport budget for sustainable projects like redesigning of 100 kilometres of streets, bicycle plan, bus rapid transit system and doubling fleet size. A street design project pursues the goal to create walkable infrastructure by offering pleasant pedestrian plazas and public spaces, thus maximising the efficiency

of available road space. The Transition period between 'motor vehicle dependent city' to 'non-motorised city' is not peaceful though. It induces discomfort to motor vehicle users demanding for road infrastructure for their vehicles. To ensure success and buy-in, and to moderate the fight over space, the municipal corporation offers comprehensive public participation drives, such as diverse consultation rounds with citizens and shopkeepers.

In his talk "Vulnerable City, Resilient Infrastructures? Contested Spatialities of Sociotechnical Networks in Berlin's Turbulent Modern History", *Timothy Moss* (Humboldt University Berlin) explored the relationship between urban politics and infrastructure throughout Berlin's turbulent history since 1920, focussing on the ways in which energy and water infrastructures proved resilient, vulnerable or – even conducive – to shifts in political rule. He gradually disentangled the 'seamless web' of the city's piped infrastructures to reveal what changed (or did not change) to the way these were envisioned, appropriated and governed in response to radical shifts in their political and socio-economic environment, thus challenging common conceptualisations of sociotechnical obduracy and change. Moss illustrated how Berlin's infrastructures have enrolled in bounding political territories, reconfiguring urban metabolisms, nurturing local self-sufficiency, advancing integrated planning, sustaining political systems and contesting civic protest since 1920. He revealed that multiple spatialities were at play in these processes, such as territory, place, scale, networks and spatial differentiation. In conclusion, Moss called for a more nuanced and relational way of theorising the temporalities and spatialities of urban infrastructures, and of infrastructure/city relations, that is sensitive to the interaction of long-term trends and short-term shocks, continuity and change, as well as sociotechnical and socio-spatial developments.

*Panel Chair: Sybille Frank (Technische Universität Darmstadt)*

## Panel „Temporality": Rhythms, Synchronisation, and Long-Lasting Impacts

As Timothy Moss had already indicated in his lecture, in the panel that followed it was very clearly emphasised that temporality is an important factor regarding the functionality of infrastructures. There are several dimensions in which time has to be taken into account. First, time may be considered as a context: Social, cultural, technical and economic circumstances in a given period shape the design and the operation of a system. Second, a system's technical features create specific time regimes or rhythms. These can be the result of the network character of a technical system, or caused by natural or environmental factors. In this panel, both perspectives have been addressed by historians and a geographer.

In his paper on "When Rivers Don't Behave: Natural Rhythms and Infrastructural Failure(s)" *Uwe Lübken* (Ludwig-Maximilians-Universität München) addressed the interplay between flooding and the use of rivers as integrated into infrastructure systems (water provision, energy production, navigation) in the era of industrialisation. Lübken highlighted the changing, yet unpredictable rhythms of floods. Despite the existence of often gigantic levees and floodwalls on its banks, rivers continued to flood, and cities bore the brunt of the damage. Railway networks were severely impaired if only a small portion was destroyed. Critical nodes of infrastructural networks such as bridges, gas and water works were often located in urban floodplains and thus spread the effects of a disaster way beyond the affected areas. Lübken proposed to categorise the flooding rhythms of rivers with the following notions: Rare events (big floods occur only scarcely), event clusters (from time to time, and for several years, floodings occur regularly), disaster gaps (a notion coined by Christian Pfister). As these rhythms never last for a very long period, flooding is perceived as highly uncertain and irregular. In a certain sense, uncertainty about a river's "behaviour" was a far bigger challenge than the physical destruction itself.

Subsequently, three PhD researchers from KRITIS at Technische Universität Darmstadt presented three case studies on “Time to be in Time”: *Stephanie Eifert* (medieval history), made a case for the importance the of so-called clock time for the highly regulated rhythms of river transportation and market access in medieval cities of Frankfurt and Mainz. She questioned the widespread assumption that synchronisation is a companion of capitalist industrialisation. *Benedikt Vianden* (history of the 19th century) presented the case of the German protestant Templer colonists in the Holy Land at the turn of the 20th century. The Templers combined an eschatological world view with a civilising mission: Building modern transport infrastructure in Palestine was a means to modernise the country, not only introducing modern rhythms of transportation but in a certain sense speeding up time for the coming of the Kingdom of God. *Nadja Thiessen* (history of the 20th century) focused on flood control on the river Rhine in the 20th century and raised the problems of an industrialised and international cross-linked environment: Measures taken on one side of the border might cause effects on the other side. Typically, the question of time shifts between different river sections is not reflected. Combining these cases, the presenters concluded that infrastructure highly affects the production of rhythms, independently from period and area.

*Susanne Krings* (Federal Office of Civil Protection and Disaster Assistance (BBK), Bonn) addressed, in her talk “Legislating Contingency and Managing Criticality” the interplay between, highly politicised, national policies and concepts of critical infrastructure protection on the one hand, and civil society protection legislation on the other hand. Her focus was on the different temporal contexts, driven by politics, changing dramatically at two historical moments: after the end of the Cold war and the German reunification, and a second time after 9/11. At the same time, basic legislation – provision and civil protection legislation in German dates back to the 1960s. Whereas civil protection was conceived initially as a matter of defence in the case of a classical war, it later merged with the new field of critical infrastructure protection. In the 1990s, however, civil protection had been totally neglected. Little is known, so far, about the long-lasting structural impacts of the Cold War legacy in today’s infrastructure protection strategies and practices. The other way round the presentation showed how different political contexts shaped the interpretation of a legislation which did not change.

*Panel Chair: Jens Ivo Engels (Technische Universität Darmstadt)*

## Keynote lecture by Christoph Lamers: “Fire Service and Technical Relief”

The smooth functioning of infrastructures does not only depend on the “right” legislation and appropriate governance. For pointing out another crucial aspect, *Christoph Lamers* (State Fire Service Institute North Rhine Westphalia, Münster) entered into his keynote “Fire Service and Technical Relief - a Structure in Space and Time” with a little anecdote: The small village "Breitenbruch", about 50 km away from Dortmund, has about 250 inhabitants. This makes Breitenbruch a typical municipality in the Sauerland region. It is exciting, however, that 59 of these 250 people are members of the local voluntary fire brigade, which in addition to its members also has a small fire station and exactly one fire engine. In the beginning, he wanted to make clear what the structure of the fire brigade and thus one of the critical aspects of this infrastructure is: the people. He then went deeper into the structures of the fire brigade and the Technical Relief Agency (THW) to demonstrate their capabilities and limitations. He repeatedly referred to the spatial and temporal relationships that are so important for this infrastructure. For example, the fire brigade claims that every major human settlement can be reached within 8 to 15 minutes with a fully operational tactical unit.

In total, the fire brigade in Germany consists of 1,3 million members, 95 % of whom are volunteers. This also explains why the availability of personnel during normal working hours is especially difficult

in rural areas with many volunteers. The availability of volunteers also reaches its limits during long term assignments. Lamers made clear that the emergency service infrastructure is also a vulnerable infrastructure due to its complex interdependencies. He made his point by describing the cascading effects in the two examples "power failure" and "epidemic".

In case of a power failure, the telecommunications network is often also affected, thus limiting the population's ability to make emergency calls. Even the PPDR (public protection and disaster relief) radio, which is used for internal communication and alerting of emergency forces, has a buffer capacity of only about 4 hours after an outage. Last but not least, most gas stations can no longer be operated, which makes the supply of emergency vehicles more difficult. In the event of an epidemic, the effects on emergency services are mainly due to the reduced availability of personnel and just-in-time logistics in the healthcare sector. In the third section of his keynote speech, Lamers addressed the vulnerabilities described above and the solutions already available or currently in research. In doing so, he emphasised, in particular, the logistical capabilities of the THW, but also the supra-regional support possibilities at federal and EU level.

In conclusion, he once again emphasised the enormous resources, both in terms of personnel and equipment, which the emergency service infrastructure has at its disposal and which prerequisites are created with it. At the same time the infrastructure, like any other, is confronted with various problems that the people involved are very aware of and that are addressed at various levels. For the future, integrative approaches to create resilience in emergency services and to overcome the "valley of death" between research and practice are important factors.

## Panel „Safety and Security“: Power Failure, Contingency Planning, and Smart Resilience

Due to the complexity of critical infrastructure systems and the importance of their reliable functioning for society, it becomes necessary to pay prime attention to the safety and security of said networks. This includes, on the one hand, approaches or methods aimed at addressing individual infrastructures, such as disruption management strategies and other backup solutions. On the other hand, it also takes into account how safety and security gain further relevance across closely coupled systems, for example, the relevance of the emergency services during larger infrastructural breakdowns. These aspects were discussed in the panel from both practical and research perspective.

In his presentation “Power Failure in Lübeck Including the Failure of the TETRA Digital Radio – Measures for Police and Non-police Emergency Response” *Thomas Köstler* (Fire Department Lübeck) opened the panel with an insights report of the events that took place on May 16th 2018 in the city of Lübeck. Due to the failure of a transmission station around midday, the power supply failed completely for almost four hours. Cascading effects also affected the city's mobile and telecommunications networks and, at times, even the TETRA digital radio network, which is used for communications between authorities and emergency response organisations. These unexpected failures posed special challenges for the emergency response teams as Köstler pointed out. Maintaining contact with the population proved to be particularly critical. Several lifts failed, a fire with people in danger and several intensive care patients that needed supplies. Another important challenge was the communication and coordination between the police and non-police units as well as with the city administration in order to get a shared situational awareness. Köstler concluded the report with the lessons learnt from the blackout. He paid special attention to the early high level coordination between the participating organisations and a regular personal exchange. He further emphasised that back-up power supplies are also needed for public administration and the police stations.

The second talk was presented by three PhD researchers from Technische Universität Darmstadt: *Anna-Katharina Brauner* (Institute of Railway Engineering), *Arturo Crespo* (KRITIS) and *Marcus Dombois* (KRITIS). In their presentation "User-based Contingency Planning for Railway Disruptions Using Network Analysis", they presented a framework for the involvement of different stakeholders (especially passengers) in the creation of disruption programs (DRPs) in commuter railway. In order to counteract the strict display of the operational perspective during development, the framework combines criteria-based prioritisation of the transport concept with a questionnaire on travel preferences and an analysis of the relationships between all criteria based on social network analysis. The authors evaluated their concept on the basis of a scenario from the S-Bahn traffic of the city of Frankfurt. They conducted a workshop with different user groups to identify operational, personal and environmental criteria and their relationship to each other. For the questionnaire, both the conference participants and a group of students were interviewed. They were able to show that the choice of alternatives can be made much more profoundly through the use of their approach, but they also found that a great deal of attention needs to be paid to the respective travel group.

The panel concluded with the presentation "Towards smart critical infrastructures – chances and risks – Smart City Bahnstadt" from *Sylvia Bach* (University of Wuppertal). In her presentation, she introduced some of the results of the EU project "SmartResilience" using the example of the Heidelberg smart city district Bahnstadt. It is assumed that smart critical infrastructures are highly automated. Based on the realization that CI will become smarter in the future, but that this smartness often only refers to the "normal" operating state, she and the project partners questioned to what extent smart critical infrastructures behave in an extreme event and whether the increase in the complexity of the infrastructure system also leads to an increase in their vulnerability. Bach then went into the urban district of Bahnstadt in more detail. She explained that this is the largest passive house settlement in the world and one of the largest urban development projects in Germany. The use of smart meters is intended to make it possible to predict energy consumption in Bahnstadt to optimise energy supply and to be better prepared for unexpected events. Bach compared the consumption in Bahnstadt to a reference area and pointed out the advantages of lower costs and a more stable and controllable grid. In particular, she focused her analysis on the identification of singularities, i.e. extreme, unexpected outliers, which can be examined more closely using the available data and incorporated into the forecast.

*Panel Chair: Uwe Rüppel (Technische Universität Darmstadt)*

## Panel "ICT Solutions in an Emergency": Decentral Intelligence, LoRaWAN, and Mesh-Net

The topic "Digitalisation in Cities" was finally deepened with three further lectures and an emphasis on Information and Communication Technology (ICT). Currently, many cities find themselves in a transformation process towards digital cities (or smart cities) to sustain the ever-increasing needs in urban infrastructure. They integrate more intelligent methods for traffic, parking, or waste management. However, the continued working of these ICT based systems in times of crisis has only been researched superficially. We expect that digital cities will grow organically, resulting in a very heterogeneous, amorphous, and unstructured set of ICT. In this setting, the concept of "Emergency Responsive Digital Cities" refers to the capability of future digital cities to adapt autonomously to arbitrary crisis situations. Such cities can sustain basic ICT operation during times of crisis, supporting efforts to handle the crisis cooperatively and allowing a return to normal and efficient operation as smoothly as possible. This panel focusses on practical challenges, opportunities, and research direction because of and with modern ICT systems.

In the presentation “Is Resilience the Real Driver for Decentral Intelligence in Energy?”, *Florian Steinke* (Technische Universität Darmstadt) questions the often held believe that the move to a more distributed energy production due to the transition toward renewable energy also comes with a decentralised control of the electrical grid. Despite providing a single point of failure for the power supply, market pressure pushes the management of these facilities to be more centralised and therefore remote control. However, he argues that in times of crisis, controlling the power grid remotely is not feasible and that the drive towards a more resilient power grid will lead to ~~a~~ more decentralised control. To support his argument, he presents a novel algorithm to manage variations in the electrical grid at the seconds to minutes scale. The autonomous nature of this algorithm enables the grid to handle these kinds of variation without the need for a central or remote interference. This, in turn, improves the resilience of the electrical grid. He finishes by suggesting a distinction of control between normal and crisis mode. In normal mode, the power grid is centrally controlled, but in times of crisis, the management moves towards a more local and therefore decentral control.

LoRaWAN, short for Long Range Wide Area Network, is a city wide, low power communication network that has been deployed in the Digitalstadt Darmstadt. It enables the integration of multiple sensors and is soon to be opened to additional, private and public partners. In the second talk of this panel, *Antonio Jorba* (COUNT+CARE, Digitalstadt Darmstadt), first described the advantages of LoRaWAN, such as the long battery runtime compared to cellular systems, and illustrated its usefulness with multiple use cases. For instance, the installation of sensors in underground dumpsters has already been used to reduce the cost of their maintenance because no one needed to drive to a half-full dumpster to see whether or not it had to be emptied. A second use case is the continuous monitoring of the canal system for flooding or blockages. Among other examples, he also described the usage of LoRaWAN to monitor the quality of the water in the swimming lake Woog and the air in and around the city.

The final talk on “Bricked or Useful Tool: The Role of Everyday Electronic Devices in Crises” illustrated the use of smartphones and Internet of Things (IoT) devices without the need for a cellular connection. In the first part, *Lars Almon* (Technische Universität Darmstadt) showed the development of a mobile application that can be used to exchange information without the need for a cellular connection. Instead, it uses the wireless network capabilities to build a mesh-net in which phones that are far away from another can communicate by routing the data through other phones with the same application. This, therefore, allows to share information and uphold communication during times in which a cellular connection cannot be maintained, e.g. during a blackout. So far, this application has gone through early testing stages in a simulated emergency scenario. The second part by *Jiska Classen* (Technische Universität Darmstadt) extended on the idea of using a mesh-net to uphold communication. Instead of focussing solely on smartphones, which have a fairly limited battery runtime, she focusses on integrating IoT devices into the mesh-net. For instance, fitness trackers or fire detectors have a considerably longer battery runtime than smartphones. Furthermore, similar modifications can also be used to map inaccessible environments. While the environment is inaccessible to humans, e.g. after an earthquake, wireless communication might not be impaired. A nearby IoT device can then be used to map its surroundings and contact other IoT devices and thereby extend the mapping abilities even further. This can then be used to try and detect phones of people that are currently trapped and might otherwise not be found.

*Panel Chair: Matthias Hollick (Technische Universität Darmstadt)*

## *About Research Training Group KRITIS*

*In the interdisciplinary Research Training Group KRITIS at Technische Universität Darmstadt, young scientists analyse what is "critical" about urban infrastructures, how interruptions in their functioning can be avoided and how cities prepare to deal with such crises. The focus of attention is on both the technical aspects and the political, social and cultural aspects of urban security. The German Research Foundation (Deutsche Forschungsgemeinschaft (DFG)) has supported the research training group since October 2016. More information on www.kritis.tu-darmstadt.de.*